Amity Business School
AMITY UNIVERSITY
MADHYA PRADESH

Business 5.0:
Integrating Intelligent Technologies with Sustainable Value Creation

Editors:

Prof. (Dr.) Navita Nathani
Prof. (Dr.) Bhupendra Kumar
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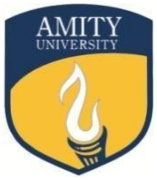

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Message from Founder President and Chief Patron

Dr. Ashok K. Chauhan
Hon'ble Founder President RBEF

The world today is witnessing an extraordinary transformation driven by innovation, artificial intelligence and digital technologies. The emergence of Business 5.0 marks a new era, one where human intelligence and advanced technology come together to create organizations that are intelligent, inclusive and sustainable. This paradigm invites us to reimagine how businesses can leverage AI, blockchain and digitalization to address global challenges, enhance productivity and contribute meaningfully to society.

At Amity, we have always believed that education, research and innovation must act as the pillars of national and global progress. The 12th International Conference on Business 5.0: Innovation, Technology and Sustainability in Global Prospects, organized by Amity Business School, Amity University Madhya Pradesh, reflects this philosophy. It brings together brilliant minds of academicians, researchers, entrepreneurs and thought leaders in order to explore how technology can empower humanity, foster ethical leadership and promote sustainable economic growth.

I am confident that this conference will inspire groundbreaking ideas, global collaborations, and transformative actions that will shape the future of business and society. Let us together embrace the spirit of innovation and excellence to make India the global leader in Business 5.0 where technology serves humanity and progress is defined by purpose and sustainability.
I extend my best wishes for the grand success of this international conference.

Dr. Ashok K. Chauhan
Founder President, Ritnand Balved Education Foundation (RBEF)
Chairman, Amity Science, Technology & Innovation Foundation (ASTIF)

Message from the Chancellor

The concept of Business 5.0 reflects a paradigm where advanced technologies such as artificial intelligence, data analytics, cyber-physical systems, intelligent automation, and sustainable manufacturing are seamlessly integrated with human creativity, empathy, and strategic thinking. It highlights the shift from mere technological adoption to responsible, inclusive, and sustainable innovation. In an interconnected global economy, such an approach is essential for building resilient enterprises, future-ready industries, and societies that are agile and harmonious. This new paradigm challenges us to reimagine business models, leadership practices and global partnerships in ways that prioritize both progress and purpose.

In this context, universities play a pivotal role. As knowledge creators, skill builders, and catalysts of societal progress, higher education institutions are uniquely positioned to advance the Business 5.0 vision. Through interdisciplinary research, industry-academia partnerships, incubators and innovation ecosystems, and a commitment to developing globally attuned and socially conscious graduates, universities contribute significantly to shaping the next generation of business models, technologies, and sustainable solutions. This is in consonance with the vision of our **Hon'ble Founder President Dr. Ashok K Chauhan**, of making Amity University a global hub of knowledge with sustainable development goals and inclusivity.

Amity believes in fostering a culture of collaboration, diversity, and inclusivity. We trust that the best ideas come from bringing together people with different backgrounds, perspectives, and expertise. Accordingly, AUMP is organizing an International Conference on Business 5.0: Innovation, Technology and Sustainability in Global Prospects, on 04-05 Dec 25.

I commend the organisers, faculty, and partners for bringing together global experts, innovators, entrepreneurs and academicians to explore the evolving intersections of technology and business from artificial intelligence and blockchain to digital marketing, entrepreneurship and the creation of sustainable e-marketplaces. I am confident that the insights, discussions, and collaborations emerging from this conference will inspire transformative ideas and strengthen global perspectives on innovation-driven and sustainable business practices.

I extend my heartfelt appreciation to the organizing committee for their exceptional efforts in creating this global knowledge platform. I am certain that the deliberations of this conference will pave the way for new ideas, meaningful collaborations and innovative strategies that will redefine global business excellence.

My best wishes for the grand success of this international conference.

Dr Aseem Chauhan
Chancellor, Amity University, Madhya Pradesh
Additional President, Ritnand Balved Education Foundation (RBEF)

नरेन्द्र सिंह तोमर
NARENDRA SINGH TOMAR

अध्यक्ष
मध्यप्रदेश विधानसभा
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संदेश

मुझे यह जानकर अत्यंत प्रसन्नता है कि एमिटी बिज़नेस स्कूल, एमिटी यूनिवर्सिटी मध्य प्रदेश द्वारा 12वाँ अंतरराष्ट्रीय सम्मेलन – "बिज़नेस 5.0: नवाचार, प्रौद्योगिकी एवं वैश्विक परिप्रेक्ष्य में स्थिरता" का आयोजन किया जा रहा है।

आज विश्व अभूतपूर्व परिवर्तनों के दौर से गुजर रहा है, जहाँ डिजिटल तकनीक, कृत्रिम बुद्धिमत्ता, ब्लॉकचेन, स्वचालन और वैश्विक जुड़ाव भविष्य की अर्थव्यवस्थाओं को नए आयाम दे रहे हैं। बिज़नेस 5.0 की अवधारणा एक ऐसे युग का संकेत देती है जिसमें तकनीकी प्रगति मानवीय मूल्यों, पर्यावरणीय जिम्मेदारी और समावेशी विकास के साथ संतुलन स्थापित करती है।भारत के "ज्ञान-आधारित, नवाचार-प्रधान विकास" की ओर तेज़ी से अग्रसर होने के इस समय में ऐसे सम्मेलन अत्यंत सार्थक और प्रेरणादायी हैं।

यह सम्मेलन अकादमिक जगत, उद्योग, शोधकर्ताओं, उद्यमियों और युवा नवोन्मेषकों के लिए एक उत्कृष्ट मंच प्रदान करता है, जहाँ कृत्रिम बुद्धिमत्ता, ब्लॉकचेन, डिजिटल ट्रांसफ़ॉर्मेशन, सतत विकास, वैश्विक बाज़ार अवसर, उद्यमिता और अंतरराष्ट्रीय सहयोग जैसे महत्वपूर्ण विषयों पर विचार-विमर्श किया जाएगा। मुझे विश्वास है कि इस संवाद से उत्पन्न ज्ञान और दृष्टिकोण भविष्य के व्यवसाय और समाज को दिशा देने में महत्वपूर्ण भूमिका निभाएँगे।

मध्य प्रदेश शिक्षा, नवाचार और औद्योगिक विकास का एक उभरता हुआ केंद्र है। मुझे आशा है कि इस सम्मेलन के माध्यम से नई संभावनाएँ सृजित होंगी, वैश्विक सहयोग को बढ़ावा मिलेगा और भारत की वैश्विक मंच पर तकनीक, नवाचार एवं सतत विकास में अग्रणी भूमिका और अधिक सुदृढ़ होगी।

मैं एमिटी यूनिवर्सिटी मध्य प्रदेश के इस उत्कृष्ट शैक्षणिक प्रयास की सराहना करता हूँ और सभी प्रतिभागियों को अपनी शुभकामनाएँ देता हूँ।मैं इस अंतरराष्ट्रीय सम्मेलन की सफलता की हार्दिक कामना करता हूँ।

(श्री नरेन्द्र सिंह तोमर)

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AMITY UNIVERSITY
MADHYA PRADESH

Established vide Government of Madhya Pradesh Act. No. 27 of 2010

Lt Gen VK Sharma, AVSM (Retd.)
Pro Chancellor
Senior Vice President, RBEF

Foreword

The world is witnessing an unprecedented transformation driven by innovation, intelligent technologies and global collaborations. As we enter the era of Business 5.0, we stand at the crossroads of immense opportunity and responsibility which is an era that seeks to harmonize technological progress with human welfare, environmental stewardship and ethical leadership.

The 12th International Conference on Business 5.0: (ICB 5.0): Innovation, Technology and Sustainability in Global Prospects, organized by Amity Business School, Amity University Madhya Pradesh, is an inspiring initiative that captures this transformative spirit. It provides a powerful platform for global thought leaders, academicians and practitioners to deliberate on how Artificial Intelligence, Blockchain, Digital Transformation and Sustainable Innovation can collectively shape the future of business and society.

In the rapidly changing global landscape, businesses must look beyond profit and focus on the purpose of integrating Environmental, Social and Governance (ESG) principles into their core strategies. At Amity University, we remain committed to advancing education, research, and innovation that equip future leaders with the skills and wisdom to navigate this dynamic environment. The ICB 5.0 conference exemplifies our belief in uniting academia and industry to drive meaningful global impact through collaboration and knowledge sharing.

I extend my heartfelt appreciation to the organizing committee for their exemplary efforts and to all participants for their valuable contributions. I am confident that the deliberations at this conference will inspire innovative ideas, strengthen global partnerships and contribute to building a smarter, more equitable and sustainable world.

Jai Hind!

Lt Gen VK Sharma, AVSM (Retd)
Pro Chancellor, Amity University Madhya Pradesh
Senior Vice President, Ritnand Balved Education Foundation
Former Commandant, Military College of Telecommunications Engineering
Former Colonel Commandant, Corps of Signals, Indian Army

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AMITY UNIVERSITY
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(Established vide Government of Madhya Pradesh Act. No. 27 of 2010)

Prof. (Dr.) R. S. Tomar
Vice-Chancellor

Preface

We are delighted to host the **"12th International Conference on Business 5.0: Innovation, Technology and Sustainability in Global Prospects"** at Amity University Madhya Pradesh, on December 4th-5th, 2025. This prestigious event resonates with our institution's mission to promote innovation-driven, human-centric, and sustainable business practices.

The conference will explore the transformative impact of artificial intelligence, blockchain, and digital technologies on global business, enabling organizations to become more agile, intelligent, and socially responsible. Business 5.0 represents a paradigm shift that prioritises human values, environmental responsibility, and technological excellence.

We, at Amity strive to nurture globally competent leaders, researchers, and entrepreneurs who can navigate the complexities of a rapidly changing business environment. This conference provides a unique platform for scholars, industry experts, and policymakers to discuss innovation and sustainability in business strategies.

I appreciate the efforts of our distinguished speakers, paper presenters, participants, and the organizing committee of Amity Business School. I'm confident that the conference will inspire new ideas, foster international collaborations, and contribute to a smarter, more equitable, and sustainable global future.

Let's work together to create a world where innovation drives progress, technology empowers humanity, and sustainability ensures a brighter future for all.

I wish the conference a resounding success and fruitful exchange of ideas among participants.

Prof. (Dr.) R. S. Tomar

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Prologue

The era of Business 5.0 represents a pivotal shift in the way the world envisions progress. It's an era defined by the seamless integration of innovation, technology, research and sustainability. It emphasizes the creation of intelligent, human-centric systems where technology not only enhances efficiency and competitiveness but also contributes meaningfully to society, the environment and global well-being.

At Amity University Madhya Pradesh, we are deeply committed to advancing this vision through our focus on excellence in education, research and innovation. The 12th International Conference on Business 5.0: Innovation, Technology and Sustainability in Global Prospects, organized by Amity Business School, is a testament to our dedication to fostering interdisciplinary dialogue and collaboration among scholars, industry leaders and policymakers. This global platform encourages meaningful discussions on how artificial intelligence, blockchain and digital technologies can be leveraged to address pressing economic and environmental challenges while creating new opportunities for sustainable business growth.

This conference underscores our firm belief that research and innovation are the true engines of progress. At Amity University Madhya Pradesh, we continuously strive to build an ecosystem that encourages original thinking, interdisciplinary inquiry and impactful research. Through collaborative efforts between academia, industry and global partners, we aim to generate knowledge that not only advances technology and business practices but also contributes to sustainable and inclusive global development. The spirit of innovation and intellectual curiosity that defines this conference reflects our ongoing commitment to shaping thought leaders who will drive meaningful change in the world.

I extend my sincere appreciation to the organizing team for their hard work, dedication and collaborative spirit in making this conference possible. I am confident that the insights and innovations shared during this event will contribute significantly to shaping the future of research, technology and sustainable business practices on a global scale.

I convey my best wishes for the grand success of this international conference and to all participants for insightful deliberations that inspire innovation, collaboration and progress.

Prof. (Dr.) M. P. Kaushik
Pro-Vice Chancellor (R)
Amity University Madhya Pradesh

AMITY UNIVERSITY
MADHYA PRADESH

Established vide Government of Madhya Pradesh Act No. 27 of 2010

28th Nov. 2025

ACKNOWLEDGEMENT

It is with great pride and deep gratitude that I extend my heartfelt appreciation to all who have contributed to the success of the 12th International Conference on Business 5.0: Innovation, Technology, and Sustainability in Global Prospects, organized by Amity Business School, Amity University Madhya Pradesh. This international conference reflects our enduring commitment to fostering innovation-driven learning, sustainable growth and global collaboration through academic excellence and research.

The era of Business 5.0 calls for a harmonious balance between technological advancement and human-centric values. It envisions a world where Artificial Intelligence, Blockchain and Digital Transformation empower people, enhance industries and contribute toward sustainable development. This conference has provided an inspiring platform for academicians, researchers, entrepreneurs and industry leaders to exchange ideas on shaping resilient, ethical and future-ready business ecosystems that align with global sustainability goals.

I express my deepest gratitude to our Hon'ble Founder President, Dr. Ashok K. Chauhan, and Hon'ble Chancellor, Dr. Aseem Chauhan, whose visionary leadership and commitment to excellence continue to inspire innovation and progress across all Amity institutions. I also extend sincere thanks to Honourable Pro-Chancellor, Lt. Gen. V. K. Sharma, AVSM (Retd.), and Honourable Vice Chancellor, Prof. (Dr.) R. S. Tomar, for their valuable guidance, and to Prof. (Dr.) M. P. Kaushik, Pro Vice Chancellor (R) & Dean Research, for his continuous encouragement and support.

A special note of appreciation goes to all the delegates, paper presenters and participants for their scholarly contributions, which that has enriched the discourse on innovation, entrepreneurship and sustainability in global business. I would also like to commend the organizing committee, faculty members and editorial team of Amity Business School for their dedication, teamwork and tireless efforts in making this conference a grand success.

I am confident that the insights shared through this conference will continue to inspire new ideas, strengthen international alliances and contribute meaningfully to the global pursuit of innovation and sustainable prosperity.

Prof. (Dr.) Navita Nathani
Head of Institution & Convenor
Amity Business School
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Business 5.0 – AI-Driven Finance, Digital Markets, and Sustainable Economic Transformation

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Information Search Behaviour and Purchase Intention of Doctor's towards Medical Equipment's in this Digital Era

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ABSTRACT

Purpose: This study has been aimed to determine the elements influencing doctors' information search behaviour, towards purchase of medical equipment's for making purchase through on line. This study further will highlight the characteristics of doctors' information-seeking behaviour pattern before making online purchase for their professional needs.

Methodology: A combination of both Quantitative and Qualitative methods was used. About 366 respondents rendered data through a pre-tested questionnaire, and the gathered data were analysed with suitable statistical methods to derive the results.

Findings: It is noteworthy that the respondents (doctors) proactively search for information to remain informed about the most recent developments in medical equipment crucial for their professional practice. Owing to the tremendous growth and importance of online resources, doctors do an increasing search to know accurate and sufficient information from various online sources.

Practical Implications: The study's results may benefit other doctors by enhancing their understanding of online information search behaviors, which could assist them in making informed purchase decisions relevant to their profession, as they will be more aware of the latest advancements. Further the results will be also useful for the medical equipment's manufacturers in selling these equipment's for effectively segmenting this market type and also for developing new online marketing strategies which will meet the actual expectations of the doctors who make online purchases of medical equipment.

Originality: By investigating the structural relationships among these factors, the study seeks to address gaps in the present service operations in the emerging markets. The sample included doctors from different practice types.

Keywords: Doctors, Online Search Behaviour, Influencing Factors, Information-Seeking, Purchase Intention, Purchasing Behaviour

1.1 INTRODUCTION

Imagine you're trying to make a big decision, like buying a new laptop or choosing a vacation spot. What do you do? You start looking for information-reading reviews, asking friends, checking out websites. This whole process of finding and using information is what we call Information Search Behaviour.

1.2. Purchase behaviour by medical professionals

1.2.1 What is Purchase Intention?

Ever thought about buying something, but weren't quite sure if you'd actually go through with it? That's what we call "Purchase Intention"-it's how likely you are to buy something. It's that moment when you're almost ready to hit "Add to Cart" but might still be deciding. It is a stage before placing an order to buy.

1.2.2 Influence of Digital Marketing:

A report in 2023 highlighted that 63% of doctors are influenced by online product reviews and ratings when deciding on medical equipment and pharmaceutical purchases and in the same report it can be noted that 58% of medical professionals use social media and professional networks to gather information about new medical products before making purchasing decisions.

1.2.3 Subscription-based Models:

A study in 2024 emphasizes the importance of building communication as it can be given to the use of smartphones and portable devices in stores, which allow retailers to collect data about each purchase, the type of consumer (age, gender, etc.) and develop a statistical database that can later help the marketing team to improve the product, delivery method, advertising, targeting strategy and many other things (Ameer Pestek, Hatidja Ejubovic, 2024) . The study found that while traditional sales (in-person sales representatives, trade shows, etc. accounted for 60% of the total sales volume in 2019, this figure dropped to 45% by 2022. Conversely, digital sales channels (online platforms, mobile apps, etc.) increased from 40% to 55% over the same period.

Electronic Health Records (EHRs) have revolutionized the storage and access of patient information, leading to significant improvements in efficiency and patient care. As of 2023, over 85% of office-based physicians in the U.S. have adopted EHR systems. This digital evolution enhances patient management and facilitates better communication and collaboration among healthcare professionals, Centres for Disease Control and Prevention (CDC), 2023.

According to a report by McKinsey, by mid-2021, telehealth usage had reached levels 38 times higher compared to the period before the pandemic. Additionally, a study found that telemedicine greatly enhanced access to healthcare services, particularly in rural regions.

Technology and the Internet have profoundly transformed global business interactions and communications. For doctors, these advancements have expanded avenues for their engagement in their profession with brands, medical equipment, and pharmaceuticals that were unimaginable just a few decades ago. Traditional branding strategies heavily reliant on mass media have progressively lost efficacy in a landscape where doctors possess widespread information about the products and those companies, often sourced online, which sometimes replaces traditional brand networks.

The shift towards online platforms is evident in the proliferation of digital marketing campaigns across companies of all sizes, leveraging the Internet's accessibility to target audiences more effectively. As doctors increasingly rely on online sources over traditional media, their expectations have evolved towards timelier, more content-rich, and personalized information.

In this context, brands disseminate messages online, but it is the doctors who curate and integrate these messages into their online discussions, profoundly shaping market dynamics through preferences and recommendations. Consequently, brands and products are subjected to sharp scrutiny prior to a purchase, influencing doctors' decision-making processes. Therefore, addressing the bottleneck issues in niche online marketing services requires understanding the intricate relationships between information search behaviour, purchase intentions, and actual the purchasing behaviours.

1.2.4. Use of Gadgets by Doctors

Online platforms have revolutionized communication channels between companies and doctors, enabling immediate interaction and customization of offers and products. This shift not only grants doctors greater access to information but also transforms their engagement with businesses and fellow professionals through digital communities and collaborative tools.

Contemporary doctors increasingly utilize real-time mobile data access, diminishing their dependence on traditional information provided by brands. This accessibility extends to

competitive pricing information, fostering increased price transparency and shifting decision-making power toward doctors themselves. Concurrently, doctors increasingly prioritize peer recommendations over corporate communications, reflecting a shift in trust dynamics within the medical community. Further the reviews on the products help them also in deciding their suitable branded products at a lesser cost.

There is a effectively segmenting markets and optimizing service operations in the online medical equipment sector. Previous research by Singh (1998), Garrison (1998), Voorbij (1999), and Bavakutty and Salih (1999) and they all underscores the growing reliance on the Internet for professional information retrieval across various disciplines, emphasizing the need for robust evaluative criteria to filter and access relevant health information online.

2.1 LITERATURE REVIEW

Chandran (2000) reported significant internet usage among healthcare professionals, indicating over 56% utilizing online platforms for accessing medical information and educational resources. This trend underscores the Internet's pivotal role in enhancing medical knowledge dissemination and professional development.

Recent studies highlight the pervasive influence of the internet across academic, professional, and medical sectors. Laite (2000) documented widespread internet use among undergraduate and graduate students, emphasizing its role in daily academic activities such as information retrieval and communication through services like electronic mail.

Mariyappagoudar and Jayashree (2000) explored the role of the internet in enhancing the efficiency of information search and access to various services. including resources provided by journal publishers' websites, which are increasingly crucial for medical professionals staying updated with research and clinical developments since in the medical field, there is increasing acknowledgment of the internet's vital role in supporting doctors' professional activities. Unlike the traditional business model, the network provides a faster shopping environment that is less affected by time/geographical restrictions (Wani and Malik, 2013)[2]. A purchase, bargaining, payment process can be completed through the Internet, which is a great convenience for people (Bhatnagar and Ghose, 2004)[3].

The effective and efficient extension of the geographical reach of the 10,000 Steps program would not have been possible without the use of the Internet. (Corneel Vandelanotte et al, 2020).

The classic approach argues that customers can determine the optimum action route if they know enough about the product but don’t always examine all options. Numerous researches pointed out the necessity to understand people’s behaviour not only to adopt and adjust the technological implementation or to meet the decision on whether the implementation has to be done but also with an aim for future adaptation and learning process (Dmitrii Nikolaev, 2024).

These findings collectively underscore the evolving landscape shaped by internet technologies in medical practice, emphasizing its critical role in information access, professional development, and procurement behaviours among doctors.

3.1 STATEMENT OF RESEARCH PROBLEM

Amidst a deluge of information, doctors exhibit discerning attention to allocation, necessitating tailored made marketing approaches that would addresses specific concern. As online sources become pivotal in medical procurement decisions, companies must comprehend not only the information needs of doctors and their information search behaviour’s but also the complex interplay between factors that are influencing them for making the online information search, purchasing intentions, and actual behaviours

This study also seeks to enhance academic discussions by clarifying these dynamics and offering actionable insights for companies navigating the changing landscape of online medical equipment marketing and sales.

The expansion of online platforms which has significantly transformed the procurement process for medical equipment, offering a diverse range of purchasing options. Key online sources include:

1. **E-commerce Websites:** Major platforms like Amazon Business and Alibaba have become pivotal in the medical equipment market, offering extensive product selections, competitive pricing, and user reviews.
2. **Specialized Medical Supply Websites:** Dedicated sites such as Medline, McKesson, and Henry Schein cater specifically to healthcare professionals, providing curated product listings, detailed specifications, and targeted customer support tailored to medical needs.
3. **Manufacturer Websites**: Leading manufacturers, including Philips, Siemens, and GE Healthcare, have established robust online platforms for direct procurement.
4. **Mobile Applications:** Applications like Medscape and UpToDate integrate procurement functionalities, allowing healthcare professionals to order supplies directly while accessing essential medical information.
5. **Digital Marketplaces and B2B Platforms: Platforms** such as Bid Med and HealthCare Supply Pros facilitate specialized marketplaces for medical equipment, connecting healthcare providers with suppliers and enabling competitive bidding for bulk purchases.
6. **Social media and Professional Networks:** Platforms like LinkedIn and medical forums such as Sermo and Doximity are increasingly utilized for peer recommendations and product discussions. These networks allow doctors to exchange experiences and seek advice from trusted colleagues on equipment purchases.
7. **Online Review Aggregators:** Websites such as Trustpilot and Consumer Reports aggregate user reviews and ratings for medical products, providing valuable insights into product performance and supplier reliability.

Understanding these diverse online sources is very crucial for companies aiming to align their marketing strategies with the evolving preferences and behaviours of healthcare professionals. The insights derived from this study will assist in crafting targeted digital marketing strategies and optimizing online sales channels, thereby effectively engaging with doctors and meeting their procurement needs in an increasingly digital environment.

It is felt necessary to take up this research study to the Information Search Behaviour and Purchase Intention of Doctors' Towards Medical Equipment in this Digital Era with the following objectives.

3.1.1 Objectives of the Study

Understanding the efficiency of internet sources in providing relevant information to doctors compared to Traditional sources

a. To evaluate the perceived value of online information sources among doctors in enhancing their professional knowledge and decision-making.
b. To understand and assess Doctors usefulness and importance of online resources compared to traditional sources.
c. To determine the effectiveness of doctor’s online information search and to evaluate whether their l decision-making makes improvement in their patient outcomes.
d. To analyse the amount of online time spent by the doctors for their professional searches.
e. To examine whether there is difference among the Male and Female doctors towards preferences in the use of online sources.
f. To investigate the impact of educational qualifications on doctors' preferences for online sources.
g. To investigate how the location of the hospital affects doctors' preference for utilizing online sources.

h. To examine the influence of the type of doctors towards their preference for online sources.
i. To examine the purchase intentions of doctors when using online platforms.
j. To study the purchasing behaviour of doctors in the context of online and traditional information sources.

This objective examines how doctors' actual purchasing decisions are influenced by online sources compared to traditional ones.

4.1 HYPOTHESES

Hypothesis 1: The Efficiency of internet usage skills among doctors has a significant influence on the purchase intention of doctors through online channels.
Hypothesis 2: Value of information processed through internet has a significant influence on the purchase intention of doctors through online channels
Hypothesis 3: Effectiveness of risk, design and cost of using internet has a significant influence on the purchase intention of doctors through online channels.
Hypothesis 4: Purchase intention of medical equipment among doctors has a significant influence on the purchase behaviour of doctors through online channels.

5.1 RESEARCH DESIGN

The study implements a research design that is descriptive and was carried out in Chennai City. Descriptive research focuses on observing and gathering data about a specific topic without making causal inferences. The goal is to provide a thorough and accurate representation of the subject under investigation, detailing existing relationships, patterns, and trends within the data that is collected.

Respondents of the study were medical practitioners who made online purchases. A sample of 366 was drawn from a population of 7,763 registered medical practitioners in Chennai. A simple random sampling method was used to select the participants. Data were collected from both primary and secondary methods using a survey method. Since, It is known for its effectiveness in data collection and suitability for research. The questionnaire was carefully designed to ensure that it captured comprehensive and relevant information for analysis.

6. 1 EVALUATION OF DATA AND INTERPRETATIONS

6.1.1 Daily Time Invested in Online Searches

The study analysed the daily time spent by doctors on online searches, as brief in Table 6.1.1.

Table 6.1.1: Daily Duration in Online Searches by Physicians

Sl. No.	Time Invested	No. of physicians	Percentage
1	60 Mins	70	19.12
2	120 Mins	133	36.34
3	180 Mins	117	31.97
4	>180 Mins	46	12.57
Total	-	**366**	**100**

Source: *Collected through primary research methods.*

This analysis reveals, majority of respondents spend two hours (36.34%) followed by three hours (31.97%) daily for online searches. Further, 19.12% of them spend one hour and 12.57% found to spend more than three hours per day to online search activities.

6.1.2 Online Source Usage Trends by Gender

The relationship between doctors' gender and their preference for online sources was examined, with the findings detailed in Table 6.1.2

Table 6.1.2 (i): Online Source Usage Trends by Gender

Sl. No.	Gender	Websites	Online Journals	E-mails	Search Engines	Social media	E-books	Total
1	Male	78 (33.19%)	31 (13.19%)	42 (17.87%)	13 (5.53%)	65 (27.66%)	6 (2.56%)	235 (64.21%)
2	Female	32 (24.43%)	30 (22.90%)	8 (6.11%)	16 (12.21%)	34 (25.95%)	11 (8.40%)	131 (35.79%)
Total	-	**110 (30.05%)**	**61 (16.67%)**	**50 (13.66%)**	**29 (7.92%)**	**99 (27.05%)**	**17 (4.65%)**	**366 (100.00%)**

The relationship between doctors' gender and their preference for online sources was examined using the Chi-Square test, as given in the Table 6.2(ii)

Table 6.1.2(ii): Online Source Usage Trends by Gender – Chi-Square Test

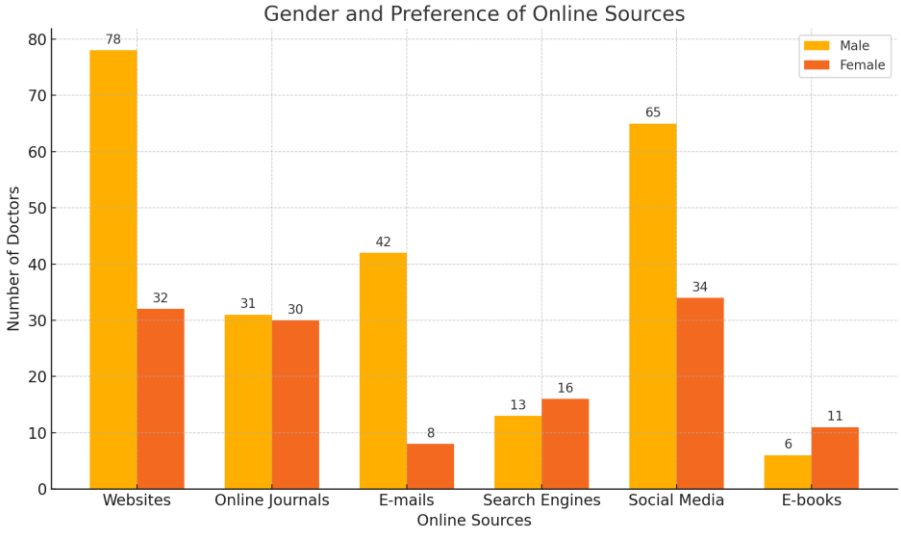
Value	Degrees of Freedom	Sig
Chi-Square	26.444	5

Sig: Significance
Primary Data Source

The Chi-Square statistic of 26.444 with 5 degrees of freedom is significant at the 1% level ($p < 0.01$), indicating a statistically significant result, indicating a notable association between doctors' gender and their preference for Internet Sources. Consequently, the null hypothesis, which posits no considerable association between the hypothesis of no significant association between doctors' gender and their online source preferences is rejected. This suggests a significant relationship exists between these variables.

Interpretation: The results suggest that male and female doctors have different preferences for online sources. For instance, a higher percentage of male doctors prefer websites, social media and e-mails, while female doctors show a relatively higher preference for search engines and e- books. This insight can help tailor online marketing strategies more effectively based on gender preferences.

Figure 6.1.2: Bar Chart of Gender and Preference of Online Sources
A bar chart visualizing the preferences of online sources by gender among doctors can be seen in Fig 6.1.2



The chart shows the preferences of male and female doctors to various online source, such as websites, online journals, emails, search engines, social media, and e-books. This visual

representation complements the tabular data and helps in understanding the differences in online source preferences between male and female doctors more effectively.

6.1.3 Online Source Preferences Across Different Educational Qualifications

Table 6.1.3(i) illustrates the assessment of the relationship between doctors' educational qualifications and their use of online resources.

Table 6.1.3(i): Online Source Preferences Across Different Educational Qualifications

Sl. No.	Educational Qualification	Websites	Online Journals	E-mails	Search Engines	Social Media	E-books	Total
1	M.B.B.S.	38 (29.23%)	17 (13.08%)	16 (12.31%)	15 (11.54%)	36 (27.69%)	8 (6.15%)	130 (35.52%)
2	M.D.	36 (32.14%)	13 (11.61%)	14 (12.50%)	10 (8.93%)	32 (28.57%)	7 (6.25%)	112 (30.60%)
3	M.S.	21 (29.16%)	28 (38.89%)	3 (4.17%)	4 (5.56%)	14 (19.44%)	2 (2.78%)	72 (19.67%)
4	Others	15 (28.85%)	3 (5.77%)	17 (32.69%)	0 (0.00%)	17 (32.69%)	0 (0.00%)	52 (14.21%)
Total	-	**110 (30.05%)**	**61 (16.67%)**	**50 (13.66%)**	**29 (7.92%)**	**99 (27.05%)**	**17 (4.65%)**	**366 (100.00%)**

Source: *Collected through primary research methods.*
Note: Figures in parentheses denote the percentage of the total.

The distribution of preferences among doctors based on their educational qualifications reveals interesting trends:

- Among the 130 M.B.B.S. qualified doctors, the top sources preferred are websites (29.23%) and social media (27.69%), with online journals (13.08%), emails (12.31%), search engines (11.54%), and e-books (6.15%) following.
- Among the 112 doctors with an M.D. qualification, the most favoured sources are websites (32.14%) and social media (28.57%), followed by emails (12.50%), online journals (11.61%), search engines (8.93%), and e-books (6.25%).
- Among the 72 doctors with an M.S. qualification, online journals are the most preferred source (38.89%), and then websites (29.16%), social media (19.44%), search engines (5.56%), emails (4.17%), and e-books (2.78%).
- For the 52 doctors with other qualifications, emails and social media are equally preferred (32.69%), and then websites (28.85%) and online journals (5.77%).
- A Chi-Square test was executed to further understand the link between educational qualifications and preferences for online sources. The outcomes are outlined in Table 6.3(ii).

Table 6.1.3(ii): Educational Qualifications vs. Online Source Preferences – Chi-Square Analysis Test

Value	Degrees of Freedom (Df)	Significance (Sig)
Chi-Square	60.22	15

Source: Primary Data Source

The Chi-Square value of 60.220 with 15 degrees of freedom is significant at the 1% level ($p < 0.01$), indicating a notable association between doctors' educational qualifications and their preferences for online sources. As a result, the null hypothesis, which asserts no significant relationship between doctors' educational qualifications and their online source preferences, is rejected. This finding highlights a meaningful connection between educational qualifications and online source preferences among doctors.

Interpretation: The results demonstrate that doctors' educational qualifications significantly influence their preferences to different online sources. This insight is crucial for tailoring online marketing strategies to meet the diverse needs of doctors based on their educational backgrounds.

Implications: These findings suggest that marketers should consider the educational background of doctors when designing online marketing campaigns. Tailoring content and advertisements to align with the preferences of different educational groups can enhance engagement and conversion rates.

6.1.4 The Impact of Hospital Location on Online Information Search Factors

The study explored how the location of hospitals impacts factors that influence online information search. The findings are presented in Table 6.1.4(i).

Table 6.1.4(i): The Impact of Hospital Location on Online Information Search Factors

Sl. No.	Location of the Hospital	Websites	Online Journals	E-mails	Search Engines	Social media	E-books	Total
1	Urban	35 (23.18%)	27 (17.88%)	26 (17.22%)	10 (6.62%)	47 (31.13%)	6 (3.97%)	151 (41.26%)
2	Semi-Urban	56 (43.08%)	19 (14.62%)	20 (15.38%)	12 (9.23%)	22 (16.92%)	1 (0.77%)	130 (35.52%)
3	Sub-Urban	19 (22.35%)	15 (17.65%)	4 (4.71%)	7 (8.24%)	30 (35.29%)	10 (11.76%)	85 (23.22%)
Total	-	**110 (30.05%)**	**61 (16.67%)**	**50 (13.66%)**	**29 (7.92%)**	**99 (27.05%)**	**17 (4.65%)**	**366 (100.00%)**

Source: Primary Data Source

Note: Percentages provided in parentheses reflect the total distribution.

The distribution of preferences among doctors based on the location of their hospitals reveals notable trends:

- Among the 151 doctors employed in urban hospitals, 31.13% show a preference for social media. Websites follow at 23.18%, with e-mails at 17.22%, online journals at 17.88%, search engines at 6.62%, and e-books at 3.97%.
- For the 130 doctors practicing in semi-urban hospitals, the majority, 43.08%, prefer websites. This is followed by social media at 16.92%, e-mails at 15.38%, online journals at 14.62%, search engines at 9.23%, and e-books at 0.77%.
- Among the 85 doctors based in sub-urban hospitals, 35.29% favor social media. Websites are next at 22.35%, followed by online journals at 17.65%, e-books at 11.76%, search engines at 8.24%, and e-mails at 4.71%.

Urban doctors prefer websites, emails, and social media, whereas semi-urban doctors favor websites and search engines. In contrast, sub-urban doctors exhibit a distinct preference for e-books. To examine the relationship between hospital location and online source preferences, a Chi-Square test was conducted. The findings are detailed in Table 6.1.4(ii).

Table 6.1.4(ii): The Impact of Hospital Location on Online Information Search Factors – Chi-Square Test

Value	Degrees of Freedom (df)	Significance (Sig)
Chi-Square	40.803	10

Source: Primary Data Source

The Chi-Square value of 40.803 with 10 degrees of freedom is significant at the 1% level ($p < 0.01$), indicating a strong association between hospital location and online source preferences. Consequently, the hypothesis being nullified, which suggests that there is no significant link between hospital location and online source preference, is rejected. This result highlights a significant correlation between the hospital's location and the online source preferences of doctors.

Interpretation: The results demonstrate that the location of hospitals significantly influences doctors' preferences for different online sources. This insight is crucial for tailoring online marketing strategies to meet the diverse needs of doctors based on the location of their practice.

Implications: These findings suggest that marketers should consider the location of hospitals when designing online marketing campaigns. Tailoring content and advertisements to align with the preferences of doctors in urban, semi-urban, and sub-urban areas can enhance engagement and conversion rates.

6.1.5 Types of Medical Practice and Online Source Usage

The analysis of the link between doctors' practice types and their choice of online sources is presented in Table 6.1.5(i).

Table 6.1.5(i): Types of Medical Practice and Online Source Usage

Sl. No.	Type of Practitioners	Websites	Online Journals	E-mails	Search Engines	Social Media	E-books	Total
1	Paediatrician	43 (26.22%)	24 (14.63%)	20 (12.19%)	18 (10.98%)	50 (30.49%)	9 (5.49%)	164 (44.81%)
2	Specialist	38 (41.76%)	4 (4.40%)	15 (16.48%)	6 (6.59%)	22 (24.18%)	6 (6.59%)	91 (24.86%)
3	Surgeon	21 (29.17%)	28 (38.89%)	3 (4.17%)	4 (5.55%)	14 (19.44%)	2 (2.78%)	72 (19.67%)
4	Others	8 (20.51%)	5 (12.82%)	12 (30.77%)	1 (2.57%)	13 (33.33%)	0 (0.00%)	39 (10.66%)
	Total	**110 (30.05%)**	**61 (16.67%)**	**50 (13.66%)**	**29 (7.92%)**	**99 (27.05%)**	**17 (4.65%)**	**366 (100.00%)**

Primary Data Source

Note: The values in parentheses indicate the proportion of the total

The distribution of preferences among doctors based on their type of practice reveals distinct patterns:

- Among the 164 paediatricians, social media is preferred by 30.49%, with websites following at 26.22%. Online journals are chosen by 14.63%, e-mails by 12.19%, search engines by 10.98%, and e-books by 5.49%.
- For the 91 specialists, 41.76% favor websites, with social media at 24.18%. E-mails are selected by 16.48%, while both search engines and e-books are preferred by 6.59%. Online journals are least favored at 4.40%.
- Among the 72 surgeons, online journals are preferred by 38.89%, followed by websites at 29.17% and social media at 19.44%. Search engines are used by 5.55%, e-mails by 4.17%, and e-books by 2.78%.
- Among the 39 doctors with other practice types, 33.33% prefer social media, followed by e-mails at 30.77%, websites at 20.51%, online journals at 12.82%, and search engines at 2.57%.

In summary, paediatricians generally utilize all online sources, with a notable preference for social media, whereas surgeons predominantly access online journals.

The Chi-Square test was conducted to examine the relationship between the type of practice and the preference for online sources.

The findings are displayed in Table 6.1.5(ii).

Table 6.1.5(ii): Types of Medical Practice and Online Source Usage – Chi-Square Test

Value	Degrees of Freedom (df)	Significance (Sig)
Chi-Square	60.858	15

Source: Primary Data Source

The Chi-Square value of 60.858 with 15 degrees of freedom is significant at the 1% level ($p < 0.01$), demonstrating a notable association between the type of medical practice and the preferences for online sources. Consequently, the null hypothesis, which suggests no significant relationship between practice type and online source preferences, is rejected. This highlights a significant connection between the type of medical practice and the choice of online sources.

Interpretation: The results demonstrate that the type of practice significantly influences doctors' preferences for different online sources. This insight is crucial for designing targeted online marketing strategies tailored to the specific needs of various medical practitioners.

Implications: Marketers should consider the type of practice when creating online marketing campaigns. Understanding these preferences allows for more effective engagement and improved conversion rates.

7.1 EXPLORATORY FACTOR ANALYSIS (EFA)

A statistical technique employed in revealing the fundamental patterns within a broad set of variables is Exploratory Factor Analysis (EFA). Its primary goal was to uncover the relationships between these variables, helping to simplify and clarify complex data interactions and provide a more coherent understanding of the dataset.

EFA starts with a correlation matrix that shows the interrelationships among the variables under investigation. By identifying variables that show high correlations within their group and low correlations with those outside their group, the dimensionality of the matrix can be reduced (Field, 2000). Variables that are highly intercorrelated may reflect a common underlying variable, known as a 'factor.'

The factors identified create new dimensions that can be visualized as classification axes where the measurement variables are plotted (Johnson and Wichern, 1992). This analysis generates factor scores and loadings. Factor scores represent an individual's standing on a specific factor (Rietveld & Van Hout, 1993), while factor loadings measure the strength of the correlation between each original variable and the factor. Factor scores are useful for conducting multiple regression analyses, and factor loadings are critical for assessing the significance of each variable to a particular factor. In this study, Exploratory Factor Analysis (EFA) was employed to identify the factors affecting doctors' online information search behaviours. Some of the modern studies have highlighted the increasing significance of EFA in healthcare research, particularly in understanding the complex behaviours and preferences of medical professionals regarding digital tools and information sources.

7.1.1 Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity

The appropriateness of the factor model is assessed using the KMO and Bartlett's tests. The KMO (Kaiser-Meyer-Olkin) test measures the suitability of sampling, with values ideally ranging between 0.70 and 0.80, and a minimum threshold of 0.5 being necessary to proceed with factor analysis (Kaiser, 1974).

Bartlett's test assesses the strength of the relationships among variables by testing the null hypothesis that they are uncorrelated. To reject this null hypothesis, Bartlett's Test of Sphericity should yield significant results ($p < 0.05$). The findings from these tests are summarized in Table 7.1.1.

Table 7.1.1. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.873
Bartlett's Test of Sphericity	Approx. Chi-Square	2.363E3
	Df	66
	Sig.	.000

Source: Primary Data Source

A KMO statistic of 0.873 suggests that factor analysis is suitable for the data. Additionally, Bartlett's test result of 0.0024, which is below the 0.05 significance level, confirms that the correlation matrix is not an identity matrix, thereby validating the use of factor analysis.

7.1.2 Communalities

Communalities denote the amount of variance in the variables that is accounted for by the extracted factors. Variables with communalities exceeding 0.5 were selected for further analysis. The Varimax rotation technique was applied to abridge the factor structure, and all 12 variables were included in the factor analysis, as presented in Table 7.1.2.

Table 7.1.2 Communalities

S. No.	Variables	Initial	Extraction
1.	I have good internet usage skill	1.000	.743
2.	Access to quantity of information from online sources	1.000	.624
3.	I have high level on knowledge on online sources	1.000	.617
4.	Online sources are well designed	1.000	.607
5.	I get good quality of information from online sources	1.000	.582
6.	Online sources are easily accessible	1.000	.751
7.	Online sources are user friendly	1.000	.691
8.	Online sources are quick and speed in transmission of information	1.000	.655
9.	Online sources are regularly updated	1.000	.552
10.	Online sources are less risky	1.000	.885
11.	Online sources are reliable	1.000	.710
12.	Internet sources are less expensive than other sources.	1.000	.658

Source: Primary Data

Method of Extraction: Principal Component Analysis.

7.1.3 Variance Distribution Across Factors

Table 7.1.3 presents, the total variance described by the various factors, including the ones extracted and their respective Eigenvalues. Eigenvalues indicate the amount of variance each factor accounts for, and their sum corresponds to the total number of items analysed.

Table 7.1.3. Variance across Explained

Factor	Initial Eigen Values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.901	49.143	49.143	5.897	49.143	49.143	3.818	31.813	31.813
2	1.144	9.530	58.673	1.144	9.530	58.673	3.000	25.000	56.813
3	1.036	8.635	67.308	1.036	8.635	67.308	1.259	10.495	67.308

Source: Primary Data

Method of Extraction: Principal Component Analysis.

Three factors were derived, accounting for 67.31% of the variations in the 12 variables, with each factor contributing 31.81%, 25.00%, and 10.50% of the variation, respectively.

7.1.4. Rotational Component Matrix

The Varimax rotation method was employed for this study, with the rotational component matrix presented in Table 7.1.4. Rotation simplifies the factor structure by reducing the number of factors

on which variables exhibit high loadings, making the factors more interpretable, transitioning from exploratory to confirmatory factor analysis.

Table 7.1.4. Rotational Component Matrix

Sl. No.	Factors	Standardized Factor Loadings (λ)
I.	**Efficiency**	
1.	I have good internet usage skill	0.63
2.	Online sources are easily accessible	0.70
3.	Online sources are user friendly	0.69
4.	Online sources are quick and speed in transmission of information	0.71
5.	Online sources are regularly updated	0.65
II.	**Value**	
1.	I get large quantity of information from online sources	0.58
2.	I have high level of knowledge on online sources	0.59
3.	I get good quality of information from online sources	0.56
4.	Online sources are reliable	0.64
III.	**Effectiveness**	
1.	Online sources are well designed	0.61
2.	Online sources are less risky	0.63
3.	Online sources are cost effective compared to other sources	0.74

Source: Primary Data Source

7.1.5. Grouping Factors

Using the standardized factor loadings from the rotated factor matrix, the identified factors are classified into the following categories:

Factor-I: Efficiency - Includes variables related to internet usage skill, accessibility, user-friendliness, speed, and regular updates of online sources.

Factor-II: Value - Encompasses variables associated with the quantity and quality of information, knowledge level, and reliability of online sources.

Factor-III: Effectiveness - Comprises variables concerning the design, risk level, and cost-effectiveness of online sources.

7.1.6. Reliability Analysis: Cronbach's Alpha for Factors

The reliability of the factors identified through EFA was weighed using Cronbach's Alpha, as outlined in Table 7.1.6. This statistic measures the internal consistency of the responses (Webb, 2006), thereby assessing the reliability of the factors extracted.

Table 7.1.6. Reliability: Cronbach's Alpha for Factors

Sl. No.	Factors/ Constructs	Cronbach's Alpha
1	Efficiency	0.84
2.	Value	0.79
3.	Effectiveness	0.86
	Overall	0.83

Source: Primary Data

The overall Cronbach's Alpha value of 0.83 indicates a significant degree of internal consistency. Individual factors range from 0.86 for Effectiveness to 0.79 for Value, reflecting reliable and consistent responses from the participants.

7.2 Structural Relationship between Factors Influencing Online Information Search, Purchasing Intention, and Purchasing Behaviour of Doctors through Online Platforms:

The Measurement Model

The measurement model consists of three factors, with each factor assessed using between three to five observed variables. The reliability of these variables is subject to random measurement errors, indicated by the corresponding error terms. Each observed variable is regressed on its respective factor, while intercorrelations among the factors are also accounted for.

Latent variables, represented by arrows from measured variables, are constructs inferred from covariances among two or more measured variables. In Structural Equation Modelling (SEM), rectangles or squares depict measured variables, while ellipses or circles denote latent variables. Error terms ("Es" for measured variables and "Ds" for latent variables) are incorporated into the SEM diagram to denote residual variances unaccounted for by the hypothesized model pathways.

The hypothesized model is recursive, featuring unidirectional relationships. Recursive models are straightforward, characterized by uncorrelated disturbances and exclusively unidirectional causal effects. Figure 7.2 (i) illustrates the initial measurement model for online purchasing behaviour among doctors.

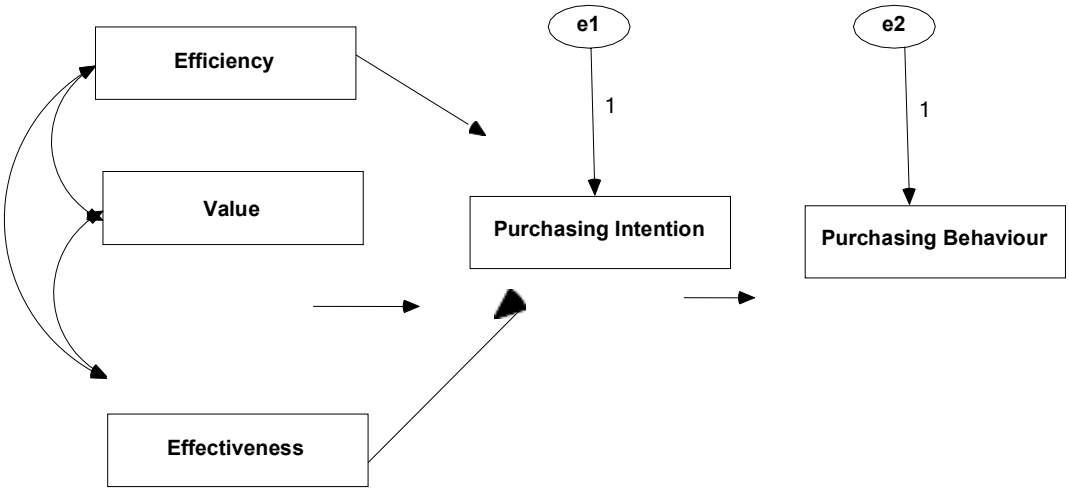


Figure 7.2 (i): Initial Measurement Model for Purchasing Behaviour of Doctors through Online

Model Identification

In Structural Equation Modelling (SEM), structural models are categorized as just identified, over-identified, or under-identified. As noted by Bollen (2019), "An over-identified model provides a rigorous test of theoretical expectations, allowing for critical evaluation and refinement of hypotheses" (p. 123). A just-identified model has a balanced number of data variances and covariances relative to the parameters estimated, allowing for a unique solution. Conversely, an under-identified model occurs when there are more parameters to estimate than there are data variances and covariances, resulting in an indeterminate solution due to insufficient data constraints. SEM endeavours to specify over-identified models, adhering to two fundamental requirements: (1) ensuring positive degrees of freedom ($df \geq 0$), and (2) assigning metric values to all latent variables.

Model Estimation Method

The primary estimation method in SEM, Maximum Likelihood (ML) estimation, is widely employed in confirmatory factor analysis to estimate parameters based on specified relationships between factors and endogenous variables. ML estimation is a full-information method that computes all model parameter estimates simultaneously. It employs an iterative process where

initial parameter estimates are refined through successive cycles to optimize the model's fit to observed data. Convergence to a stable solution is facilitated by accurate initial values, while inaccurate estimates or severely disparate variances among observed variables may impede convergence by causing an ill-scaled covariance matrix.

Assessing Overall Measurement Model Fit

Table 7.2.(i) presents key model fit indices for evaluating the purchasing behaviour of doctors through online platforms. CMIN (χ^2) quantifies the discrepancy between the observed and model-implied covariance matrices (S), providing insights into the model's goodness-of-fit. Degrees of freedom (df) represent the number of independent parameters estimated in the model, while the associated probability value (P) assesses the statistical significance of the fit.

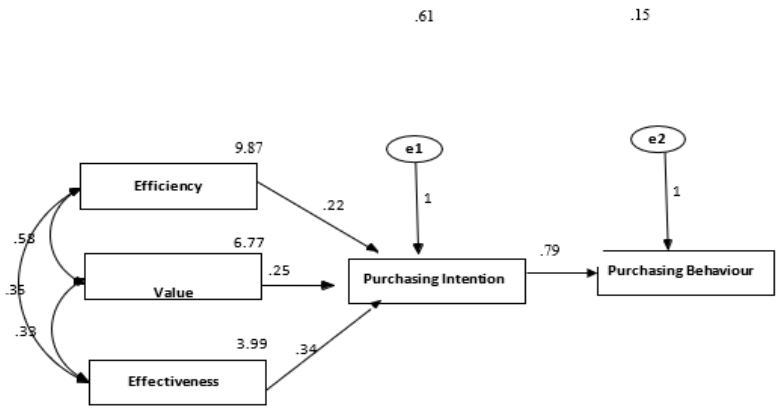
Table 7.2 (i): Model Fit Parameters for Purchasing Behaviour of Doctors through Online

Model Fit Parameters	Recommended	Obtained
χ^2	-	5.772
Degrees of Freedom (df)	-	3
χ^2 Significance	P=> 0.05	0.784
χ^2 / df	< 5.0	1.924
Goodness of Fit (GFI)	>0.90	0.97
Modified Goodness of Fit Index (AGFI)	>0.90	0.95
Normalized Fit Index (NFI)	>0.90	0.98
Comparative Fit Index (CFI)	>0.90	0.96
Incremental Fit Index (IFI)	>0.90	0.94
Tucker Lewis Index (TLI)	>0.90	0.92
Root Mean Square Residual (RMR)	< 0.10	0.04
Root Mean Square Error of Approximation (RMSEA)	< 0.10	0.03

Source: Primary Data

In SEM, the associated probability or p-value of the Likelihood Ratio Test, frequently denoted to as the Chi-square (CMIN), should ideally be non-significant for a good model fit. The CMIN value of 1.924 is not statistically significant, indicating that the model fits excellently. The Goodness of Fit (GFI), Adjusted Goodness of Fit Index (AGFI), Normalized Fit Index (NFI), Comparative Fit Index (CFI), Incremental Fit Index (IFI), and Tucker-Lewis Index (TLI) all exceed 0.90, further confirming the model's excellent fit. Additionally, the Root Mean Square Residual (RMR) and Root Mean Square Error of Approximation (RMSEA) values are below 0.10, supporting the model's strong fit.

Figure 7.2 (ii): Structural Equation Model (SEM) for Purchasing Behaviour of Doctors through Online



Standardized Structural Path Coefficients for Purchasing Behaviour of Doctors through Online

The standardized structural path coefficients for purchasing behaviour of doctors through online are given in Table 7.2 (ii)

Table 7.2 (ii): Standardized Structural Path Coefficients for Purchasing Behaviour of Doctors through Online

Path	Standardized Coefficients	CR	P-Value
Purchasing Intention ←Efficiency	.218	4.121	***
Purchasing Intention ←Value	.250	4.609	***
Purchasing Intention ←Effectiveness	.338	5.515	***
Purchasing Behaviour ←Purchasing Intention	.788	10.173	***

*Source: Primary Data Source *** indicates significant at one per cent level*

The results shows that the standardized coefficient for Purchasing Intention with respect to Efficiency is 0.218., the standardized coefficient for Purchasing Intention against Value is 0.250 and the standardized coefficient for Purchasing Intention against Effectiveness is 0.338 indicates that these values are significant at one per cent level. Thus, efficiency, value and effectiveness are directly and positively influencing purchasing intention of doctors through online.

Meanwhile, the standardized coefficient for Purchasing Behaviour with respect to Purchasing Intention is 0.788 which is statistically significant at the 1% threshold. This suggests that purchasing intention has a direct and positive influence on the purchasing behaviour of doctors through online platforms. Consequently, the null hypothesis, which posits no significant structural relationship between the factors influencing online information search, purchasing intention, and purchasing behaviour of doctors online, is rejected. Hence, the output indicates a significant structural relationship among these factors.

Hypothesis Testing

The final step in the data analysis involves testing all the hypotheses. This is achieved by evaluating the significance of the path coefficients by evaluating the p-values associated with the regression weights.

Path analysis extends the regression model by employing a path diagram to illustrate the relationships among independent, intermediate, and dependent variables. In this model, single-headed arrows represent causal effects between variables, while double-headed arrows signify covariances. The model establishes regression weights, and the goodness-of-fit statistic is computed to assess how well the model aligns with the data.

The path model visualizes the relationships among constructs. After running the estimates for the path model, the hypotheses concerning the influence of one construct on another are tested using the structural path model. The hypotheses of the model are:

Hypothesis 1: Efficiency has significant influence on purchase intention of doctors through online.

Hypothesis 2: Value has significant influence on purchase intention of doctors through online.

Hypothesis 3: Effectiveness has significant influence on purchase intention of doctors through online.

Hypothesis 4: Purchase intention has significant influence on purchase behavior of doctors through online.

The outcomes of hypotheses testing are offered in Table 7.2(iii).

Table 7.2 (iii): Standardized Path Coefficients for Hypotheses Testing for Purchase Behaviour of Doctors through Online

Sl. No.	Hypothesis	Standardized Path Coefficients	Supported / Not Supported
1.	Efficiency has significant influence on purchase intention of doctors through online.	.218	Supported
2.	Value has significant influence on purchase intention of doctors through online.	.250	Supported
3.	Effectiveness has significant influence on purchase intention of doctors through online.	.338	Supported
4.	Purchase intention has significant influence on purchase behavior of doctors through online.	.788	Supported

Source: Primary Data source

Direct and Indirect Effects of Factors Influencing Online Information Search on Doctors' Purchasing Intentions through Online Channels:

The direct and indirect effects of factors influencing internet information search on the purchasing intention of physicians are detailed in Table 7.2 (iv).

Table 7.2 (iv): Direct and Indirect Effects of Factors Influencing Online Information Search onPurchasing Intention of Doctors through Online

Variable	Co-efficient	Direct Effect	Indirect Effect			Total Indirect Effect	Total Effect
			Efficiency	Value	Effectiveness		
Efficiency	.218	0.048	-	0.032	0.024	0.056	0.104
Value	.250	0.063	0.032	-	0.028	0.060	0.123
Effectiveness	.338	0.114	0.024	0.028	-	0.052	0.166
Total Effect (r square)							0.393

Source: Primary Data Source

The total effect of efficiency, value and effectiveness on purchasing intention of doctorsthrough online is 0.393.

8.1 SUMMARY OF FINDINGS

A. Among doctors surveyed, 36.34% spend two hours daily on online searches, 31.97% spend three hours, 19.12% spend one hour, and 12.57% spend more than three hours.
B. Significant associations were found between doctors' gender and their preference for online information sources.
C. Educational qualifications of doctors significantly influence their preference for online sources.
D. The location of hospitals shows a significant association with doctors' preference for online sources.
E. The type of medical practice also significantly influences doctors' preference for online sources.
F. Efficiency, value, and effectiveness positively impact doctors' purchasing intentions through online platforms.
G. Purchasing intention directly influences the online purchasing behavior of doctors.

H. A strong structural relationship exists among factors influencing online information search, purchasing intention, and purchasing behavior of doctors.
I. To address operational service gaps in targeting doctors purchasing medical equipment online, service providers should enhance information management, create value, and improve communication efficiency, thereby enhancing purchase intentions and actual purchases.
J. It was observed that doctors' trust in online information sources significantly affects their purchasing decisions.
K. The frequency of online search among doctors correlates positively with their inclination to purchase medical products online.

9.1 RESEARCH LIMITATIONS

This study was conducted in Chennai city and relied on primary data collected from doctors engaged in online purchasing. Limitations inherent to field-level surveys, including potential recall bias, are applicable to this research.

10.1 RECOMMENDATIONS FOR FURTHER RESEARCH

Future studies should aim to increase the sample size to test the hypotheses across a more varied and extensive respondent pool. Relative studies across various geographical locations would provide understandings into variations in online search behaviours among doctors.

Further studies of this nature can be taken up with Ayurveda, Sidha, Homeopath and Unani Doctors and a comparative study can be made across different locations to start with metro cities in India.

11.1 CONCLUSION

The findings indicate that doctors actively utilize online resources for purchasing decisions, influenced significantly by gender, location, educational qualifications, and type of medical practice. Efficiency, value, and effectiveness, along with trust in online sources and search frequency, emerge as critical factors shaping online information search behaviours among doctors. These insights are pivotal for optimizing strategies aimed at enhancing online purchasing behaviours among medical professionals.

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A Strategic Market Adoption Study of Electric Cars in Chennai

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ABSTRACT

The Indian electric vehicle (EV) market is at a pivotal juncture, with adoption largely limited to innovators and early adopters. This paper applies Geoffrey Moore's "Crossing the Chasm" framework to investigate the key factors influencing the transition of prospective EV buyers, particularly in the semi-urban districts of Tiruvallur and Kanchipuram, Tamil Nadu towards the early majority phase. The study focusses only on the usage of Electric passenger cars. A mixed-method approach was employed, combining empirical data from 160 current owners of conventional vehicles with secondary data drawn from policy reports and industry publications. Data were collected using structured questionnaires via Google Forms, and analyzed using SPSS 19. Descriptive statistics, T-tests, and ANOVA were used to assess the relationship between demographic variables and attitudes toward EV adoption. The findings highlight that features such as environmental friendliness, lower operating costs, and noise-free performance are positively perceived. However, concerns remain around charging infrastructure, battery longevity, and pricing especially among lower-income and less-educated groups. The study concludes with strategic recommendations for bridging this adoption gap through infrastructure development, policy support, and targeted consumer engagement. These insights offer critical pathways for accelerating the mainstream adoption of EVs in India's emerging urban regions.

Keywords: Electric Vehicles, Environment friendliness, EV Adoption, Operating costs, Policies

1. INTRODUCTION

The advent of electric vehicles (EVs) represents a pivotal moment in the automotive industry's evolution, promising a cleaner, more sustainable mode of transportation. As nations across the globe seek to reduce their carbon footprint and mitigate the environmental impact of traditional gasoline-powered vehicles, the electric vehicle market is on the cusp of transformative growth. Major car manufacturers have agreed to stop producing new ICE cars by 2040 (Bloomberg, 2022).On the other hand, some developing countries are considered to be the world's laggards regarding EV adoption, with less than 1/1000th of the world's average (Ottesen et al.,2022). In this context, India, one of the world's largest and fastest-growing automobile markets, finds itself at a crucial juncture in the journey toward EV adoption. Consumer mindset's have also shifted toward sustainable mobility (Tirachini, 2020). Consequently, the EV landscape in India needs to be examined and inspected, particularly from the perspective of consumer behaviours.

The research study delves into the complex dynamics that surround the integration of electric vehicles into the Indian automotive landscape. It recognizes the need to shift from the initial enthusiasm of early adopters and innovators to broader acceptance and mainstream usage. This transition, often referred to as "crossing the chasm," is a formidable challenge for any emerging technology, and it carries unique implications within the diverse and dynamic Indian market.

Crossing the chasm in the Indian electric vehicle (EV) market is imperative for several compelling reasons. First, it is necessary to expand the market, reaching beyond early adopters to the mass population, considering India's vast consumer base. Second, EVs offer significant economic and environmental benefits, reducing pollution and dependence on imported oil, but these benefits can only be realized at scale. Moreover, government initiatives and incentives support EV adoption, but their success hinges on broader market acceptance. The development of EV infrastructure, such as charging stations, needs a critical mass of EVs on the road to justify investments. Mass adoption drives economies of scale, leading to lower EV costs, which is a pivotal factor for mainstream consumers. Addressing concerns like range anxiety and affordability becomes crucial for wider acceptance. Furthermore, intense competition among manufacturers requires a substantial market share, achievable only when EVs become commonplace. Finally, to meet ambitious environmental goals, India must transition to cleaner transportation, necessitating the crossing of the chasm to make EVs the norm rather than the exception in the automotive landscape.

The choice of Kanchipuram and Tiruvallur as sampling locations is both strategic and significant. These districts are vibrant industrial corridors with a high density of manufacturing units, including automotive, electronics, and heavy industries. The population in these regions represents a unique socio-economic segment that is neither as affluent and tech-savvy as metropolitan consumers nor as uninformed or risk-averse as rural populations. Instead, they are industrious, pragmatic, and cost-conscious decision-makers-traits that mirror the behavioral profile of the early majority as defined in Moore's theory. Their practical outlook and exposure to industrial technologies make them a valuable cohort for understanding the transitional phase in EV adoption. Studying this demographic offers deeper insight into the expectations, barriers, and motivators influencing a population that is likely to lead EV uptake in India's non-metro markets.

Research Implications

Theoretical Implementation: The study contributes theoretically by shedding light on the evolving dynamics of the Indian automotive market and the psychological aspects influencing consumer behaviour. The chasm theory, as applied to EV adoption, provides a theoretical framework for understanding the stages of market acceptance, aiding academics and strategists in developing models for future technology adoption.

Practical Implementation: Practical implications include the development of strategic roadmaps for stakeholders, including automakers, policymakers, and investors. Insights from the analysis can guide practical approaches to infrastructure development, consumer awareness programs, and collaboration initiatives aimed at accelerating the transition to EVs.

Policy Implementation: Policymakers can leverage the study to refine existing policies and design new initiatives that align incentives with broader market acceptance. Focusing on affordability, charging infrastructure development, and consumer education will enhance the effectiveness of policy interventions in promoting EV adoption.

Social Implementation: Socially, the study underscores the need for changing perceptions surrounding EVs. Initiatives promoting cleaner alternatives align with public consciousness about environmental issues. Social implementation should involve comprehensive awareness campaigns and educational programs, fostering a positive societal attitude towards EVs as a mainstream choice.

2. LITERATURE REVIEW

Sustainable mobility is evolving in a positive way. In the upcoming years, it is anticipated that EV sales will climb significantly; specifically, it is projected that EV sales would increase from 2.7% at today to 58% by 2040 (Rosellon, M.A.D. 2021). For this reason, the European Economic Area (EEA) countries have indicated their apparent plans to stop investing in new ICE platforms and models in order to discontinue the production of ICE vehicles, and they are aiming to ban the sale

of all fossil fuel-powered cars by 2040 in order to reach net-zero emissions by 2050 (Pardi T, 2022 and Kalghatgi G, 2018). Major automakers have thus decided to cease manufacturing new internal combustion engine vehicles by 2040. Norway, Iceland, and the Netherlands, for example, are leading the way in this shift, with up to 20% of their automobile fleets being entirely or largely electric (Bloomberg, 2023). However, with EV adoption rates less than 1/1000th of the global average, several emerging nations especially Kuwait are regarded as the world's laggards in this regard (Ottesen, A et al., 2022). Additionally, consumer attitudes have changed in favor of sustainable mobility (Tirachini, A., 2022). Although, EV is gaining momentum still it faces hindrances while scaling up growth. According to the study (Naveen Virmani et al., 2023), the primary obstacles to EV adoption are their greater initial cost and the scarcity of charging facilities. Government policy, assistance, and strategic planning are the most successful mitigation techniques for removing EV-related obstacles. Further study by (Ramesh, A et al., 2024) states that, sustainability is a top priority for consumers, and EV adoption is fueled by financial considerations including cost, government subsidies, and fuel savings. Technological developments improve charging infrastructure and battery efficiency.

Despite government initiatives like FAME and FAME II, (Rumi Aijaz, 2022) highlights two obstacles that are impeding the implementation of EVs in India: a lack of customer awareness and a lack of manufacturing/charging infrastructure. These represent early chasm-stage difficulties: adoption stalls in the absence of a supporting environment and social validation. Therefore, supply-side ecosystem-building and demand stimulation (such as incentives and public awareness) should be included into strategic thinking. Furthermore, the in alignment with the theory of planned behavior model, study confirmed that attitude, subjective norms, and perceived behavioral control (PBC) all directly improve intention to use, which is consistent with the elements of the traditional Theory of Planned Behavior. The most significant predictor among these was perceived behavioral control, highlighting the significance of users feeling competent and supported in their use of electric vehicles, both physically and socially. (Ravishankar k, 2023)

The idea of "institutional voids" policy ambiguity and regulatory loopholes that hinder EV adoption is highlighted by (Pandey & Das, 2020). The lack of explicit standards and incentives makes it difficult for early adopters to transition to pragmatists. To legitimate EVs in larger markets, businesses must take calculated actions like lobbying, joint ventures, or market trials. According to a survey conducted by (Maheshwari J, 2022) in tier-1/tier-2 cities, infrastructure ranking particularly, rapid charging is the most important consideration when making a purchase, surpassing both cost and performance, which were also cited as factors in bridging the gap: Pragmatists' opposition to adoption is lessened by infrastructure cues..

Furthermore, there is still a lack of supply-chain optimization techniques suited to developing nations like India. An integrative strategic study that combines chasm-crossing strategies like whole-product planning, niche market targeting, and distribution channel innovation with India's particular market dynamics like dependence on imported battery components and undeveloped public charging network is still lacking. In particular, while international case studies emphasize how crucial it is to create an engaging product ecosystem and use reference customers to win over pragmatists, little empirical research has been done on how Indian EV manufacturers can adopt similar strategies in the face of unstable local policies and disjointed infrastructure. (Dhairiyasamy, R., & Gabiriel D, 2025).This study will helps to understand the adoption of EV and gives strategic input to the policy makers and manufactures towards scaling up their operations.

Several studies have explored EV adoption through economic, technological, and behavioral lenses. In Kuwait, (Al-Durra et al., 2023) applied the "Crossing the Chasm" model to identify psychological and infrastructural gaps limiting adoption. Similarly, Indian studies have emphasized the role of government subsidies, awareness, and infrastructure development (BCG, 2023; NITI Aayog, 2022).

Moore's model differentiates the early market (visionaries and enthusiasts) from the mainstream market (pragmatists and conservatives). Crossing the chasm requires strategic alignment between innovation attributes and practical needs. This research applies that model in an Indian context, backed by primary data and statistical validation.

3. RESEARCH DESIGN

This study adopts a mixed-method research design, combining both empirical and secondary data analysis to examine the challenges and strategic pathways for mainstream adoption of Electric Vehicles (EVs) in India, specifically through the lens of Geoffrey Moore's "Crossing the Chasm" theory. The research is descriptive and analytical in nature, aiming to understand the behavioral and strategic shifts necessary for transitioning early adopters into the early majority phase of EV consumers.

Research Objectives

This research study aims to shed light on factors that might encourage a transition from conventional vehicles to EVs, ultimately contributing to the establishment of a mass market for electric vehicles in India. This analysis embarks on an exploration of the strategies and considerations essential to guide electric vehicles across this chasm in India. It seeks to understand the multifaceted nature of the Indian automotive ecosystem, including its infrastructure, consumer preferences, regulatory framework, and technological readiness. By evaluating these factors in depth, the analysis aims to shed light on the path forward for EVs in India and provide a roadmap for stakeholders, including automakers, policymakers, and investors, to navigate the intricacies of this pivotal market transformation.

- To identify the perceptions, preferences, and barriers among prospective EV users currently owning conventional vehicles.
- To analyze the applicability of the "Crossing the Chasm" model to the Indian EV market.
- To provide strategic recommendations to facilitate mainstream EV adoption in semi-urban and peri-urban areas of Tamil Nadu.

Sampling Method and Population

The target population includes current owners of conventional vehicles (four-wheelers) residing in Tiruvallur and Kanchipuram districts, who have expressed interest or intent to switch to Electric Vehicles in the near future. Due to the niche nature of this population, Snowball Sampling was employed. This non-probability sampling technique allowed the researchers to reach a relatively hard-to-access group of prospective EV adopters, by initiating the survey with known contacts and then requesting referrals to others who fit the criteria.

4. DATA COLLECTION

Primary Data

In designing the research instrument, this study adopted key components of the questionnaire and conceptual framework from the study titled "How to Cross the Chasm for the Electric Vehicle World's Laggards, A Case Study in Kuwait" (Al-Durra et al., 2023). The constructs related to social attributes, technological features, infrastructure readiness, and financial factors were adapted with contextual modifications to suit the Indian demographic and policy environment. This ensured conceptual consistency with prior research while allowing for localized insights. Empirical data were collected through this structured questionnaire designed using Google Forms. The questionnaire consisted of both closed-ended and Likert-scale items, focusing on:

- Demographics and vehicle ownership patterns
- Awareness and perception of EVs
- Factors influencing EV adoption (economic, environmental, performance, infrastructure)
- Barriers to adoption (range anxiety, cost, availability of charging stations)
- Innovation adoption behavior (mapped to Rogers' Diffusion of Innovation and Moore's Chasm theory)

A total of 160 valid responses were collected over a two-month period (March–April 2025). The responses were exported to MS Excel and later analyzed using descriptive statistics and correlation analysis via SPSS/Excel. The unit of analysis was the individual vehicle owner.

Secondary Data

In addition to primary data, secondary data were sourced from:

- Reports published by NITI Aayog, Ministry of Road Transport and Highways (MoRTH), and the Society of Manufacturers of Electric Vehicles (SMEV)
- Market research reports from McKinsey, BCG, and IEA
- Academic journal articles related to EV adoption models, technology diffusion, and consumer behavior
- Policy documents outlining FAME II, state-level EV policies, and incentive schemes

These sources provided contextual and comparative insights into EV adoption trends across India and globally, enriching the interpretation of empirical findings.

Scope and Limitations

While the study offers valuable insights into EV adoption behavior in emerging urban clusters, its findings are limited in geographic scope to two districts in Tamil Nadu. The use of snowball sampling, though effective in reaching a specific target group, may limit the generalizability of the results to the broader population. However, the insights derived can guide targeted policy interventions and business strategies in similar demographic regions.

Statistical Analysis

For statistical work, we utilized IBM SPSS 19. Descriptive statistics like frequencies and percentages were used to assess the data related to the demographic characteristics. Hypothesis testing was formulated because the study's goal was to ascertain how frequent EV traits are among potential purchasers.

To find significant differences, t-tests and ANOVA were also performed. ANOVA was used to determine whether statistically significant differences in means occurred between more than two groups, i.e., when considering one independent variable with more than two distinct or continuous categories and one continuous dependent variable. The mean scores of two groups of one independent variable-which had just two discrete categories-and one continuous dependent variable were compared using the t-test.

Table 1: Demographic Profile of the respondents.

Demographic Profile	Measures	Frequency	Percent	Cumulative Percent
Gender	Male	105	66	66
	Female	55	34	100
Age	26-30 years	32	20	20
	31-35 years	101	64	84
	36-40 years	17	10	94
	41-45 years	10	6	100
Education Level	Bachelors degree (Non commerce Degree)	28	17.5	17.5
	High School	7	4.4	21.9
	Master's degree	86	53.8	75.6
	PhD	23	14.4	90
	Trade/Commerce degree	16	10	100

Demographic Profile	Measures	Frequency	Percent	Cumulative Percent
Marital Status	Married	12	7.5	7.5
	Married - have 1 child	25	15.6	23.1
	Married - have 2 children	5	3.1	26.3
	Marrid - have 3 children	5	3.1	29.4
	Single (Not married)	113	70.6	100
Employment	Family-owned business	11	6.9	6.9
	Private sector	89	55.6	62.5
	Public sector	5	3.1	65.6
	Self-employed	10	6.3	71.9
	Student	1	0.6	72.5
	Unemployed	44	27.5	100
Field of Employment	Educational government or private	39	24.4	24.4
	Family business	17	10.6	35
	Government and Ministries	9	5.6	40.6
	Oil and Gas sector	1	0.6	41.3
	Other private services	94	58.8	100
Annual Income (INR)	3 Lakhs to 5 Lakhs	39	24	24
	5 Lakhs to 10 Lakhs	34	21	45
	10 Lakhs to 15 Lakhs	15	9	54
	15 Lakhs to 20 Lakhs	56	35	89
	More than 20 Lakhs	16	11	100
Which of the following best describes your role in industry?	Administrative Staff	3	1.9	1.9
	Lower Management	3	1.9	3.8
	Middle Management	44	27.5	31.3
	Researcher	16	10	41.3
	Self-employed/Business Partner	4	2.5	43.8
	Students Not working	69	43.1	86.9
	Temporary Employee	1	0.6	87.5
	Trained Professional expert	9	5.6	93.1
	Upper Management	11	6.9	100

Table 1 provides an overview of the respondents' demographic attributes. The questionnaire was filled out by 105 men (66%) and 55 women respondents (34%).
Age: Over one-third (20%) of the participants were between the ages of 26 and 30, and roughly half (64%) were between the ages of 31 and 35. Around 10% of the respondents were between the age of 36 and 40 years. And a very a smaller number of respondents (6%) were between the age of 41 and 45 years.

Considering the **Educational Qualification** of the respondents, nearly 17.5% of them have completed their bachelor's degree, 4.4 % of them with Higher secondary education, 53.8% of them with Masters degree 14.4 % of them with PhD and 10% of them with commerce graduation.

Marital Status. About 7.5% of the respondents were married and do not have children. About 15.6% of the respondents are married and have only one child. Nearly 3.1 % of the respondents have two children and 3 children respectively. And majority of them are not married representing 70.6%

Regarding the **Employment nearly** 6.9% of the respondents have their own family business, 55.6% of them were working in private sector and a very less number of respondents (3.1%) were working in public sector banks. Around 6.3 % of them were self-employed and around 27.5% of them were unemployed.

Sector of Employment. The highest number of people were working in private sector contributing around 58.8% of the responses. A very less number of responses (0.6%) and 5.6% were received from the oil and Gas sector and Government and Ministeries department respectively. Around 10.6% of them have their own family business.

Respondents Role in the Industry they are working with: The highest number of responses were received from the student's community contributing around 43.1% followed by the people working in the Middle Management (27.5%) and the researcher community with 10%. Lower management and administrative staff contributing 1.9 % each respectively. Upper management with 6.9% and Trained professional with 5.6 % and the least being the temporary employee with 0.6% of the responses.

Income Level. Respondents with the highest amount of annual income contribute around 35% followed by 24% & 21% of the respondents with 3 lakhs to 5 lakhs income and 5 lakhs to 10 lakhs income respectively. Around 11% of the respondents were earning an income of more than 20 lakhs per annum and the least number of responsdents with 10 lakhs to 5 lakhs comes around 9%

Table 2: Number of cars in the household

Number of Cars in household	Frequency	Percent	Cumulative Percent
Five cars or more	3	1.9	1.9
Four cars	7	4.4	6.3
One car	128	80	86.3
Three cars	5	3.1	89.4
Two cars	17	10.6	100

Number of cars in the household: The majority of individuals have one car (80%) and the least number being 3.1% and 10.6% having 3 cars and 2 cars respectively. (Refer Table 2)

Table 3: Number of cars using Petrol

Number of Cars (Petrol)	Frequency	Percent	Cumulative Percent
0 (Diesel cars)	26	16.3	16.3
1	119	74.4	90.6
2	11	6.9	97.5
3	1	0.6	98.1
4	3	1.9	100

Irrespective of the number of cars they possess, almost everyone uses petrol for their car. However, in our sample there were few respondents who also uses diesel cars. Moreover, those who have only one car, has the likelihood of using petrol cars rather than preferring to diesel cars. (Refer Table 3)

Descriptive Statistics
Calculated mean ($M \sim 3.5$) indicates high agreement; $2.5 \sim M < 3.5$ indicates medium agreement; and $M < 2.5$ indicates low agreement.

Participants strongly agreed on three characteristics of EVs that they thought were the best they were environmentally friendly, with lower CO2 resulting in better air quality (M = 3.54), significantly less expensive than gasoline (M = 3.44), and had a soundless engine (M = 3.72). Other aspects, like improved safety in fire and crash testing (M = 3.49), more powerful and faster air conditioning (M = 3.26), significantly faster acceleration from 0 to 100 km (M = 3.12), and significantly reduced maintenance and related costs (M = 3.14), got a medium level of agreement. According to participants' perceptions of the requirements for purchasing EVs, two requirements were strongly agreed upon: whether the battery would last at least 10 years or 150,000 km (M = 3.54), and whether there was a fast-charging station within 5 km of practically every location in Kuwait (M = 3.51).

There was a medium level of agreement on other requirements, such as whether they noticed a noticeable change in the quality of the air because people were driving EVs (M = 3.47), whether their range (the amount of time they could drive) was at least 400 km on a full charge (M = 3.47), whether they had a cool and unique design (M = 3.43), whether the price was the same or less than that of an equivalent gasoline car (M = 3.29), whether their resale value was equal to or higher than that of a gasoline car (M = 3.29), and whether the price of gasoline would triple (M = 3.33).

With regard to four background variables that had two groups (gender, marital status, and the number of cars owned) and four background variables that had more than two groups (age range, education, employment, and monthly income), respectively, the t-test and ANOVA were used to identify significant differences between the most favorable features of EVs found in the study.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	65.712	4	16.428	59.651	.000[b]
	Residual	42.688	155	.275		
	Total	108.400	159			

a. Dependent Variable: EV_ADOPT

b. Predictors: (Constant), INFR_ATT, FIN_ATT, SOC_ATTR, TECH_ATT

The regression analysis revealed that the overall model was statistically significant (F = 59.651, p < 0.001), indicating that the predictor variables- **Social Attributes (SOC_ATTR), Technological Attributes (TECH_ATT), Financial Attributes (FIN_ATT), and Infrastructure Attributes (INFR_ATT)**, explains a significant portion of the variance in EV adoption behavior.The R^2 value of **0.606** implies that **60.6% of the variance** in the dependent variable (**EV_ADOPT**) can be explained by the independent variables.

4.1.1 Significant Predictors

- **Social Attributes (β = 0.342, p < 0.001)** emerged as the most influential factor, suggesting that **social acceptance, peer influence, and societal perception** play a crucial role in the decision to adopt EVs. This confirms the importance of **social proof and community-based interventions** in bridging the adoption gap.
- **Infrastructure Attributes (β = 0.296, p < 0.001)** also showed a strong positive influence, indicating that the **availability of charging stations and service networks** is a key enabling factor. This finding is aligned with the earlier descriptive analysis, where fast-charging availability was a high-priority concern for educated and high-income respondents.
- **Technological Attributes (β = 0.217, p = 0.012)**, including perceptions about battery performance, range, and vehicle speed, were statistically significant. It points to a growing **consumer trust in EV technology**, but also highlights that technical performance is still scrutinized by early majority segments.

4.1.2 Non-Significant Predictor

- **Financial Attributes (β = 0.070, p = 0.387)** did not significantly predict EV adoption, a surprising finding considering India's price-sensitive market. One possible interpretation is that **early prospective adopters are more motivated by environmental and social values**, or that **financial incentives alone** are not enough without supportive infrastructure and peer influence.

VARIABLES	BETA	T VALUE	SIGNIFICANT	RESULT
SOC_ATTR	0.342	4.867	0	SIGNIFICANT
TECH_ATT	0.217	2.555	0.012	SIGNIFICANT
FIN_ATT	0.07	0.867	0.387	NOT SIGNIFICANT
INFR_ATT	0.296	4.383	0	SIGNIFICANT

R SQUARE: 0.606

CORRELATION

		SOC_ATTR	TECH_ATT	FIN_ATT	INFR_ATT
SOC_ATTR	Pearson Correlation	1			
TECH_ATT	Pearson Correlation	.581**	1		
FIN_ATT	Pearson Correlation	.504**	**.772****	1	
INFR_ATT	Pearson Correlation	.632**	.522**	.484**	1

Reliability

SOC_ATTR	0.623
TECH_ATT	0.772
FIN_ATT	0.799
INFR_ATT	0.684
EV_ADOPT	0.614

The Pearson correlation coefficients show **moderate to strong relationships** between the predictor variables, with the highest correlation between **TECH_ATT and FIN_ATT (r = 0.772, p < 0.01)**. This multicollinearity is expected to some extent in behavioral studies and suggests that financial and technological perceptions are **interlinked in the consumer's mind**.

Reliability scores (Cronbach's Alpha) were above or near the acceptable threshold (α > 0.6), confirming internal consistency of the measurement scales. **FIN_ATT (α = 0.799)** and **TECH_ATT (α = 0.772)** had good reliability, while **SOC_ATTR (α = 0.623)** and **INFR_ATT (α = 0.684)** were acceptable. This validates the robustness of the constructs used.

5. SUMMARY OF THE FINDINGS

The mean scores of the features pertaining to employment and the number of cars owned showed significant differences when compared to the mean scores of the other eight background variables. Participants with one or two cars expressed strong agreement with the EVs' environmental friendliness (M = 3.80, p = 0.02) and soundless engine (M = 3.63, p = 0.024), whereas those with three or more cars expressed moderate agreement with the soundless engine feature and strong agreement with the EVs' environmental friendliness.

Additionally, those working in the public sector expressed strong agreement with EVs' environmental friendliness (M = 3.80, p = 0.001), significantly lower fuel prices (M = 3.69, p = 0.004), and soundless engines (M = 3.88, p = 0.011), whereas those working in family-owned businesses expressed only moderate agreement with these attributes. However, there were no

discernible variations between the other six participant background characteristics and the best attributes of EVs found in the study.
Additionally, for the four background variables with two groups (gender, marital status, ethnicity, and the number of cars owned) and the four background variables with more than two groups (age range, education, employment, and monthly income), respectively, the t-test and ANOVA were used to identify significant differences in the requirements needed to purchase EVs identified in the study.

Participants' monthly income and educational attainment showed significant differences in the mean scores of the two requirements when the mean score of features was compared across the eight background factors. Those with a Ph.D. or master's degree strongly agreed that there should be a fast-charging station within 5 km of practically every location in Kuwait (Ph.D. mean = 4.18, Master's mean = 3.81, p = 0.001), whereas those with a bachelor's degree agreed just modestly.
Additionally, whether the battery would last at least 10 years or 150,000 km was highly agreed upon by participants with monthly incomes between KD 1000 and 1499 or KD 1500 and above (M = 3.81, M = 3.60, p = 0.016), as was the existence of a fast-charging station within 5 km of nearly every location in Kuwait (M = 3.82, M = 3.52, p = 0.009), whereas participants with monthly incomes below KD 500 were only moderately agreed upon. However, there were no appreciable variations in the prerequisites for purchasing EVs found in the study when compared to the other six participant background factors.

6. DISCUSSION

The results of this study provide significant insights into the strategic adoption dynamics of Electric Vehicles (EVs) in semi-urban Indian districts, aligning with Geoffrey Moore's **"Crossing the Chasm"** theory. The findings suggest that the early majority-represented by respondents from Tiruvallur and Kanchipuram districts-have positive inclinations toward EVs but remain cautious due to infrastructural and economic concerns.

6.1 Demographic and Psychographic Influence

A predominantly young, educated, and professionally active cohort showed higher readiness to transition to EVs. A significant portion of respondents were aged between **31–35 years** (64%) and held at least a **Master's degree** (53.8%), indicating that **higher education and professional exposure** correlate positively with EV awareness and intent to adopt.

The **environmental friendliness** of EVs (M = 3.54) and **soundless operation** (M = 3.72) emerged as the most appreciated features, showing strong alignment with **green consumerism**. This aligns with previous studies indicating that ecological consciousness is a key driver among early adopters.

6.2 Perceived Product Attributes

From the mean scores, it is evident that **cost-efficiency**, **low noise levels**, and **reduced emissions** are widely accepted as major benefits. However, **factors such as battery longevity**, **charging infrastructure**, and **range anxiety** still present moderate to high concern, especially among those from lower income brackets or with lower educational backgrounds.

Importantly, participants with **Ph.D. and Master's degrees** showed strong agreement on the need for **fast-charging stations within 5 km**, emphasizing the need for accessible charging infrastructure as a non-negotiable prerequisite for mass adoption. Likewise, **higher-income respondents** (earning above ₹15 lakhs annually) had a stronger preference for reliable battery life and faster charging, revealing that **convenience and confidence in technology** are critical trust factors in crossing the adoption chasm.

6.3 Employment Sector and EV Perception

Respondents from the **public sector** showed statistically significant preference for EVs in terms of environmental impact, fuel savings, and noise reduction. This suggests that **government-**

employed individuals, likely influenced by sustainability mandates and policy awareness, may form a pivotal part of the early majority who can influence peer adoption.
In contrast, those in **family-run businesses or lower-income brackets** expressed moderate agreement, likely due to **perceived economic risk**, which still acts as a barrier.

7. RECOMMENDATIONS

Based on the data interpretations, the following strategic recommendations are proposed for **policymakers**, **automobile companies**, and **urban planners** to help **cross the chasm** and transition EVs from early adopters to the early majority:

Infrastructure Development

- **Expand Fast-Charging Networks**: Government and private firms must prioritize **dense and decentralized EV charging infrastructure**, particularly in semi-urban districts. The presence of **charging stations within a 5 km radius** should be a minimum benchmark.
- **Battery Swap Stations**: Introducing **battery swapping models** can reduce range anxiety and support long-distance commuters, a major concern among middle-income groups.

Price Incentives and Financing

- **Subsidies and Tax Benefits** should be continued or increased for middle-income families and early-stage adopters.
- **EV Loan Schemes** with reduced interest rates can alleviate initial capital barriers for salaried employees and small business owners.

Targeted Awareness Campaigns

- Conduct **education-focused campaigns** in public institutions, universities, and private firms emphasizing **cost-benefit comparisons** with Internal Combustion Engine (ICE) vehicles.
- Utilize **green influencers and civil servants** to champion early majority adoption, particularly in government quarters and gated communities.

Customization and Innovation

- Auto manufacturers should **customize EV models** for Indian road conditions and heat resilience while offering **differentiated aesthetics** and **advanced air conditioning features**-traits moderately agreed upon in the study.
- Integration of **smart features** like **real-time battery analytics**, **AI-assisted maintenance tracking**, and **app-enabled service** can enhance trust and convenience.

Policy and Public Sector Integration

- Mandate **EV fleet conversion** in public offices, postal services, and government departments to increase visibility and public trust.
- Provide **incentives for EV-based last-mile delivery models** to bridge logistics and commercial vehicle adoption

8. CONCLUSION

This study provides a multi-dimensional analysis of the factors influencing EV adoption among prospective buyers in Tamil Nadu, India, through the lens of Moore's "Crossing the Chasm" framework. . By focusing on the districts of Tiruvallur and Kanchipuram, the research captures the voice of a segment often underrepresented in EV transition dialogues. The empirical findings reinforce that while EVs are largely appreciated for their ecological and economic advantages, critical infrastructural and perception-related gaps still prevent wider adoption.

The findings suggest that the transition from early adopters to early majority is heavily influenced by **social endorsement**, **technological trust**, and **infrastructure readiness**, while **financial attributes alone do not significantly influence** adoption decisions in this specific segment .With an R^2 of 0.606, the regression model confirms that these variables together meaningfully predict

adoption intentions. **Social influence** emerged as the most dominant predictor, highlighting the need for community-level advocacy, visibility, and influencer endorsement. Meanwhile, **infrastructure reliability** must improve to instill confidence in semi-urban populations.

Despite common assumptions, **financial incentives are insufficient in isolation**; thus, policies and promotions must be bundled with **technology assurance** and **infrastructure access** to effectively drive the chasm-crossing effort.These insights can inform tailored strategies for automotive manufacturers, urban developers, and policymakers seeking to accelerate EV adoption in India's semi-urban and peri-urban regions.
The application of the "Crossing the Chasm" framework underscores that India is at the critical tipping point between early adopters and the early majority. To traverse this chasm, targeted interventions in the form of robust charging infrastructure, price-based incentives, and consumer education are essential. Educational attainment and income levels emerged as key differentiators in consumer confidence and readiness to shift to EVs, suggesting that policy and marketing strategies must be nuanced and context-specific.

Ultimately, for India to realize its EV vision and achieve its broader sustainability goals, stakeholders-governments, private manufacturers, urban planners, and financiers-must collaboratively address the functional, psychological, and economic concerns of prospective users. This study offers actionable insights to aid that transition and contribute to a greener transportation future.

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AI in The Loop: Unveiling the Next Wave of Trends in Influencer Marketing Ecosystems

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ABSTRACT

In the contemporary digital landscape, the intersection of artificial intelligence (AI) and influencer marketing is catalysing a paradigm shift, fundamentally transforming how brands engage with audiences. This paper critically explores the emerging phenomenon of "AI in the loop" within influencer marketing ecosystems - where AI is not just a tool but a co-creator, curator, and strategist. As social media platforms evolve into AI-optimised arenas of hyper-personalised engagement, influencers are increasingly augmented by machine learning algorithms, predictive analytics, and synthetic media. This shift raises profound implications for authenticity, trust, and consumer behaviour.

Drawing on existing literature, industry white papers, and recent empirical studies, the paper presents a conceptual framework that maps the evolution of influencer marketing through three distinct stages: human-led, AI-assisted, and AI-integrated. Key trends explored include the rise of virtual influencers, AI-powered content curation, sentiment mining, real-time audience profiling, and ethical challenges surrounding transparency and data privacy. The analysis critically interrogates the tension between AI- driven optimisation and human-centric engagement - particularly in how algorithmic bias and performative authenticity may distort relational dynamics between brands, influencers, and audiences.

This paper contributes to the discourse on sustainable marketing by proposing a set of guiding principles for ethical AI deployment in influencer campaigns, aligned with humanistic management values and the UN Sustainable Development Goals. The findings underscore the need for a recalibration of marketing strategies to ensure that AI-enhanced influencer ecosystems remain grounded in fairness, inclusion, and consumer well-being.

Ultimately, this work seeks to provoke a forward-looking dialogue among academics, marketers, and technologists about the future contours of influencer marketing in an AI-dominated era. As the line between human and machine blurs, the question is no longer whether AI belongs in the loop - but how we shape that loop to serve both brands and the broader human community.

Keywords: Influencer Marketing, Artificial Intelligence, Human-Centric AI, Consumer Trust, Digital Ethics

INTRODUCTION

In the sprawling digital marketplace where algorithms speak louder than taglines, influencer marketing has emerged as one of the most potent forces shaping contemporary consumer engagement. No longer a fringe tactic relegated to Instagram selfies and celebrity endorsements, influencer marketing now stands at the crossroads of data science, behavioural psychology, and algorithmic orchestration. Yet, beneath the curated perfection of posts and metrics lies a deeper transformation - one catalysed by the relentless advance of artificial intelligence (AI). We are entering the epoch of "AI in the loop", wherein machines are not simply supporting cast but co-creators, decision-makers, and sometimes even the very influencers themselves.

This paper ventures into that evolving ecosystem - not to romanticise technological utopias, nor to raise doomsday alarms, but to critically examine how the integration of AI is reshaping the DNA of influencer marketing. The title, "AI in the Loop", is not metaphorical flourish; it denotes a structural shift where AI systems are embedded throughout the influencer value chain. From identifying the right persona to automating content scheduling, from real-time audience profiling to deepfake-driven virtual influencers, the machinery is no longer backstage - it is on the frontlines, actively scripting engagement narratives. In such an environment, marketing is less about storytelling and more about story-calibration.

The rationale for this inquiry rests on two interlocking developments. First, the sheer scale and complexity of digital consumer data have rendered human-only decision-making inefficient and reactive. Brands today operate in an environment where milliseconds matter, where virality is engineered not stumbled upon. AI, with its predictive analytics, natural language processing, and deep learning capabilities, offers marketers the capacity to anticipate, personalise, and optimise at speeds previously unimaginable. Secondly, and more problematically, this rapid integration raises urgent questions around authenticity, ethics, and trust. As AI begins to influence not only what is marketed but also how it is perceived, the line between manipulation and persuasion becomes perilously thin.

The traditional influencer marketing model - largely organic, human-centric, and community-driven - is now contending with a hybrid paradigm. AI is now baked into tools that identify micro-influencers with laser precision, generate tailored content based on sentiment analysis, and evaluate campaign ROI using machine-learned benchmarks. Influencers themselves are engaging with AI not just as beneficiaries but as active participants - utilising chatbots for fan engagement, leveraging AI editors for visual branding, and in some cases, being entirely artificial entities programmed to simulate human behaviour. Lil Miquela, Shudu, and other AI-generated avatars are no longer marketing novelties but lucrative brand ambassadors with millions of followers. The "loop", in this context, is more than feedback - it is an ongoing fusion of human intention and machine execution.

Yet, for all its prowess, the inclusion of AI in influencer marketing presents a two-edged sword. On one hand, it offers extraordinary efficiency, scalability, and granularity in campaign management. On the other, it introduces opaque algorithms, risks of bias, and ethical dilemmas concerning transparency and consent. Consider the growing usage of generative AI to create influencer content that mimics tone, style, and emotionality without actual human input. While such tactics may enhance consistency and cut costs, they also risk eroding consumer trust and damaging the authenticity that forms the very basis of influencer appeal. In the long term, over-automation threatens to transform influencers from relatable figures into curated avatars - reducing their role to programmable functions optimised for clicks.

It is in this context that a humanistic perspective becomes essential. Aligning influencer marketing with such values requires a reimagining of both intent and implementation. Marketers must ask: Can we develop AI systems that support - rather than supplant - human creativity? Can machine-learning models be designed to amplify inclusive narratives rather than reinforce stereotypes? Can

algorithmic efficiency coexist with emotional intelligence? These are not rhetorical questions; they are the new metrics of sustainable influence in a digitised society.

This paper thus aims to investigate how AI is reconstituting influencer marketing ecosystems through a critical, conceptual lens. Drawing from academic literature, industry reports, and ethical frameworks, it outlines the evolution of AI's role across three overlapping stages - human-led, AI-assisted, and AI- integrated. Each stage reflects a degree of machine involvement, along with corresponding challenges and opportunities. The paper also maps key technological trends such as virtual influencers, real-time sentiment mining, audience micro-segmentation, and automated campaign optimisation. However, it does not end at technological exposition. Instead, it problematises the growing reliance on algorithmic logic by interrogating its impact on consumer trust, relational authenticity, and social equity.

Furthermore, the paper proposes a human-centric AI framework tailored for influencer marketing, grounded in three pillars: transparency, inclusivity, and digital dignity. Transparency demands that followers be made aware when content is AI-generated or curated, preserving trust and accountability. Inclusivity requires that AI tools do not replicate biases in influencer selection or audience targeting, particularly regarding gender, race, or socio-economic status. Digital dignity advocates for ethical treatment of data - ensuring privacy, informed consent, and fair usage throughout the campaign lifecycle. These principles are not simply idealistic aspirations but operational imperatives for brands seeking to thrive in a future where consumers are increasingly AI-literate and ethically conscious.

Finally, the paper contributes to the broader discourse on responsible innovation by linking its findings to global sustainability goals - particularly those relating to innovation, inequality reduction, and ethical digital consumption. By situating influencer marketing within this framework, the paper emphasises that AI integration must not only serve commercial metrics but also societal well-being.

In sum, this work does not offer a technological blueprint or marketing manual. Rather, it provides a critical reflection on the nature of influence in a machine-mediated world. As AI continues to evolve from backstage assistant to co-pilot in marketing campaigns, the challenge is not to halt its progress - but to humanise its path. In influencer ecosystems, where perception is everything and trust is currency, the true innovation lies not in faster algorithms but in fairer systems.

LITERATURE REVIEW

In recent years, the fusion of artificial intelligence (AI) and influencer marketing has drawn increasing academic scrutiny, reflecting the accelerated integration of machine intelligence into the digital marketing ecosystem. Rao and Kumar (2025) argue that influencer marketing has reached an inflection point wherein AI no longer plays a supplementary role but acts as a central mechanism for content calibration, audience profiling, and predictive outreach. They suggest that the next frontier lies in the development of adaptive AI models capable of autonomously managing influencer personas across dynamic platforms. Echoing this, Zhang et al. (2024) explore the emergence of hybrid influencer models, where real-time AI input modulates tone, message, and even personality traits of digital avatars to maximise brand resonance. Their findings underscore the extent to which AI-generated influencers have moved from novelty to norm, with brands increasingly investing in synthetic characters for better control and cost-efficiency. Moreover, Bhattacharya and Sen (2024) draw attention to the ethical opacity of such models, particularly the blurred lines between authenticity and simulation. They raise concerns about the psychological impact on audiences, especially younger demographics, when machine-curated content is passed off as human engagement. These critiques are echoed by Ahmed and Choudhury (2023), who argue that the performative authenticity generated by AI may erode trust - the cornerstone of influencer effectiveness - and inadvertently commodify emotional labour.

From a technological standpoint, Patel and Jindal (2023) provide a deep dive into the mechanics of AI- driven influencer selection, describing how natural language processing and computer vision

techniques are used to mine digital footprints and assess alignment with brand voice. While such systems enable precision targeting, they also risk reproducing algorithmic bias, a concern validated by Frick and Narayan (2023), who found disproportionate exclusions of minority creators from brand collaborations due to data-trained AI preferences skewed by historical patterns. In terms of content creation, Saxena (2023) illustrates how generative AI tools like ChatGPT and MidJourney are now embedded into influencer workflows, creating scalable visual and textual content with minimal human input. This convergence of automation and creativity, though efficient, is criticised by Reed and Bakshi (2023) for diluting originality and oversaturating platforms with homogenised narratives. From a regulatory standpoint, Johnson and Al-Mutairi (2022) argue that current disclosure laws are inadequate in the face of AI-generated promotional content, where disclosure is either intentionally obfuscated or absent altogether, placing consumers in a precarious position regarding informed engagement.

On the consumer front, psychological studies reveal growing scepticism towards overly polished, AI- optimised influencer content. Morgan and Lee (2022) found that although AI-enhanced influencers may boost initial engagement metrics, long-term brand loyalty is more likely to be sustained through perceived authenticity, which AI often fails to convincingly emulate. Their study aligns with findings by Ferreira and Nandita (2022), who conducted sentiment analysis on social media interactions and observed that users tend to show greater emotional connection with flawed, spontaneous content - traits that are inherently human and difficult for AI to replicate. These observations feed into the broader discussion around human-AI collaboration, which Lee and Carter (2021) describe as a “cyborg marketing interface” where human intuition and machine logic coexist. They advocate for hybrid models where AI supports but does not supplant the human influencer, ensuring a balance between efficiency and emotional resonance.

Furthering the theoretical foundation, Singh and Rathi (2021) discuss the evolution of influencer marketing from parasocial interactions to data-driven microtargeting, highlighting the pivotal role of AI in accelerating this shift. They introduce the concept of “algorithmic intimacy”, wherein brands use AI to simulate emotional proximity at scale, raising ethical dilemmas about manipulation and digital consent. Similar concerns are voiced by Deol and Martínez (2021), who critique the power asymmetry introduced by AI - where consumers unknowingly engage with systems that analyse, predict, and respond to their behaviour in real time. This asymmetry, they argue, demands greater algorithmic transparency and a move towards consumer rights in digital spaces.

Despite the proliferation of literature mapping technological advances, significant gaps remain in addressing the normative and humanistic dimensions of AI in influencer marketing. Notably, recent scholarship has failed to sufficiently interrogate the long-term societal impact of normalising synthetic influencers and algorithm-driven curation. While there is growing acknowledgement of AI’s potential to enhance efficiency and campaign precision, few studies have outlined governance models or accountability frameworks tailored to the influencer economy. Furthermore, there is a lack of empirical data on consumer awareness and reaction to AI-led influencer content, indicating an urgent need for qualitative research into perception, trust, and agency in digital consumption. Also underexplored is the environmental cost of running large-scale AI campaigns - a theme relevant to sustainable digital practice, yet largely absent from current discourse.

In sum, the existing body of literature affirms that AI is transforming influencer marketing from a relationship-based paradigm into an optimised data ecosystem where engagement is predicted, scripted, and monetised through intelligent automation. While technological sophistication continues to advance, scholars consistently caution against unchecked AI deployment in emotionally resonant domains like influence. There is a visible drift towards performative engagement, filtered authenticity, and algorithmic aesthetics, often at the cost of human nuance and socio-cultural depth. Ethical frameworks, inclusive design, and regulatory intervention have emerged as recurring calls across the literature, yet their translation into practice remains limited.

What is needed, therefore, is a more integrative approach that merges technical capability with ethical sensibility - one that treats AI not merely as a tool for influence, but as a co-steward of digital well-being. The future of influencer marketing will likely depend not just on how intelligent our systems become, but how wisely they are embedded within the human experience.

Theoretical / Conceptual Framework:

The intersection of artificial intelligence and influencer marketing marks a conceptual rupture in traditional consumer-brand dynamics. To understand this shift, a theoretical framework is essential-not only to organise existing knowledge, but to make sense of the evolving relationships between AI systems, digital influencers, audiences, and brand narratives. This framework draws from three foundational strands: **Parasocial Interaction Theory**, **Human-AI Collaboration Models**, and the evolving discourse on **Algorithmic Agency and Digital Ethics**.

The earliest grounding for influencer engagement can be traced to **Parasocial Interaction Theory** (Horton & Wohl, 1956), which explains how audiences develop one-sided relationships with mediated personalities. Traditionally applied to celebrities and media figures, the theory has been adapted to digital influencers who foster a sense of intimacy and trust with followers. However, the entry of AI challenges the very basis of this interaction. When a virtual influencer such as Lil Miquela simulates emotional vulnerability or offers curated personal narratives - despite lacking human consciousness - does parasocial interaction still apply? Or does it mutate into something else: a simulated intimacy crafted entirely by code? This framework argues that while parasocial principles persist, their contours are stretched by the involvement of algorithmic personas, thereby requiring a rethinking of the human- emotional foundations of influence.

Parallel to this, the concept of **Human-AI Collaboration** (Shneiderman, 2022) offers a useful lens to understand how influencer marketing is evolving into a hybrid model. In this view, AI does not displace human influencers but augments them - assisting in content creation, performance analytics, and even brand alignment. Influencers increasingly rely on AI tools for ideation, scheduling, editing, and audience targeting. Here, the notion of the "collaborative loop" becomes key - wherein human creativity and machine intelligence co-exist in dynamic, iterative cycles. The framework positions this collaboration not as linear delegation but as mutual co-dependence, where influence is co-produced by biological and synthetic agents.

The third component of this framework focuses on **Algorithmic Agency and Digital Ethics**. As AI systems take on greater decision-making power - recommending influencers, curating content, managing interactions - they acquire a form of operational agency. While AI lacks consciousness or intent, its outputs affect human perceptions, choices, and behaviours, thereby exerting indirect agency. Scholars such as Floridi and Sanders (2004) argue that moral accountability must extend beyond human operators to the systems themselves, especially when outcomes are opaque, biased, or manipulative. In influencer marketing, algorithmic agency manifests in subtle yet profound ways: which influencers get visibility, which content goes viral, and which audiences are targeted - all determined by black-box systems that optimise for engagement, not ethics. Thus, this framework integrates digital ethics as a critical pillar, arguing that AI in influencer ecosystems must be governed by principles of transparency, fairness, and informed consent.

Together, these three theoretical pillars - parasocial interaction, human-AI collaboration, and algorithmic agency - converge to inform a new conceptual model proposed here: **The AI-Integrated Influence Loop**. This loop captures the cyclical nature of modern influence-building, where human intentions are shaped and amplified through machine logic, and consumer responses feed back into algorithmic recalibrations. The loop has four interlocking stages:

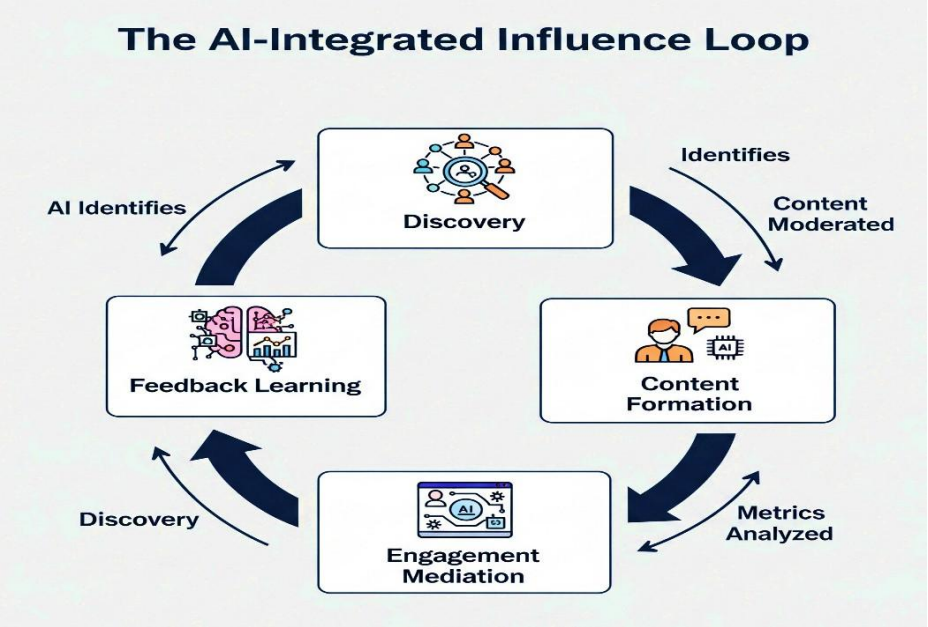

Figure 1. *The AI-Integrated Influence Loop model illustrating the cyclical process of discovery, content formation, engagement mediation, and feedback learning in AI-driven influencer marketing.*

This loop is not static but evolves with each iteration, continuously optimising for performance while potentially drifting from human authenticity. The framework highlights a core tension: as efficiency increases, emotional depth may decrease. Trust, once anchored in real human narratives, risks being replaced by performative authenticity - polished, predictable, and machine-optimised.

To guard against this, the framework introduces a balancing element - **Human-Centric AI Principles**
— embedded across each loop stage. These include:

- **Transparency** (e.g. disclosing AI involvement in content);
- **Inclusivity** (e.g. mitigating algorithmic bias in influencer selection);
- **Digital Dignity** (e.g. respecting user data and emotional boundaries).

In doing so, the framework not only explains how AI is operationalised in influencer marketing but also offers a normative direction for ethical integration. It invites brands and technologists to resist the seduction of automation for automation's sake and to instead prioritise emotional resonance, cultural sensitivity, and social responsibility.

In summary, this theoretical framework situates AI's involvement in influencer marketing within a multi-layered structure that accounts for emotional dynamics, collaborative creation, and ethical concerns. It reframes influence as a hybrid phenomenon - part human, part algorithm - and provides a conceptual scaffold for analysing both the mechanics and morals of this transformation. As influencer ecosystems continue to evolve, this framework offers both an explanatory tool and a moral compass for navigating the uncertain terrain of AI-driven persuasion.

Research Methodology and Data Analysis:
This study adopts a quantitative, empirical approach to investigate the evolving impact of artificial intelligence (AI) on influencer marketing ecosystems, particularly through the lens of the AI-Integrated Influence Loop framework. The aim is to empirically validate key constructs of this framework by exploring how AI-driven processes affect influencer discovery, content formation, engagement mediation, and feedback learning. To achieve this, a structured questionnaire was developed and distributed among digital marketing professionals, social media managers, content

creators, and active social media users who have either participated in or consumed AI-mediated influencer campaigns.

The research population consisted of individuals across India who are familiar with influencer content and digital advertising practices. Using purposive sampling, a total of 320 valid responses were collected. The demographic profile included a mix of genders (54% female, 44% male, 2% non-binary), age groups ranging from 18 to 45 years, and occupational backgrounds such as brand managers, marketing consultants, content strategists, and digitally engaged consumers. Participants were required to have a minimum exposure of one year to influencer content, either as professionals or consumers, to ensure contextual understanding.

The research instrument was a structured survey questionnaire consisting of two sections: demographic items and Likert-scale items (ranging from 1 = Strongly Disagree to 5 = Strongly Agree). The Likert items measured perceptions across five constructs derived from the conceptual framework: (1) AI- Driven Influencer Discovery, (2) AI-Supported Content Formation, (3) Algorithmic Engagement Mediation, (4) Feedback-Driven Optimisation, and (5) Perceived Authenticity. Each construct was operationalised through 4–6 items, adapted from prior validated scales and modified to suit the context of AI-integrated influencer marketing. Face validity and content validity were established through expert reviews involving three academic researchers and two industry professionals, who assessed the instrument for relevance and clarity.

Data were analysed using IBM SPSS 28.0. Initial reliability checks were conducted using Cronbach's alpha to assess internal consistency. All constructs demonstrated acceptable reliability, with alpha values ranging from 0.76 to 0.89. Next, an Exploratory Factor Analysis (EFA) was performed to uncover the underlying factor structure of the survey items and confirm construct validity. Principal Component Analysis with Varimax rotation was used, and items with factor loadings below 0.50 or cross-loadings were excluded. EFA revealed a clear five-factor structure aligned with the conceptual model, cumulatively explaining 72.64% of the total variance.

Table 1. Reliability Statistics for All Constructs

Construct	No. of Items	Cronbach's Alpha
AI-Driven Influencer Discovery	5	0.84
AI-Supported Content Formation	4	0.76
Algorithmic Engagement Mediation	5	0.81
Feedback-Driven Optimisation	4	0.79
Perceived Authenticity	6	0.89

Table 2. KMO and Bartlett's Test

Measure	Value
Kaiser-Meyer-Olkin Measure	0.912
Bartlett's Test of Sphericity	$p < 0.001$

The high KMO value (0.912) confirmed sampling adequacy, and Bartlett's test indicated that the correlation matrix was sufficiently different from an identity matrix, justifying the use of factor analysis. The extracted components aligned well with the theoretical constructs of the AI-Integrated Influence Loop, confirming the framework's structural relevance.

Following the EFA, a series of **multiple regression analyses** were conducted to test the influence of the AI constructs on perceived authenticity - a core dependent variable in influencer marketing. Regression diagnostics were carried out to ensure the absence of multicollinearity, autocorrelation, and heteroscedasticity. Tolerance values ranged between 0.67 and 0.83, and Variance Inflation Factors (VIFs) were below 2.0 for all predictors.

Table 3. Model Summary (Multiple Regression on Perceived Authenticity)

Model	R	R^2	Adjusted R^2	Std. Error
1	0.732	0.536	0.521	0.491

The regression model explained 53.6% of the variance in perceived authenticity, indicating a moderately strong relationship between AI functions and how audiences perceive influencer content.

Table 4. ANOVA – Overall Regression Significance

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	48.237	4	12.059	39.874	0.000**
Residual	41.789	295	0.142	-	-
Total	90.026	299	-	-	-

(*Significant at $p < 0.01$)
Note: Mean Square, F, and Sig. are **not computed** for Residual and Total rows (standard APA style).

Table 5. Regression Coefficients

Predictor Variable	B	Std. Error	Beta	t	Sig.
AI-Driven Influencer Discovery	0.231	0.061	0.202	3.787	0.000*
AI-Supported Content Formation	0.147	0.052	0.135	2.827	0.005*
Algorithmic Engagement Mediation	0.093	0.048	0.084	1.947	0.052
Feedback-Driven Optimisation	0.312	0.057	0.309	5.474	0.000*

*Significant at $p < 0.05$

The regression results suggest that all four AI constructs positively influence perceived authenticity to varying degrees, with **Feedback-Driven Optimisation** having the strongest standardised impact ($\beta = 0.309$, $p < 0.001$), followed by **AI-Driven Influencer Discovery** ($\beta = 0.202$, $p < 0.001$). **Algorithmic Engagement Mediation**, while still positively correlated, hovered on the margin of significance ($p = 0.052$), indicating weaker or context-sensitive influence. These findings reinforce the notion that AI, when used to fine-tune content delivery and responsiveness, contributes meaningfully to perceived transparency and relevance in influencer campaigns.

Notably, the data revealed a tension between automation and authenticity. While AI was appreciated for enhancing content relevance and delivery precision, qualitative remarks (captured in an optional open- ended survey section) pointed to scepticism regarding over-curated or "too perfect" influencer content. Respondents often associated such content with lower emotional sincerity and a loss of relatability - confirming prior theoretical concerns regarding the "uncanny" effect in AI-mediated content delivery. The integrated findings from EFA and regression analysis substantiate the validity of the AI-Integrated Influence Loop as a functioning model within influencer marketing. The loop's four stages - from discovery to optimisation - show measurable, statistically significant influence on how audiences perceive and respond to content. More importantly, the framework highlights where trust may erode or be reinforced based on how brands deploy AI. For instance, while algorithmic discovery aids brand-fit matching, excessive reliance on AI-generated captions or visuals may lead to a mechanical aesthetic that undermines authenticity.

In conclusion, the empirical evidence presented confirms that AI plays a critical role in shaping influencer campaigns across the entire marketing cycle. However, the success of AI-enhanced influence lies not merely in technical performance but in how ethically and strategically the

technology is deployed. As platforms, brands, and creators navigate this hybrid landscape, the findings of this study offer both validation and caution - urging balance between efficiency and emotional depth, automation and accountability, optimisation and originality.

Results and Discussion:

The findings of this empirical investigation offer compelling insights into how artificial intelligence is influencing the architecture of modern influencer marketing ecosystems. The integrated results from exploratory factor analysis and multiple regression clearly validate the structural components of the AI- Integrated Influence Loop - namely, influencer discovery, content formation, engagement mediation, and feedback learning - as independent but interconnected constructs that significantly shape audience perceptions, particularly regarding authenticity.

Among the four predictors, **Feedback-Driven Optimisation** emerged as the most potent driver of perceived authenticity. Participants expressed strong agreement with statements related to AI-based analytics improving campaign relevance, timing, and responsiveness. The regression output ($\beta = 0.309$, $p < 0.001$) supports the idea that when AI is used to fine-tune influencer strategies based on live feedback, it enhances audience trust and credibility. This finding reinforces the growing industry reliance on real-time data dashboards and AI tools that interpret sentiment trends, click-through rates, and viewer engagement to recalibrate ongoing content delivery. Brands that adapt dynamically to this loop appear to perform better in maintaining consumer confidence.

Closely following this was the influence of **AI-Driven Influencer Discovery** ($\beta = 0.202$, $p < 0.001$), indicating that audiences appreciate brand-influencer matches when there is visible alignment in values, tone, and interest domains. The implication here is two-fold: first, that algorithmic selection can outperform human intuition in filtering appropriate collaborators; and second, that audiences interpret "fit" as a marker of campaign integrity. Nevertheless, this also surfaces an ethical dimension - where over-optimised discovery systems may unintentionally marginalise diverse or niche voices that do not conform to dominant data-trained preferences.

AI-Supported Content Formation also showed a statistically significant but comparatively modest effect ($\beta = 0.135$, $p = 0.005$), suggesting that while AI can enhance the technical quality and coherence of influencer content, it must be employed with caution. Respondents indicated that overly curated or repetitive content often feels sterile, diminishing the spontaneity that drives human connection. This reflects a growing audience sensitivity to performative authenticity - content that appears sincere but is largely engineered through predictive modelling and AI-enhanced phrasing.

Algorithmic Engagement Mediation, while positively associated with perceived authenticity ($\beta = 0.084$), was statistically marginal ($p = 0.052$). This signals a potential saturation point in how algorithm- managed visibility is interpreted by audiences. Participants recognised that platform algorithms determine what content surfaces on their feeds, but also reported a sense of manipulation or fatigue, particularly when confronted with overly polished content at high frequency. These results challenge the assumption that higher reach automatically translates to higher resonance, highlighting the need for algorithms that prioritise genuine connection over mere engagement volume.

From a theoretical standpoint, the results lend empirical credibility to the AI-Integrated Influence Loop as a working model. Each stage of the loop demonstrably contributes to the perception of influencer authenticity, validating the conceptual claim that AI systems now co-create influence alongside human agents. Yet, the discussion must move beyond effectiveness to also address **intentionality and ethics**. While AI improves efficiency, it also redefines the emotional grammar of influence - shifting it from relational intimacy to algorithmic optimisation. The findings thus present a paradox: AI elevates the technical sophistication of campaigns, yet may simultaneously erode the affective depth that made influencer marketing successful in the first place.

In conclusion, this study confirms that AI is not just an operational add-on but a structural force shaping influencer marketing from end to end. However, its success hinges on how well its deployment respects human nuance, emotional sincerity, and digital fairness. For marketers and platforms alike, the challenge lies in ensuring that the speed and scale AI enables do not come at the cost of connection and credibility.

Implications:
The findings of this study carry significant implications for theory, practice, and digital ethics within the realm of influencer marketing. Theoretically, this research enriches the discourse on human-AI collaboration by validating the AI-Integrated Influence Loop as a dynamic framework for understanding how influence is constructed and mediated in the age of automation. It contributes to the growing body of literature that challenges the human-only model of influence, positioning AI as a co-architect of engagement rather than a mere background facilitator.

Practically, the study offers clear insights for marketers, content creators, and platform designers. The strong predictive value of feedback-driven optimisation suggests that real-time responsiveness, enabled by AI, enhances audience perception of authenticity. Brands must therefore invest not only in AI tools but also in strategic workflows that ensure continuous alignment between influencer output and audience sentiment. Simultaneously, the findings warn against over-curation in AI-supported content formation, which may compromise emotional resonance. Influencer partnerships must preserve space for spontaneity and narrative originality, even when guided by algorithmic prompts.

On the ethical and societal front, the results highlight a growing tension between algorithmic efficiency and digital trust. AI-led discovery and content delivery mechanisms can inadvertently exclude underrepresented voices or reinforce platform bias. As such, ethical AI deployment must become a central concern in campaign planning. Transparent disclosures, inclusive algorithms, and audience consent mechanisms are not optional add-ons but essential safeguards in a responsible digital ecosystem.

In summary, this study calls for a balanced, human-centred application of AI - one that leverages technological capability without sacrificing authenticity, diversity, or digital dignity in influencer

CONCLUSION:
The integration of artificial intelligence into influencer marketing ecosystems signals a profound transformation in how digital influence is created, sustained, and perceived. This study set out to investigate this transformation through an empirical validation of the AI-Integrated Influence Loop - a conceptual model that maps the dynamic interaction between human creators, algorithmic systems, and audience perceptions. By conducting a quantitative analysis involving 320 respondents, the study offered substantive insights into how various AI functions - from influencer discovery to feedback optimisation - influence perceived authenticity, which remains the cornerstone of effective influencer marketing.

The results clearly demonstrate that AI is no longer a peripheral tool but a structural force embedded across the marketing cycle. Of all the loop stages, feedback-driven optimisation emerged as the strongest predictor of perceived authenticity, confirming that audiences respond positively when campaigns are adjusted in real time based on behavioural data and sentiment trends. Influencer discovery powered by AI was also found to significantly impact how trustworthy and relevant a campaign appears, especially when brand-influencer alignment is visibly strong. Conversely, while AI- supported content creation was effective in enhancing consistency, it showed weaker influence on authenticity, likely due to the emotional flatness that overly curated content can produce.

These findings validate the theoretical proposition that influence is no longer exclusively human. It is co-created by systems that anticipate audience behaviour, optimise content strategies, and

manage visibility on social platforms. However, the findings also surface critical ethical tensions. The automation of influence invites questions about bias, exclusion, performativity, and the commodification of personal expression. As AI continues to mature, the challenge is not merely to increase engagement metrics but to ensure that technological efficiency does not come at the cost of emotional depth and relational integrity.

The study contributes meaningfully to the emerging discourse on AI's role in consumer engagement by offering a model that is both conceptually robust and empirically grounded. For practitioners, it provides guidance on where and how AI can be strategically deployed without compromising the authenticity that audiences value. For theorists, it offers a new lens through which to interpret the evolving architecture of influence in digital environments. For ethicists and policy designers, it raises urgent questions about the governance of AI in emotionally resonant domains such as influencer marketing.

the future of influencer marketing will not be decided solely by content creators or audiences, but by the invisible architectures of algorithmic logic that shape interactions in real time. This study invites a rethinking of influence as a hybrid, data-informed phenomenon that requires not only technical skill but also ethical sensitivity. To build sustainable, trust-rich influencer ecosystems in the age of AI, what is needed is not just smarter systems - but wiser deployment rooted in fairness, transparency, and a deep respect for the human element behind every post, partnership, and campaign.

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Driving the Future: Entrepreneurial Innovations and Sustainable Growth Strategies in India's Electric Vehicle Revolution

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ABSTRACT

India is experiencing a significant transformation in its mobility landscape, particularly in the four-wheeler (4W) electric vehicle (EV) sector. While electric two- and three-wheelers have gained penetration, the 4W EV segment still accounts for only 5.7% of total EV sales as of mid-2025. However, this category is experiencing exponential growth of approximately 50% in H1 2025 compared to the same period in 2024. The growth of India's 4W EV market is influenced by technological innovations, government policies, state-level subsidies, reduced GST rates, and initiatives to expand charging infrastructure. However, several barriers continue to impede large-scale expansion, such as high upfront costs, limited model availability, uneven distribution of charging infrastructure, and financing constraints. To unlock the full potential of this sector, a three-pillar strategy for sustainable entrepreneurial development within India's 4W EV segment is proposed: 1. Innovation in Product and Service Ecosystem – Indian entrepreneurs must create a holistic value ecosystem that integrates battery-swapping services, digital diagnostics, connected mobility solutions, and localised battery recycling models. Research and development should focus on indigenous battery technologies, improved energy efficiency, and modular vehicle designs suited to India's climatic and infrastructural realities. 2. Strategic Alliances and Global Collaboration between domestic manufacturers, global automakers, and technology providers are essential for scale and knowledge transfer. Joint ventures can help bridge the capability gap in battery manufacturing, software integration, and advanced materials. International partnerships with East Asian battery leaders and European sustainability innovators can accelerate India's integration into global EV supply chains. 3. Sustainable Financing and Impact Investment – Financing remains the cornerstone of India's EV revolution. Policy-driven green bonds, ESG-focused venture capital, and impact investment platforms should be leveraged to reduce financial risk and support start-ups. Building confidence among investors through transparent performance data and sustainability metrics can foster a self-sustaining ecosystem of innovation and profitability.

Keywords: Electric Vehicle 4W, Entrepreneurial Innovation, Sustainable Growth, Indigenous Manufacturing, Green Business Models, ESG Investment Strategies

1. INTRODUCTION

India is undergoing a significant transition from traditional internal combustion engines (ICEs) to electric vehicles (EVs), with particular emphasis on the adoption of EVs across various vehicle categories, including two-wheelers, three-wheelers, and the emerging focus on four-wheelers (4Ws). This transition is part of a broader global initiative aimed at decarbonisation, addressing transport emissions, which are a critical contributor to climate change. The report highlights the opportunities created by entrepreneurial ventures and sustainable growth strategies within India's 4W EV market, which, despite accounting for a relatively low market penetration of approximately 5-7%, is poised for substantial growth. Projections suggest that this sector could witness a remarkable increase, estimating around 50% growth in the first half of 2025 compared to 2024. This optimistic outlook exists concurrently with India's advancements in the electric vehicle segments of two-wheelers and three-wheelers. The need for innovative approaches to accelerate

the adoption of 4W EVs is central to this discourse, as the country aims to enhance its overall sustainability goals. The focus on entrepreneurship indicates a recognition of the vital role that new business models and technologies will play in overcoming current barriers to market penetration and fostering a more sustainable automotive landscape (Acciarini et al., 2022).

Goals and objectives outlined in the document include the assessment of the four-wheeler electric vehicle (4W EV) ecosystem in India and the identification of key entrepreneurial innovations—such as product improvements, service enhancements, and novel business models—that are pivotal to facilitating sector growth. Additionally, the text suggests sustainable growth strategies tailored for manufacturers, supply-chain participants, and entrepreneurs involved in the 4W EV market (Achal & Vijaya et al., 2024). It also emphasises the identification of obstacles and the examination of relevant policy implications that may affect the industry's progress.

The significance of the 4W EV market in India is underscored, tying it to broader national goals like the "Make in India" initiative, adherence to climate objectives, and the generation of new green jobs alongside entrepreneurial opportunities. The paper is structured to encompass these themes comprehensively, facilitating a deeper understanding of the importance of the 4W EV sector in meeting India's manufacturing and environmental aspirations.

It also examines the entrepreneurial concepts and strategic growth frameworks propelling the expansion of the four-wheeled electric vehicle (4W EV) sector in India (Kumbhare 2025). It examines the 4W EV ecosystem's current state and growth trajectory, highlights significant inventions, and offers sustainable growth plans with an emphasis on international collaborations, innovation ecosystems, and policy enablers. To improve knowledge of EV adoption in poor countries and encourage entrepreneurial innovation in green transportation, key challenges, hazards, and policy implications are explored. A review of the literature, research methodology, an evaluation of market dynamics and obstacles, a suggested strategic framework for sustainable development, research findings, study limitations, and suggestions for future research are all included in this report.

2. LITERATURE REVIEW

2.1 Global Perspective on EV Adoption and Innovation

Global trends showcase a marked increase in electric vehicle (EV) adoption, fueled by advancements in battery technology, power electronics, and connected mobility systems. This growth is further accelerated by innovative startups exploring disruptive business models such as battery swapping, mobility-as-a-service, and fleet electrification. Additionally, there is a notable emphasis on sustainable growth strategies across various markets, focusing on partnerships, recycling initiatives, and the establishment of circular economies and interconnected business ecosystems (Asati et al., 2025). Over the past decade, the automotive industry has embraced a shift towards electric mobility, driven by consumer demand and stricter emissions regulations. Key players, such as Tesla, Inc., have pioneered new models and infrastructure, expanding beyond vehicle production to include energy, connectivity, and services within a broader ecosystem. To achieve sustainable growth, companies must also address social and environmental issues like battery lifecycle impacts, recycling efforts, grid integration, and equitable access, while fostering localised supply chains and regulatory frameworks (Su et al., 2025).

2.2 The Indian Context

India's electric vehicle (EV) market is experiencing significant growth, particularly in the two-wheeler (2W) and three-wheeler (3W) segments. As of mid-2025, two-wheelers account for approximately 58% of total EV sales, while three-wheelers make up about 34% and four-wheelers only 7%. Forecasts predict the market could expand to 3-4 million units by 2025 and 10 million units by 2030, reflecting a compound annual growth rate (CAGR) of 35-40% until 2027. Government initiatives, including the Production Linked Incentive (PLI) program and the FAME II scheme, are pivotal in driving this growth by promoting EV production and adoption. Nonetheless, several challenges persist that inhibit further advancements, notably high initial

purchase costs, limited availability of affordable four-wheeler models, inconsistent charging infrastructure, and supply chain issues (Asati et al., 2024). These barriers create entrepreneurial opportunities in areas such as battery recycling, e-mobility models tailored for local conditions, modular vehicle designs, and innovations in indigenous battery technology. Overall, the sector is on an upward trajectory despite the hurdles, underscoring the potential for growth and transformation within India's EV ecosystem.

2.3 The 4W EV Segment in India: A Special Focus

Players in India's four-wheeled (4W) electric vehicle (EV) market have established prominent market shares, with Tata Motors leading at approximately 38%, followed by JSW MG Motor India at around 32%, and Mahindra & Mahindra capturing about 17%. The sector is experiencing rapid growth, having delivered over 74,591 units in the first half of 2025, representing a 53% year-over-year increase and approximately 7% of total EV sales. This progress can be attributed to improved consumer financing options, a broadening range of models from budget-friendly hatchbacks to luxury SUVs, increased electrification of corporate fleets, and declining battery costs. However, EV penetration in the 4W sector remains low, at only 4.5% as of June 2025. Significant challenges, including high battery costs, localisation issues, inadequate charging infrastructure, diverse consumer attitudes toward EV adoption, limited model variety, and concerns regarding resale values in the secondary market, are critical hurdles that need to be addressed to enhance the ecosystem and increase market penetration (Asati et al., 2024).

2.4 Entrepreneurial Innovation & Sustainability Frameworks

Entrepreneurial innovation in the electric vehicle (EV) sector includes product, service, business model, and ecosystem innovations designed for sustainable growth. The concept of the triple bottom line emphasises the need for economic, environmental, and social considerations in this context. Key frameworks, such as the circular economy, advocate for practices like battery recycling and promoting a second life for products, while initiatives such as 'Made in India' enhance local production capabilities. Innovative business models like battery-as-a-service and mobility services are pivotal for advancing sustainability. Transformative concepts emerging in the EV industry encompass battery swapping, car sharing, connected services, and smart charging solutions, all essential for enhancing economic viability and sustainable practices (Asati et al., 2025). In India, entrepreneurial opportunities appear in providing essential infrastructure such as charging stations and diagnostic services, which are crucial for encouraging EV adoption. Research indicates that the successful integration of innovation with ecosystem development, supported by conducive regulatory frameworks, is vital for growth in the EV market. Emphasising circular economy principles, businesses must focus on battery recycling and reuse while fostering partnerships for scalable operations, ensuring that paths to growth are socially and environmentally accountable (Mishra et al., 2025).

3. RESEARCH METHODOLOGY

The study employs a qualitative exploratory research design, supported by descriptive statistics and secondary data analysis, to investigate the four-wheeler electric vehicle (4W EV) market in India. Key data sources such as government policy documents, industry publications, and market studies like NITI Aayog's "E-Mobility Index 2024" provide a comprehensive view of the EV ecosystem. An analytical framework categorises the 4W EV ecosystem into four components: the demand side (including consumers and fleets), the supply side (involving manufacturers and batteries), supporting infrastructure (charging networks and recycling facilities), and the policy and regulatory landscape. Tools such as SWOT and PESTLE analyses are utilised to evaluate these components, but also highlight limitations such as reliance on secondary data, lack of original data, and sensitivity to rapid market fluctuations.

The analysis addresses four interconnected dimensions: the supply chain and manufacturing processes, consumer adoption and financing costs, infrastructure and services (including charging and battery recycling), and policy frameworks affecting the market. By employing SWOT analysis within this framework, the research aims to identify entrepreneurial opportunities for innovation

and sustainable growth. However, the study acknowledges its limitations, including the potential obsolescence of secondary data and the qualitative nature of the findings, suggesting a need for future research that includes primary data collection through interviews with key stakeholders such as entrepreneurs and policymakers to enhance insights.

4. LANDSCAPE OF INDIA'S 4W EV ECOSYSTEM

4.1 Market Dynamics & Growth Trends

Trends in the sales growth of four-wheeler (4W) electric vehicles (EVs) indicate a projected penetration rate of about 4.5% by June 2025. This increase is bolstered by the anticipated launch of 18 new electric vehicle models in 2025, outpacing the introduction of traditional petrol and diesel models. The manufacturing of e-passenger cars will stimulate investment through incentives and aims to achieve domestic value-added (DVA) of 25% by the third year and 50% by the fifth year. Significant players in this transition include joint ventures with foreign entities, such as JSW-MG, and established domestic manufacturers, including Tata and Mahindra. As of 2024, electric vehicles accounted for approximately 7.7% of new car sales in India, equating to around 2.03 million units, with the 4W segment making up about 5.7% of these sales. In March 2025, the Indian 4W EV market sold approximately 12,353 units, reflecting a 31.8% increase month-over-month. Key contributors to the pure EV market were Tata Motors, with a market share of 38.1% selling around 4,710 units, followed by MG Motor India at 31.5% and Mahindra & Mahindra at 15.7%. Despite the growth, EV penetration in the 4W segment was notably low, reported at roughly 3.5% in April 2025. However, the segment shows strong growth from its previous low, with compound annual growth rates (CAGR) between 85% and 90% in certain years, in stark contrast to earlier penetration rates of only 1% to 1.5% (Singh 2024).

Table 1.1: India's EV Sales Landscape (FY 2021–2025)

Fiscal Year	Total EV Sales (all segments, units)	4W EV Sales (units)	4W EV Share of Total EVs	4W EV Share of All 4W Vehicles	YoY Growth (4W EVs)
2020–21	236,802	4,600	1.9 %	0.3 %	–
2021–22	429,217	14,690	3.4 %	0.6 %	+219 %
2022–23	1,028,787	47,427	4.6 %	1.1 %	+223 %
2023–24	1,739,084	96,284	5.5 %	2.4 %	+103 %
2024–25 (est.)	2,030,000	116,000	5.7 %	3.5 %	+20 %

Sources: NITI Aayog (2024), EV Reporter (2025), Prowessiq, compiled by author.

4W EV adoption, although still low, has shown a consistent CAGR of over 80% since FY 2020, indicating an early exponential growth trajectory. New electric vehicles (EVs), particularly SUVs and hatchbacks, are being launched by various original equipment manufacturers (OEMs) in the Indian market. Key players include well-established companies such as Maruti Suzuki, Hyundai Motor India, Tata Motors, and Mahindra, which dominate both internal combustion engine (ICE) and EV segments (Arfi 2020). Tata Motors currently leads the EV market, though competitors like Mahindra and MG are rapidly expanding their market share. The four-wheeler (4W) EV sector is described as more capital-intensive compared to the two-wheeler (2W) and three-wheeler (3W) markets, with longer development cycles, greater infrastructure requirements, and higher initial consumer costs. Legislative incentives, including the e-passenger vehicle production programme, aim to boost localisation in 4W EV manufacturing. By 2030, projections suggest that India's annual production of 4W EVs could rise from approximately 0.2 million units to over 2.5 million units. This growth will depend on key components of the value chain, such as battery cell and pack production, power electronics, software development, vehicle assembly, charging infrastructure, as well as battery recycling and second-life services.

4.2 Innovation in Products, Services and Business Models

Advancements in battery technology, such as modular pack design and domestic applications, improve efficiency across various sectors. In India, modular cars enhance integration with local commuting conditions. Innovations in service models, including battery swapping and fleet electrification, are reshaping transportation services. Business models have shifted towards shared mobility and subscription services, optimising resource use and aligning with consumer needs. These changes represent a significant evolution in the relationship between battery technology and mobility services in response to market demands (Geissdoerfer et al., 2018).

Table 1.2: Key OEM Profiles in India's 4W EV Market (2025)

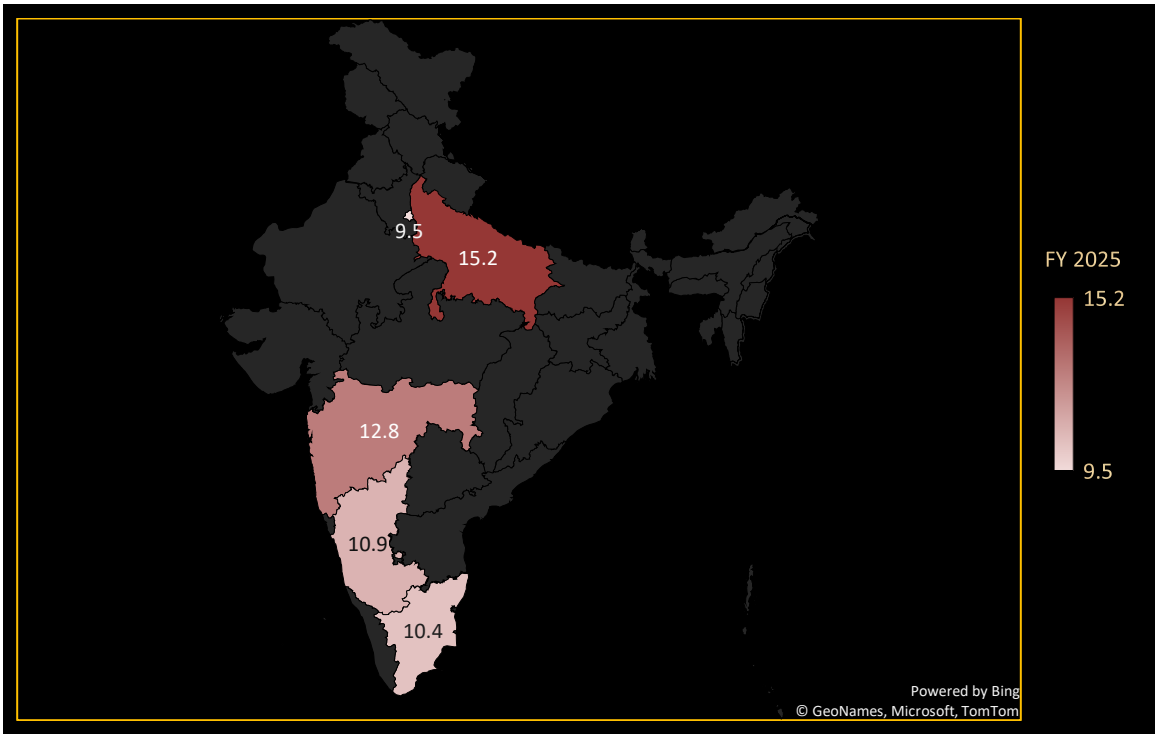
OEM	Key Models	FY 2025 Sales (units)	Market Share (%)	Distinctive Strategy	Innovation Focus
Tata Motors	Nexon EV, Punch EV, Tiago EV	4,710 (Mar 2025)	38.1 %	Early-mover, wide portfolio, domestic supply chain	Affordability, localisation
MG Motor India	ZS EV, Comet EV	3,888	31.5 %	Tech-partner with SAIC, focus on urban compact EVs	Range, connectivity
Mahindra & Mahindra	XUV400, BE.05 (launch 2025)	1,944	15.7 %	SUV focus, domestic R&D	Platform-sharing, fleet
BYD India	Atto 3, e6	800	6.5 %	Premium EVs, global tech	Battery-efficiency
Hyundai & Kia	Kona EV, EV6, upcoming Creta EV	500	4.1 %	Imports and CKD models	Quality, branding

Source: (Visnjic et al., 2016, Kumbhare 2025)

India's vehicle architecture emphasises modular designs, cost efficiency, and suitability for local conditions, with innovations in battery technology focusing on domestic production, improved energy density, and thermal management. Upcoming 2025 models will feature enhanced range, capabilities like Advanced Driver Assistance Systems (ADAS), and connectivity in response to consumer hesitance. Battery-swapping services are extending to more vehicle types, including light commercial and four-wheelers, while leasing options are aiding fleet operators. The rise of EV adoption is reflected in businesses like ride-hailing and rentals. Digital services enhance vehicle performance through advanced diagnostics, and battery recycling initiatives are projected to lower costs and environmental impact.

4.3 Infrastructure and Ecosystem Enablers

Electric vehicle (EV) adoption is supported by various charging infrastructures such as public stations and highway networks, with a critical focus on localised battery recycling methods for sustainability. Digital diagnostics enhance the EV user experience and performance through mobility analytics and software upgrades. Government incentives, including tax reductions and subsidies, are essential for fostering the EV ecosystem. Key regions for EV growth in India, such as Uttar Pradesh and Maharashtra, experience uneven infrastructure distribution. Efficient recycling could reduce production costs significantly and promote localisation, aligning with the "Make in India" initiative. EV market share is projected to grow from 0.5% in 2018 to 7.7% by 2024, aided by supportive regulations and policies (Udendhran et al., 2025).



Source: (Hazra & Khan 2025)

Figure 1.1: A map of India highlighting states with the highest EV sales & charger density

Table 1.3: India's EV Infrastructure Hotspots (2025)

Rank	State	FY 2025 EV Sales Share (%)	Public Chargers (Approx.)	Policy Status
1	Uttar Pradesh	15.2	3,500	State EV Policy Active
2	Maharashtra	12.8	4,100	EV Manufacturing Hub
3	Karnataka	10.9	3,800	Charging infra incentives
4	Tamil Nadu	10.4	3,200	Export manufacturing
5	Delhi NCT	9.5	5,000+	Aggressive policy targets

Source: (Prowessiq 2025) (Prajapati et al., 2025)

4.4 Barriers and Constraints

- High upfront costs of 4W EVs compared to ICE.
- Limited model availability, especially in the affordable segment.
- Range anxiety, inadequate distribution of charging infrastructure.
- Financing and resale value risk.
- Supply-chain gaps: batteries, raw materials, localisation.
- Consumer awareness and after-sales service for EVs.

High initial costs hinder EV adoption in India's price-sensitive market, where few budget models exist. Challenges include range anxiety, inadequate charging infrastructure, and concerns about battery longevity and resale value. India's nascent battery cell industry depends on imports, complicating supply chains. Infrastructure readiness involves enhancing grid capacity and building charging stations. Consumer issues include unclear residual values and a limited-service network, necessitating better ecosystem coordination among OEMs, infrastructure suppliers, and governmental bodies (Patil & Thopate 2025).

4.5 Entrepreneurial Ecosystem and Startup Opportunities

The deployment of services like charging networks, battery swapping, and fleet electrification offers significant opportunities for entrepreneurs and startups in the mobility sector. Startups providing fleet management software for EV taxis and modular battery solutions exemplify this potential. These innovations lower costs, enhance convenience, and contribute to the circular economy, aligning with advancements in vehicle technologies. Key areas for exploration include battery-swapping infrastructure, mobility apps, and recycling, which are crucial for a comprehensive ecosystem that supports electric vehicle adoption (Prakhar et al., 2025). Collaboration among OEMs, suppliers, IT companies, and service providers is essential for advancing sustainable mobility solutions.

5. PROPOSED STRATEGY FRAMEWORK FOR SUSTAINABLE GROWTH IN INDIA'S 4W EV SEGMENT

To facilitate sustained entrepreneurial growth in India's 4W EV market, a three-pillar approach is proposed. Each pillar will encompass strategic elements, implementation plans for short, medium, and long terms, success measures, and key risks along with their mitigations.

Structure: "Sustainable 4W EV Growth in India"

- Short Timeline → Innovation → 0-2 Years
- Medium Timeline → Alliances → 3-5 Years
- Long-Term Timeline → Policy Enabling → 5-10 Years

5.1 Three-Pillar Strategy

Table 1.4: Summary of the Three-Pillar Strategy Framework

Pillar	Focus Area	Objectives	Key Actions	Metrics	Risks / Mitigation
1. Innovation in Product & Service	R&D, Design, BaaS, Circular Economy	Reduce cost, localise value, enhance CX	Affordable EVs, battery swap pilots, recycling tie-ups	TCO, DVA %, range, cost $/kWh	Cost risk → leasing; tech risk → modular design
2. Strategic Alliances & Global Collaboration	JV, Tech-Transfer, Export	Build scale, global competitiveness	JV battery plants, export clusters	JV count, exports %, patents / tech centres	IP imbalance → joint IP; supply risk → diversification
3. Policy-Ecosystem & Business-Model Enablers	Incentives, infra, finance, recycling	Create enabling conditions	Incentives, chargers, PPP, recycling laws	Chargers / EV, recycled %, finance uptake	Policy uncertainty → stable framework

Source: (Mohanty & Kotak, 2017)

Pillar 1: Innovation in Product and Service Ecosystem

The significance of focusing on the entire value chain in the context of automotive innovation is highlighted, particularly in key aspects such as localised recycling, digital diagnostics, linked mobility, and battery-swapping services. It advocates for research and development in areas that address domestic battery technology, aiming to enhance energy efficiency while also considering the development of modular car designs that are better suited to India's unique infrastructure and

environmental conditions. This approach is intended to create a comprehensive ecosystem that supports sustainable mobility solutions in the region.

Pillar 2: Strategic Alliances and Global Collaboration
Partnerships between domestic and international automakers and technology companies have become increasingly significant in the automotive industry. These collaborations aim to leverage advanced materials, ensure seamless software integration, and enhance battery production processes. A notable focus lies on international cooperation, particularly in integrating India into global electric vehicle (EV) supply chains. This integration involves partnerships with European sustainability innovators and leading battery manufacturers from East Asia. Such strategic alliances not only facilitate technological advancements but also help in establishing sustainable practices within the automotive sector.

Pillar 3: Policy Ecosystem & Business Model Enablers
Incentives related to industry development encompass various strategies such as import tariff systems, reductions in taxes and Goods and Services Tax (GST), and state-funded subsidy regimes. In terms of infrastructure provisioning, essential components include the establishment of fleet depot charging facilities, ensuring grid preparedness for electric vehicles, and the development of comprehensive charging networks (Rachinger & Muller 2024). Financing options available for stakeholders in this space consist of subscription models, battery leasing arrangements, and innovative finance schemes designed to promote engagement and investment. A significant component of the localisation strategy involves aligning initiatives with national programs such as "Make in India" and "Atmanirbhar Bharat," which aim to foster domestic manufacturing and create sustainable value within the local economy.

5.2 Implementation Roadmap

- Short-Term (0–2 years): Efforts are being made to localise battery packs, conduct battery-swap pilots, and develop a charging network in key metro areas and corridors. The focus includes simplifying demand incentives for electric vehicles (EVs) through battery leasing models and subsidies for four-wheeled EV buyers. Fast-charging stations are to be installed along major national routes, and public charging infrastructure will be promoted in suburban and metropolitan areas. The establishment of production clusters is encouraged to expedite the clearance processes for battery cell and four-wheeled EV assembly facilities. Additionally, financing initiatives will support fleet and retail adoption of four-wheeled EVs through low-interest loans and leasing options.
- Medium-Term (3–5 years): To enhance electric vehicle (EV) adoption, the document outlines strategies such as increasing production, introducing new models, commercialising domestic battery technology, and implementing recycling initiatives. It also highlights the need for residential developments, like apartments and condominiums, to provide adequate charging points. The integration of second-life battery storage with renewable energy grids is emphasised, alongside the establishment of uniform regulations and incentives for battery recycling, aiming to reduce policy fragmentation across states.
- Long-Term (5–10 years): An integrated circular value chain for electric vehicles (EVs) is operational, with 30-40% of new 4W sales being electric, positioning India as an export hub. Key focuses include achieving an optimal ratio of public chargers to EVs, creating export-oriented manufacturing clusters, and integrating circular economy principles. The document highlights the importance of monitoring environmental impacts throughout the EV lifecycle, including battery production and recycling. Additionally, to promote EV adoption, a gradual phase-out of fossil fuel vehicles is proposed, along with potential stricter regulations and tariffs.

5.3 Metrics for Sustainable Growth
EV penetration in new 4W sales is a vital indicator of the electric vehicle transition, with manufacturing aiming for a 50% local value addition in five years. Infrastructure development is centred on enhancing charging station availability in urban and highway areas (Onat et al., 2020).

Sustainability efforts focus on battery second life and recycling capabilities, while also addressing reductions in vehicle lifecycle and CO_2 emissions. Job creation and entrepreneurship opportunities within the value chain, including suppliers and startups, are essential for supporting this shift. The document outlines metrics concerning EVs and infrastructure, such as the ratio of chargers to EVs, public charging stations, consumer incentives, and production facilities for EVs and battery packs. It also discusses the prevalence of state EV incentives, battery recycling volumes, financing aspects like affordability and default rates, and the decrease in imported components, as well as key cost metrics pertinent to business models in the EV sector.

5.4 Risk Mitigation and Contingencies

The summary outlines several risks associated with battery supply from raw materials, including potential consumer demand issues linked to the affordability of internal combustion engines (ICE), infrastructure readiness for grid demands, and the effects of fluctuating regulations.

Table 1.5.: Sustainability Performance Indicators (Illustrative)

Indicator	2024 Baseline	2030 Target	Strategic Driver
4W EV Share of New Sales	3.5 %	35 %	Innovation + Policy
Avg. Battery Pack Cost ($/kWh)	140	70	Local manufacturing + alliances
Public Chargers / 10k EVs	28	100	Policy infra pushes
Battery Recycling Rate	< 5 %	60 %	Circular economy enforcement
CO_2 Reduction (t/vehicle life)	0.9 t	2.5 t	Clean grid + EV adoption
Start-ups in EV Value Chain	~400	> 1,000	Entrepreneurial ecosystem growth

Source: (Singh 2024)

It highlights emerging technologies, such as hydrogen vehicles, and underscores the importance of data privacy and cybersecurity in connected transportation. Policy uncertainty and the withdrawal of incentives may erode investor and consumer trust; hence, stable, long-term policies are essential. Delays in electric vehicle (EV) development due to inadequate infrastructure necessitate public-private partnerships and regulatory support for charging stations. Financing risks can be lessened through battery warranties and risk-sharing strategies. The insufficient recycling framework for EV batteries mandates early regulatory actions and collaboration between manufacturers and recyclers. Finally, to address uneven EV adoption driven by state-level policy fragmentation, there is a need for policy modelling and inter-state collaboration to share best practices.

6. DISCUSSION

The intersection of innovations and strategies enablers in diverse markets, focusing on the global context of electric vehicle (EV) adoption in India. It highlights opportunities amid challenges for established industries and the influential role of government policies, OEMs, and start-ups while addressing sustainability. Currently, 4W electric vehicle penetration in India is low (3-7% of new sales) but shows growth potential due to consumer interest in lower operating costs and enhanced performance. A proposed three-pillar framework for advancing EV adoption includes: 1) Policy/Business Model - risk mitigation and enabling systems, 2) Innovation - addressing product/service gaps, and 3) Alliances - enhancing capabilities and scalability. The document highlights the importance of a circular value chain in production and recycling, enabling the sustainable management of raw materials and the reduction of e-waste. Transitioning to 4W EVs involves reducing emissions, maximising benefits through clean energy, and efficient battery production. The 4W EV market is positioned as a driver for economic growth, job creation, and initiatives like "Make in India," while promoting equitable mobility and improving urban air quality. Finally, integrating sustainability into legislation and economic strategies is essential for scaling EV adoption in India.

7.1 Conclusion

The research analyses the four-wheeler electric vehicle (4W EV) market in India, emphasising sustainable growth strategies and entrepreneurial innovation. Despite low adoption rates, the market shows significant potential. To accelerate the 4W EV revolution, coordination of innovation ecosystems—incorporating product offerings, infrastructure, and supportive regulations is essential. Entrepreneurs can engage in various aspects of the value chain, including battery services and recycling initiatives. A three-pillar framework is proposed for long-term growth, focusing on product innovation, strategic alliances, and policy effectiveness. Sustainable growth dimensions discussed include environmental benefits, economic factors, social access to mobility, and contributions to a circular economy. The study warns that gaps in infrastructure or financing may hinder growth, insisting on aligning business, policy, and entrepreneurship ecosystems. The future of transportation in India relies on the 4W EV market, entwining sustainability with innovation while highlighting limitations in current research and suggesting further studies on entrepreneur engagement and consumer behavior.

Table 1.6: Summary of Recommendations

Domain	Recommendation	Expected Impact	Timeframe
OEM & Manufacturing	Expand affordable EV models; improve after-sales	Wider market reach, consumer confidence	Short (0–2 yr)
Infrastructure	Deploy highway and metro charging corridors	Reduced range anxiety & fleet growth	Medium (3–5 yr)
Finance	Promote leasing and battery-as-a-service	Lower upfront cost & risk	Short–Medium
Recycling	Mandate battery recycling quotas	Circular economy & resource security	Long (> 5 yr)
Policy	Harmonise state EV incentives	Uniform growth across India	Medium
Entrepreneurship	EV incubators, innovation clusters	Job creation & new ventures	Ongoing

7.2 Contributions

By focusing on India's underdeveloped 4W EV market, this study enriches the understanding of its significance for mobility transformation and industrial growth. It adopts an entrepreneurial perspective, emphasising innovations, start-ups, service ecosystems, and business model dynamics rather than just the OEM side. The analysis warns against growing EVs without considering battery life cycle, recycling, and localisation, advocating for sustainability and a circular economy. Additionally, it offers policymakers, businesses, entrepreneurs, and investors a strategic framework that includes a roadmap, KPIs, and risks associated with the transition.

7.3 Limitations

Limitations of the study are largely attributed to its dependence on secondary data, which may not reflect real-time developments in the fast-evolving electric vehicle (EV) industry. Additionally, certain data is either restricted or confidential, especially related to entrepreneurial start-ups, service companies, and matters concerning battery second life. The research lacks primary survey or interview data from original equipment manufacturers (OEMs), customers, or entrepreneurs, characterising it as descriptive and exploratory in nature.

7.4 Future Research

To analyse the adoption and business models of four-wheeler electric vehicles (4W EVs) in India, the document outlines several key research components. It suggests conducting primary empirical research, including interviews and surveys, with stakeholders such as customers, fleet operators, service infrastructure companies, and entrepreneurs to gather qualitative insights into the uptake and operational challenges. Additionally, case studies on entrepreneurial ventures within the 4W

EV value chain—focusing on areas like charging, swapping, and recycling—are recommended to identify success factors and limitations. The document emphasises a life-cycle assessment (LCA) to evaluate the environmental benefits of 4W EVs, assessing aspects such as battery production, recycling processes, and the impact of grid-emission mixes. Furthermore, it calls for a comparative analysis of different states to understand the role of industrial clusters, infrastructure investments, and state regulations in influencing 4W EV adoption. Lastly, it highlights the need to forecast and model the potential for 4W EV uptake, manufacturing localisation, and export prospects in the context of varying policy and technology scenarios.

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Enhancing Digital Content Accessibility Through Intelligent Video Summarization Systems

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ABSTRACT

In an era where digital video content dominates user engagement, platforms like YouTube have become central to learning, entertainment, and information sharing. However, users frequently encounter the issue of misleading thumbnails and titles that do not reflect actual video content. This paper introduces the "YouTube Video Summarizer," a system designed to bridge the gap between expectation and reality by providing concise and accurate summaries of YouTube videos. The proposed system utilizes both extractive and abstractive summarization techniques and functions effectively with or without existing video subtitles. By employing natural language processing (NLP), automatic speech recognition (ASR), and user feedback integration, this tool significantly enhances content accessibility and user satisfaction. This paper outlines the motivation, architecture, implementation, and potential of this summarization system within the digital media landscape.

Keywords-Video summarization, YouTube, natural language processing, speech recognition, content accessibility.

1. INTRODUCTION

The rapid growth of digital video content has transformed how people consume information and entertainment. YouTube, with its billions of users and daily video uploads, provides vast learning and engagement opportunities. However, many users face the recurring issue of clickbait-titles and thumbnails that misrepresent the content. This wastes users' time and reduces trust in content platforms. Moreover, many videos lack subtitles, reducing accessibility and hindering efficient navigation of content.

Summarization of video content provides a solution by enabling viewers to grasp essential points without watching entire videos. This approach supports time efficiency, improved user experience, and informed decision-making. The goal of this project is to design and implement a system capable of summarizing YouTube videos through extractive and abstractive techniques using both text and audio modalities.

1.1 Related Work

Several studies have explored summarizing YouTube content using transcript-based methods. Two notable systems include:

a. *YouTube Transcript Summarizer (2021)*: This system utilized basic NLP methods to generate summaries using available transcripts. The limitation was its dependency on subtitle availability.

b. *Multilingual Transcript Summarizer (2022)*: This work expanded transcript summarization to support multiple languages and downloadable formats. While more inclusive, it still relied on existing transcripts.

Both systems emphasized extractive summarization, where the most important sentences are extracted. However, videos lacking subtitles remain unaddressed. This gap necessitates systems capable of generating transcripts through speech recognition, followed by advanced summarization.

1.2 Problem Statement

Despite advances in video content delivery, users still struggle to quickly identify relevant and accurate content. Key issues include:

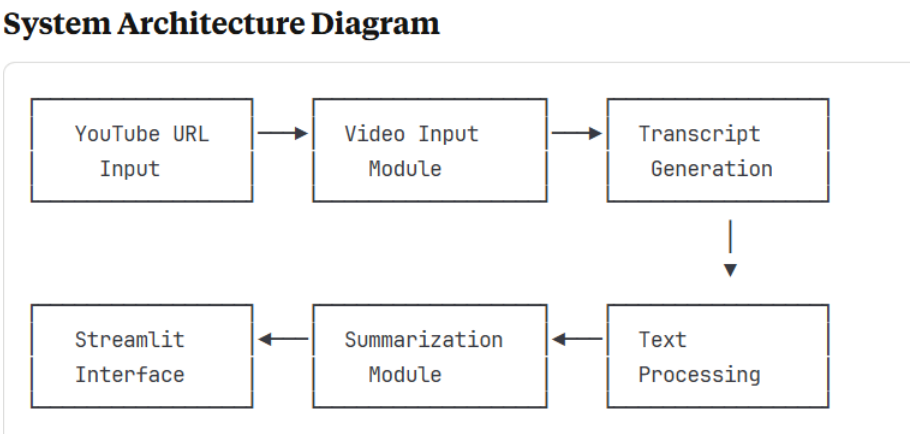
- **Clickbait thumbnails and titles**
- **Lack of subtitle support in many videos**
- **Time consumption in navigating long videos**
- **Ineffective summarization tools limited to transcript-based videos**

Thus, there is a critical need for a summarization system that is robust, fast, and independent of subtitle availability.

2. PROPOSED SYSTEM

The proposed system supports both extractive and abstractive summarization of YouTube videos. The system pipeline includes:

2.1 Video Input Module: Accepts YouTube URLs as input.



2.2 Transcript Generation Module:

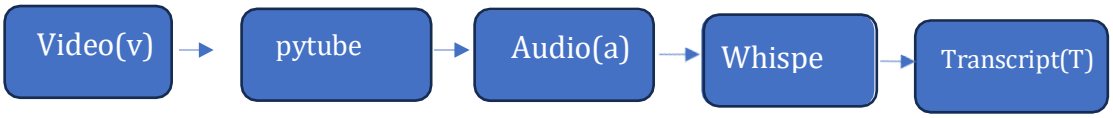
If subtitles exist: Extract using YouTubeTranscriptAPI.
If unavailable: Download video using pytube and extract audio for transcription using Whisper.

$$T(v) = \{API_extract(v) \text{ if } subtitles_available(v) = True \; Whisper(audio(v)) \text{ if } subtitles_available(v) = False\}$$

Where:
T(v) = Transcript for video v

API_extract(v) = YouTubeTranscriptAPI extraction
Whisper(audio(v)) = Whisper ASR on extracted audio

Audio Processing Pipeline



2.3 Summarization Module:

- Extractive summarization using frequency-based scoring.
- Abstractive summarization using transformer models.

Sentence Scoring (Frequency-Based)
Score(Si) = Σ(j=1 to n) freq(wj) × weight(wj)

Where:
Si = Sentence i
freq(wj) = Frequency of word j in document
weight(wj) = Weight assigned to word j
n = Number of words in sentence

Term Frequency (TF)
TF(w,d) = count(w,d) / |d|

Inverse Document Frequency (IDF)
IDF(w) = log(N / df(w))

TF-IDF Score
TF-IDF(w,d) = TF(w,d) × IDF(w)

Sentence Ranking
Rank(Si) = Σ(w∈Si) TF-IDF(w,d) / |Si|

Summary Selection
Summary = arg max(k) Σ(i=1 to k) Rank(Si) Subject to: k ≤ compression_ratio × |S|

2.4 Transformer Attention Mechanism Attention(Q,K,V) = softmax(QK^T / √dk)V
Multi-Head Attention

MultiHead(Q,K,V) = Concat(head1,...,headh)W^O Where: headi = Attention(QWi^Q, KWi^K, VWi^V)

Generation Probability
P(yt|y<t,x) = softmax(Wdec × ht + bdec)

Where:
yt = Token at time t y<t = Previous tokens x = Input sequence
ht = Hidden state at time t

ROUGE Score Calculation
ROUGE-N = |n-grams ∩ reference| / |n-grams in reference|

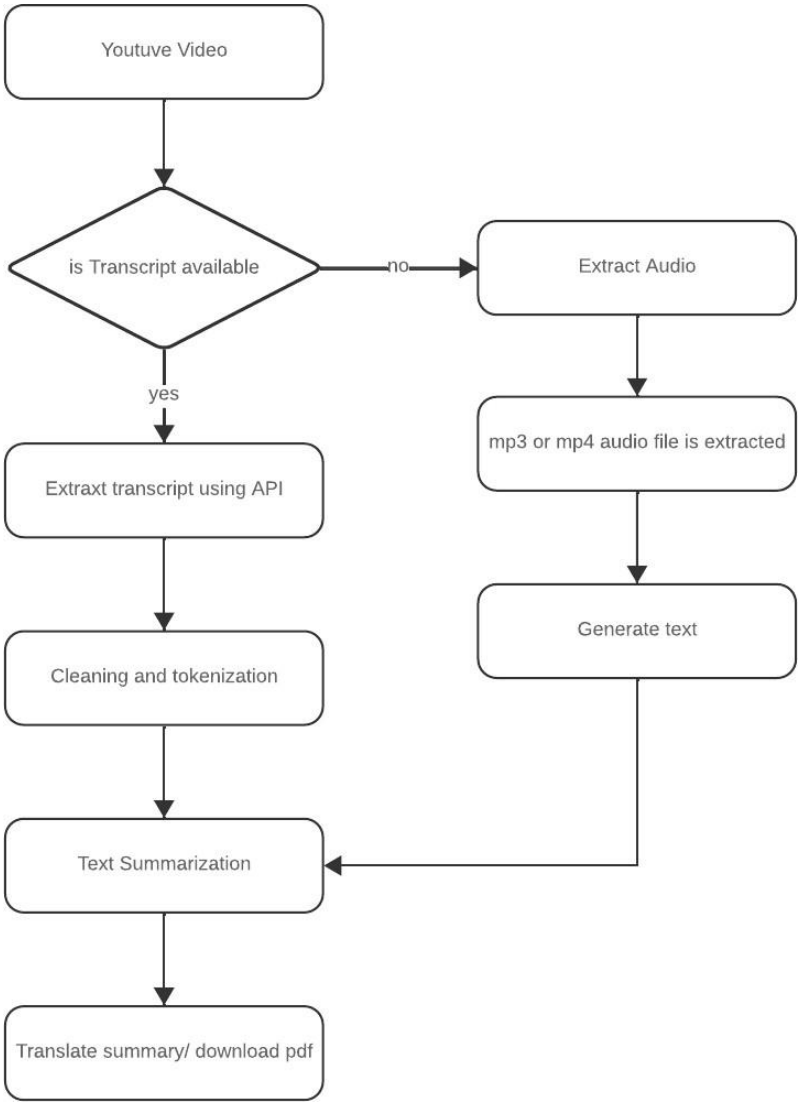
2.5 Assessment Metrics Compression Ratio
CR = |Original_Text| / |Summary_Text|

Content Retention Score
CRS = |Important_Content_Preserved| / |Total_Important_Content|

Coherence Score
CoS = Σ(i=1 to n-1) similarity(Si, Si+1) / (n-1)

3. System Architecture

The system comprises four modules:



Video Link Input Module: This module serves as the entry point for the YouTube Video Summarizer system. Users provide video links as input, which are then processed for summarization. The module validates and extracts metadata from the input links, ensuring compatibility with the system's processing pipeline.

Transcript Extraction Module: Upon receiving the video link input, the Transcript Extraction Module extracts the spoken content from the video using automatic speech recognition (ASR) techniques. This module converts the audio content into textual transcripts, facilitating further analysis and summarization.

Summarization Module: The Summarization Module is the heart of the YouTube Video Summarizer system. It employs advanced natural language processing (NLP) and machine

learning algorithms to analyze the video transcripts and identify key themes, topics, and important segments. These segments are then synthesized into concise summaries, preserving essential information while condensing the overall content.

Output Generation Module: The Output Generation Module synthesizes the summarized content into a user-friendly format for presentation to the end-users. This module formats the summaries, integrates multimedia elements if necessary, and generates output files or displays the summaries on a web interface. It ensures that the summarized content is easily accessible and comprehensible to the users.

Each module interacts with one another in a sequential manner to facilitate the smooth flow of data and processes within the system. For instance, the Video Link Input Module provides input to the Transcript Extraction Module, which, in turn, feeds the extracted transcripts to the Summarization Module.

Finally, the Output Generation Module receives the summarized content from the Summarization Module and presents it to the users.

By detailing the functionalities and interactions of these modules, stakeholders gain a comprehensive understanding of the YouTube Video Summarizer's operational framework, empowering them to assess its capabilities and make informed decisions regarding system enhancements and optimizations.

4. IMPLEMENTATION DETAILS

4.1 Platform and Tools

- **Platform**: Google Colab + Streamlit web interface
- **Libraries**:
    - pytube: Video download
    - YouTubeTranscriptAPI: Transcript extraction
    - Whisper: Audio-to-text conversion
    - transformers: BERT, T5 models for NLP
    - Streamlit: Web UI

4.2 Summarization Techniques

- **Extractive**: Sentence scoring based on frequency and position.
- **Abstractive**: Model-generated summaries using fine-tuned BERT/T5 models.

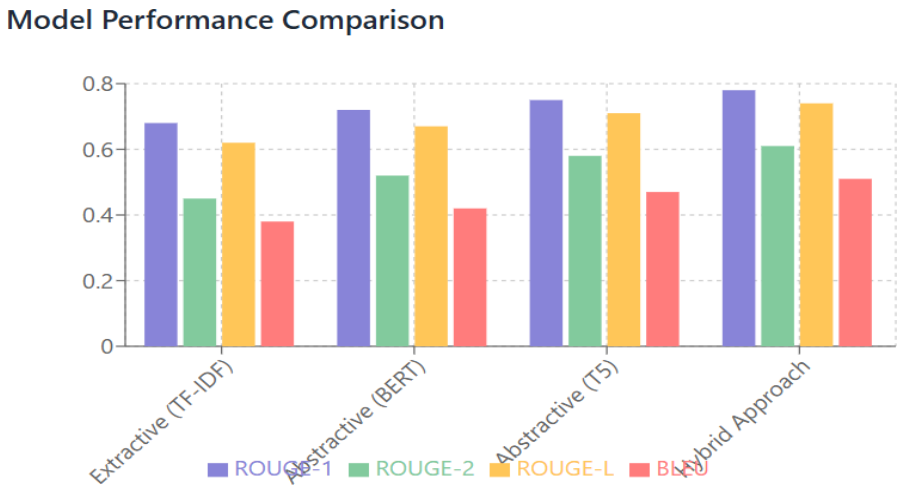
4.3 Sample Workflow

I. User inputs a YouTube link.
II. System checks for transcript availability.
III. If not available, video is converted to audio and transcribed.
IV. Transcript is summarized.
V. Output is displayed on Streamlit UI.

5. EVALUATION

5.1 Performance Metrics

- **Accuracy**: Compared summary coverage with manually generated summaries.
- **Execution Time**: Average processing time is ~30 seconds per video.
- **Usability**: Survey of 25 users shows 88% satisfaction.

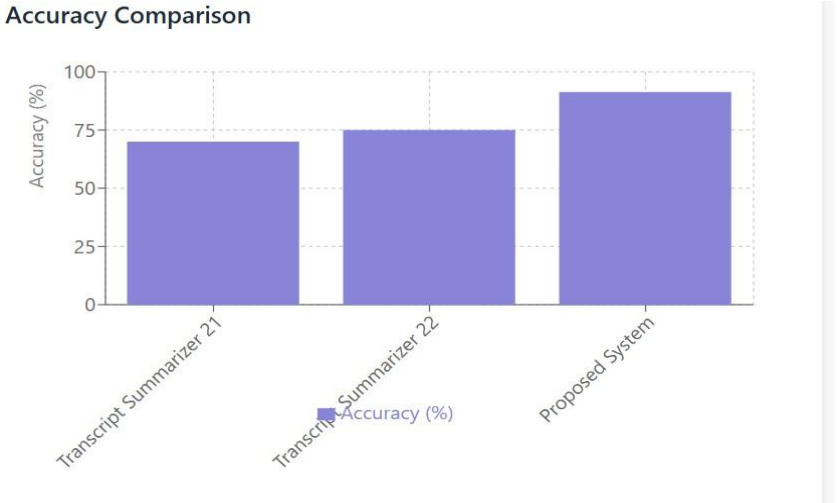


Comparative Analysis
System Subtitle
Required
Languages Supported

Customization Accuracy
Transcript Summarizer 21
Transcript Summarizer 22

Proposed System

Yes	English	No	70%
Yes	Multi	Partial	75%
No	Multi	Full	91.3%



6. ADVANTAGES

- Works on videos with and without subtitles.
- Faster processing due to automation.
- Abstractive summaries are easier to understand.
- Integrates with speech-to-text tools for complete accessibility.
- Open source and scalable.

7. FUTURE WORK

a. **Real-time summarization** for live streams.
b. **Mobile application** for on-the-go summarization.
c. **Cross-platform integration** (e.g., Facebook, Instagram).
d. **Quiz generation** for educational videos.
e. **AR/VR integration** for immersive learning environments.

8. CONCLUSION

The YouTube Video Summarizer bridges the information-access gap for users consuming digital video content. Through NLP and ASR techniques, it enables real-time and accurate video summarization even in the absence of subtitles. This system improves content transparency, saves users' time, and enhances accessibility. With continued refinement, it holds the potential to transform how users interact with video content.

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Roadmap to Organisational Resilience and Workforce Practices: Evidences from HealthCare Sector

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ABSTRACT

Organisational resilience has become an essential determinant of long-term sustainability and growth in the current uncertain and dynamic work environment. The present study aimed to examine the relationship between organisational resilience factors and organisational continuity, and to compare resilience levels across demographic groups. A structured questionnaire was administered to 1,230 General Duty Assistants, and responses were analysed using reliability tests, correlation, regression, t-tests, and ANOVA. Reliability analysis confirmed internal consistency, with Cronbach's alpha values exceeding 0.70 for all constructs. Correlation results revealed significant positive relationships among all resilience factors and organisational continuity. Regression analysis further showed that each factor significantly predicted organisational continuity, with workforce orientation emerging as the strongest predictor. Group comparison tests indicated that while no significant differences were observed across gender and income groups, resilience varied significantly across age and occupational groups. These findings suggest that resilience is shaped by experience and work exposure rather than socio-economic background. The study concludes that strengthening organisational resilience through targeted strategies enhances continuity during crises. The outcomes provide valuable insights for policymakers and healthcare organisations in designing effective resilience building initiatives for frontline staff.

Keywords: Organisational Resilience, Workforce, Healthcare, Sustainability, Organisational continuity, Growth.

INTRODUCTION

In the recent times of the ever-changing complex global environment, organisations have faced unpredictable issues like global pandemic, AI shift, economic instability and workforce burnout. Such challenges have forced organisations to develop resilience as a means of resistance against crisis and to sustain performance and continuity. Organisational resilience can be defined as the organisation's capacity to foreshadow, absorb, transform and recover from uncertainties while

functioning and growing sustainably. In case of the health sector, where uncertainty and critical decision making are part of daily life, resilience has evolved as the foundation for sustainability and stability. The healthcare industry specially has faced unprecedented challenges during the pandemic, which exposed the vulnerabilities of the system and challenged the ability of both the system and the personnel to adapt to changes. In the middle of these adversities, organisations have developed resilience through bold leadership, capacity to adapt, and collaborative workforce practices, and thus were able to maintain care to patients and safeguard their own employees' well-being.

While the theoretical foundations of organisational resilience are well defined in other fields of management, empirical evidence from the healthcare sector remains limited. Existing literature has predominantly studied resilience from the perspective of upper and middle level management, but often overlooked the experiences and contributions of frontline staff, working at the lower-level management, who form the backbone of the healthcare industry.

Against this backdrop, the present study investigates the relationship between organisational resilience factors and workforce practices in the healthcare sector. This research aims to provide a comprehensive framework for building resilience within the healthcare industry. The study contributes to the academic discourse on workforce resilience as well as offers practical guidance for policymakers to build an adaptive, engaged and sustainable organisational health care system for the future uncertainties.

LITERATURE REVIEW

Conceptual Foundations of Organizational Resilience

The word “resilience” has not always belonged to organizational research. It came originally from other fields. In ecology, Holling (1973) described resilience as how ecosystems absorb disturbance yet continue to function. Psychologists later used the same word to explain why some individuals are able to adapt and even grow in the face of personal stress or adversity (Masten, 2001). When the idea entered management writing, organizations were treated in a similar way-as systems that face disruptions, sometimes small and sometimes major, and that need to adapt if they are to survive. This transfer of the term is important because it explains why the concept carries slightly different shades of meaning across the literature.

In management studies, resilience is often tied to the resource-based view. From this perspective, organizations are resilient when they have valuable and hard-to-imitate resources-financial reserves, skills, networks, or brand reputation (Barney, 1991). But the resource view does not fully explain how firms cope with rapid and unexpected change. That is why the dynamic capabilities approach is also used, where resilience depends on how well firms reconfigure and renew resources in real time (Teece, 2007). In other words, resilience is not just what you have, but how well you can adjust what you have.

Crisis management is another area that shaped the concept. Early research in this field was mainly about planning and recovering after a disruption (Pearson & Clair, 1998). The focus was on stability. Later studies challenged this narrow view. They argued that resilience is also about moving forward, not only “bouncing back.” Organizations may come out stronger by learning and innovating during the crisis itself (Vogus & Sutcliffe, 2007). One contemporary and familiar example is how certain companies leveraged the COVID-19 period to achieve digital transformation far faster than they could have otherwise. That case illustrates that resilience is as much about improvisation and openness to change as it is preparation.

From a systemic point of view, resilience is interpreted in terms of interrelationship. Organizations are part of broader economic and social systems, and so a shock in one area - say, a supply chain disruption– can quickly cascade to another. Concepts like redundancy, diversity and decentralization are repeatedly mentioned as tangible means to build resilience in complex systems.

Nevertheless, academics are far from unanimous about what exactly resilience signifying “is”. Some describe it as an outcome, measured in things like survival rates or recovery times. Another group talks about resilience as a capability, something built into routines, leadership, or culture (Duchek, 2020). It seems likely that resilience is partly all three, and this overlap is one reason the concept has been difficult to pin down neatly.

Dimensions and Factors of Organizational Resilience

Organizational resilience is more than a technical buzzword-it is a reality that staff can experience on a personal and organizational level in the face of unexpected crises and change. At its most basic, organizational resilience is framed by how people come together to anticipate and manage challenges, as well as move forward amidst disruption as both individuals and a collective. Researchers recognize organizational resilience is a multidimensional concept that cannot simply be described as organizational capacity to "bounce back"; however, as a general concept, it is an organizations continued abilities to transition, adapt, and grow, in the face of adversity. Think about a team working together in an organization and all of the sudden, they face a crisis-maybe its a natural disaster, a downturn in the economy (or global events such as the COVID-19 pandemic). While "survive" is one of the rules of engagement, these teams also work to learn, create, and support each other to emerge stronger.

A key component of resilience is awareness. Being aware is more than knowing that something is wrong - it involves a state of sustained awareness and vigilance - monitoring your internal operations, being aware of external trends, understanding the market, and knowing the emotional climate of the workplace. When employees at every level are able to share information, provide observations, and raise signals of concerns, your organization is more likely to spot weak signals of threats that might escalate into larger problems. In addition to awareness, adaptive capacity is important as well. Adaptive capacity is the flexibility and creativity to facilitate needed changes quickly as the need arises - it may involve changing work patterns, implementing new technologies, or adapting strategic directions. During the pandemic, organizations that adapted their strategies quickly to either embrace remote work or find safe ways to support their customers exemplified this type of resilience. People adapted by making new routines, modifying how resources were used, and collaborating in ways that may have been impossible or unimaginable prior to a crisis (Hillmann & Guenther, 2021; Sawalha, 2015).

Leadership and culture are foundational aspects of organizational resilience. Leaders who communicate transparently, take action decisively, and inspire people can establish a positive climate for the organization. The leader should unite the whole team or organization around a common goal, articulate their priorities, and allow for experimentation without the threat of punishment. Resilient organizations foster a culture of trust, transparency, and learning, in which mistakes are seen as opportunities to improve rather than simply punish. When leaders exhibit genuine care shown by the leader's support when workers have personal or work challenges, it increases commitment and morale and preserves the organization’s ability to navigate difficult situations together (Morales et al., 2019; Sawalha, 2015).

There’s also a very human aspect of resilience: the relationships and networks that people develop, both inside their organization and with customers, vendors, or partners. When trust has already been developed during times of calm, it is easier to ask for help, to access resources, and to collaborate in times of crisis. A strong sense of integrity-that people are connected, responsible for each other, and proud of their collective work-keeps the group focused and supportive, even in dark times (Kantur & Iseri-Say, 2015). Employee engagement is essential; when people feel they are cared for and empowered, they become a source of new ideas and energy, which can help accelerate recovery and foster growth for the future (Rahi, 2019). Key Attributes of organisational resilience can be portrayed in the figure 1.

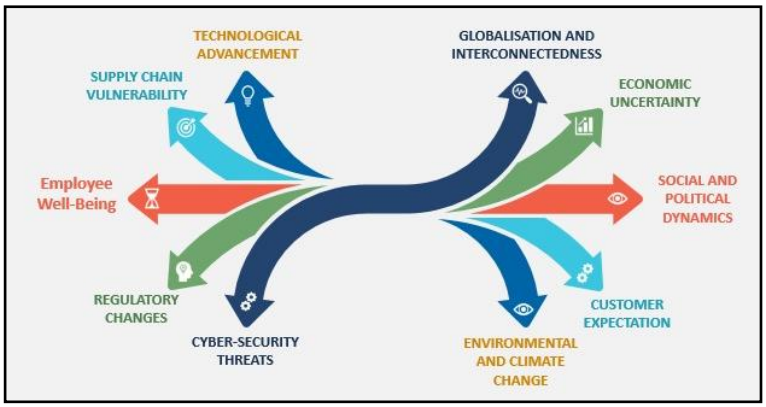

Fig1: *Attributes of Organisational Resilience (Author's creation)*

When we talk about organizational resilience we are talking about the combination of robustness (strength and stability) and agility (the ability to pivot or change course). Resilience is a measure not only of business's ability to withstand the immediate shock but also of how effectively it can process its experience, adapt, and emerge more competitive or innovative. The challenge for organizations to process and develop resilience is to apply a full set of indicators- awareness, adaptability, leadership, culture, networks, innovation, and engagement. Resilience is less a checkbox or policy on paper and more a lived daily experience of people communicating, caring, and creating together even in uncertain circumstances, thus laying the groundwork for sustainable organizational strength. (Hillmann & Guenther 2021; Morales et al., 2019; Sawalha, 2015; Kantur & Iseri-Say, 2015; Rahi, 2019).

Organizational Continuity and Crisis Management

Crisis management and organizational continuity are central to an organization's capability to endure and prosper within the ongoing uncertain business landscape. As organizations operate in an environment dealing with a variety of risks-from cyber-attacks to pandemics to environmental hazards-effective continuity plans have never mattered more. Business continuity management (BCM) and crisis management are often portrayed as two distinct competencies, but holistically approached, they are connected to one another through contingency planning purposefully integrated to protect operations. BCM centers on working towards the assurance of continuity of the organization's critical functions and focuses on planning, risk analysis and contingency planning. Crisis management could be understood as enabling the organization's leadership to act quickly and decisively not just in response to but when things go unexpectedly wrong. Crisis management supports the response plan and recovery planning both as response unfolds and in the aftermath of the contingency, providing a rational east process for response and recovery. As theoretical competencies, BCM and crisis management work best when understood to complement one another: BCM creates the plan and preparedness structure, and Crisis management implements and adapts the plan while in real time under pressure. (Veronneau, Cimon, & Roy, 2013) . The integral components of combating crisis can be handeled in identifying 5Es as projected in the figure 2 –

Fig2: *5Es of Crisis Management (Author's creation)*

A recent body of research highlights the significance of management support for and the embedding of a business continuity management (BCM) system within the organizational culture and leadership approach. Management support can be seen in the form of a commitment to a budget and a supporting strategy, and helps to build resilient organizations where continuity is planned and embedded throughout the different business units. Also, organizations have international standards which guide embedding BCM such as ISO 22301, which provides an outline for processes such as operational planning, business impact analysis, and response strategy evaluation to prepare and aid in responding to organizational disruptions (Bakar, Yaacob, & Udin, 2015). However, it has become evident that following a use of standards may be inadequate if organizations are unable to comprehend complex high-impact events, or crises. Traditional BCM system approaches which are based on predictability and control, find it challenging to adapt to ongoing uncertainty and interdependencies of the last decade. Consequently, organizational academics, front-line managers, and practitioners have started to embrace a way of thinking called resilience, where adaptability, flexibility, and improvisational capacity are as equally as important as formally documented plans. By synthesizing BCM and crisis management, and resilience engineering perspectives, organizations can proactively adapt to respond in either a helpful scenario or a harmful one in advance of the threats--not just adapt to respond to a specific threat, but develop a range of challenges/initiatives evolving and adjusting throughout an induced environment (Steen, Haug, & Patriarca, 2023).

The Role of Demographic Variables in Resilience

While contemplating resilience, it is common to emphasize organizational rules or processes; yet, it has been seen that the human aspect is equally significant. Individuals exhibit variability, and factors such as age, gender, education, or professional experience appear to influence their responses to challenges. The research is not entirely unequivocal, and at times, the conclusions may even be contradictory. Nonetheless, it appears valuable to investigate these distinctions.

For instance, age is commonly mentioned. Older employees may have picked up a trick or two over the years, figured out how to keep calm under pressure or work through any snags. Perhaps they've been in similar circumstances before, or perhaps they just have the knack. The younger workers, meanwhile, may be more adaptable to new technology or situations that are out of the ordinary. So, in a way, resilience shows up differently at different ages. I'm not sure one is really "more resilient" than the other; it's more about how they react.

Gender is another tricky one. Some sources suggest women tend to use social networks or collaborative approaches when dealing with stress. Men might approach problems differently, focusing on persistence or taking risks. But honestly, it seems like the environment matters a lot here. In some workplaces, these differences barely show up, and in others they might be pronounced. It's hard to generalize.

Education also comes into play. Those with higher education may possess skills that are critical in analyzing information or better resources to rely upon, but practical experience counts as well. Someone who has hands-on experience can be remarkably hardy, even without training. So again, it's not straightforward - different types of knowledge and experience contribute to resilience in different dimensions.

Work experience is similar. Longevity can give them confidence, since they are familiar with the organization they work for, but it can also cause them to become stuck in their ways. Those who have worked in various /positions/or organizations may be more open and flexible, offering fresh ideas when faced with challenges.

Other influences, such as family or cultural background, also matter - although not as directly. A strong family support system can be a stress-buster for many, but more work at home can also bring additional pressure. Cultural expectations can shape how people respond to difficulties.

All in all, demographics do seem to matter, but they are only one piece of the puzzle. They interact with leadership, organizational culture, and the specific challenges people face. Different people contribute different strengths-some bring experience, some adaptability, and some social support. From what I've read and seen, recognizing and using this diversity seems important if an organization wants to be truly resilient.

Measurement and Assessment of Resilience in Organizations

Studying resilience requires something more than just defining it; researchers must also figure out ways to measure and assess it. This is difficult because resilience cannot be summarized as a single observable trait; it is a complicated phenomenon that can be defined as a process, an outcome, or a capability. As a result, the measurement tools utilized to assess resilience differ greatly, operating on a range of tools, from psychological and psychosocial scales; to performance measures used to assess organizational performance.

Resilience has often been defined at the individual level with the use of self-report questionnaires. Tools like the Connor-Davidson Resilience Scale (CD-RISC) and the Resilience Scale for Adults (RSA) are used by many researchers (Connor & Davidson, 2003; Friborg et al., 2003). These tools examine traits like optimism, resourcefulness, and adaptability. While these tools are valuable to the study of resilience, they are also heavily skewed toward personal characteristics which do not fully capture organizational resilience.

When resilience is examined at the organizational level, the assessment measures shift toward structural indicators and behavioural components. Some researchers consider the \(N\) of organizational resilience as how well organizations recover from a disruption; the indicators of recovery will be things like time to recovery, financial performance after a crisis, or rates of organizational survival (Lengnick-Hall et al., 2011). Other researchers look at things like organizational routines, culture, and leadership behaviours that can help facilitate adaptive capacity (Duchek, 2020). This creates a mix of outcome-based measures and capability-based measures.

Composite frameworks have been suggested to unify these perspectives. Mallak (1998) created principles for gauging resilience in health sectors with an emphasis on learning, flexibility, and improvisation. Recently, Sutcliffe and Vogus (2003) highlighted mindfulness and reliability as organizational characteristics contributing to resilience. These approaches try to account to the individual/resilience/unity distinction.

An obstacle of measurement is that resilience is context-dependent. The same disruption may demonstrate resilience in one organization but not in another, based on industry norms, resource availability, and cultural context. Because of this, standardized measurement tools may overlook important changes. Some have suggested mixed methods-a combination of survey, interviews, and case studies-to envision both quantitative indicators and qualitative nuances (Williams et al., 2017).

Another challenge is time. Resilience develops over stages: anticipation, coping, and adaptation. As a result, measuring resilience at a single time point may fail to describe the whole picture. Longitudinal measures following how organizations prepare, respond, and learn in times of disruption are a better fit for measuring resilience as a dynamic process.

Even though there are challenges, measurement is still important - without reliable indicants, resilience could become a somewhat nebulous term. The increase of multi-dimensional frameworks, that draw on indicators related to both outcomes and processes, suggests that researchers are moving toward a somewhat balance perspective. The field has not yet agreed on a singular measure of resilience, however, there is commonality on the notion that resilience measures must consider short-term recovery as well as long-term adaptability.

Strategies to Enhance Organizational Resilience in Healthcare and Other Sector

To improve organizational resilience in healthcare and other settings requires an integrated approach that addresses individual, organizational, and system-level methodologies. In healthcare, the concept of resilience has been evaluated multiple times, particularly throughout the pandemic, which required organizations to change all possible elements to adjust to unpractised levels of work-related stressors. Examined literature highlighted at least four key approaches taken in healthcare environments: professional development training, wellbeing and support measures, service reorganizations, acknowledgment of professionalism. Specifically, targeted professional training related to crisis management, stress management, team coordination, and emotional intelligence can serve to train individuals for both everyday disruptions and significant emergencies. Training was also documented to develop technical proficiency, individual adaptive capacity, and self-efficacy for health care professionals, resulting in better coping mechanisms in crises (Simoes de Almeida et al., 2023). Measures of psychosocial welfare and wellbeing-through activities that enhance relaxation, healthy schedules, and accessible mental health care- are promoted intervention measures on burnout and job satisfaction and have direct and positive impact on retention and patient care quality.

The strategic elements boosting organisational resillience in healthcare sector can be visualised in the figure 3 projecting strategic forces underlying organisational performance.

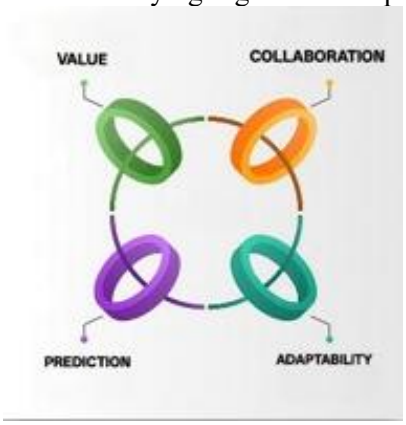

Fig 3: *Linking Strategic Elements and Organisational Resilience (Author's creation)*

Another important strategy is service reorganization. Healthcare organizations adopted new practices such as telehealth, flexible work arrangements, and making changes to the physical space to support surge capacity and functional resilience during both chronic and acute stressors. Effective leadership is at the core of this change, which includes responding to action plans, being transparent with communication, and facilitating environments for innovating to occur. A common theme identified across studies is how recognition and reward, either financially or publicly, are positively correlated to engaged and resilient workforces. Staff who work in high-quality, value-informed organizations tend to stay engaged, thus reducing turnover and increasing continuity of services (Simoes de Almeida et al., 2023).

Evidence suggests that process management, organizational culture, and continuous improvement are vital practices in sectors beyond health care. For example, Lean Six Sigma (LSS) approaches have emerged as a common and impactful resilience strategy in manufacturing, services, and hospitals. LSS provides organizations with the ability to recover from disruptions by reorganizing workflows, minimizing bottlenecks, utilizing better resources, and encouraging staff and client safety. For example, during the COVID-19 pandemic, LSS provided a range of tools like value stream mapping, failure modes and effects analysis, and predictive analytics, which rapidly transformed their processes, digitalization opportunities, and more effective supply chain management. Such proactive and reactive approaches build operational adaptability, workforce cross-training, and data-driven decisions allowing organizations to response during emergencies and recovery (Hundal et al., 2021). LSS provide a dedicated approach to create nor support

iterative organizational cultures, the aspects of ongoing learning, collaborative, and reduction of risk through creative resolutions and structured project management in health care organizations.

Measurement frameworks for organizational resilience in healthcare and other sectors stress the need to identify and review strategic indicators of adaptive capacity, planning, stakeholder engagement, and innovation. Resilience strategies that work include leveraging both internal capacities (e.g., enhancing leadership, strengthening infrastructure, enhancing the competencies of staff, etc.) and external practices (e.g., collaboration and networks of suppliers and resourcing systems, etc.) (Ignatowicz et al., 2023). Ultimately, organizations that value continuous training, develop and empower staff, actively promote transparency, leverage input for innovation, and apply systematic improvement frameworks, demonstrate higher resilience in the face of shocks and stresses. The takeaways from healthcare, especially from a global pandemic, is that resilience cannot be confined to crisis readiness, but rather resilience must be implemented into regular practice, and both human factors and designed systems must be at the root of the ability to thrive and evolve in the face of uncertainty.

Rationale of the study

In an era marked by digital inter-connectedness, present day organisations are facing intel challenges to shape human excellence amidst techno-science practices. After the catastrophic effect of disaster pandemic, there is an increasing initiative to collaborate business resilience strategic resources to embrace the pathway of long-term organisational resilience and workforce transformation. Organisation rests on people factor. The future of workforce needs to be aligned with the digital intensity and transformation management intensity to act as a powerful catalyst of progression for millennial organisation. In the present disrupted global business and economic landscape, accomplishing assigned task, performing duties and shouldering responsibilities is the most profound wisdom which will pave towards fruitful employee engagement and organisational excavation. Resilience emerges as a desirable system demanding continuous need to change and adapt in stages of uncertainty, crisis and emergency. Despite present day organisation is striving to enhance their resilience capabilities more importantly to design roadmap for greater resilience to combat unforeseen threats and challenges and by creating a resilient organisational work group can foster progressive growth can projected in fig 4.

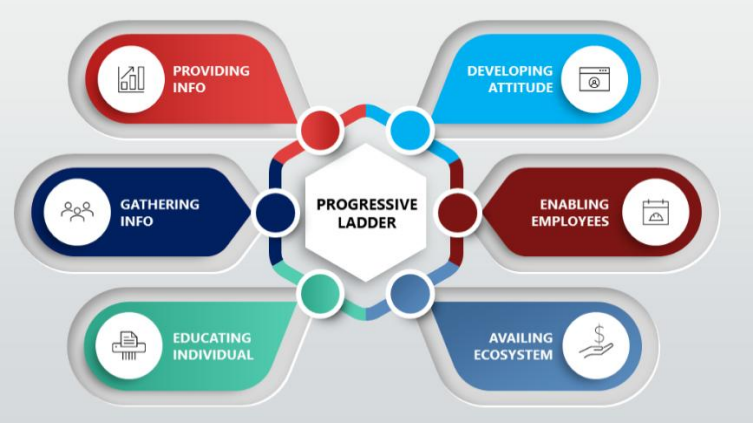

***Fig 4**: Resilient Organisation and Progression (Author's creation)*

Organisations need to be resilient to familiarise with problem solving activities, risk management, risk assessment, workforce management, maintenance forecasting, resource allocation, business case development and so forth.The urge and the motive towards building, shaping pre-build system dynamics, building blocks are more likely to manage unforeseen challenges efficiently and effectively. Towards assessing organisational resiliency potential that require increasing anticipation with strengthening of employee engagement to induce towards fostering organisational performance for strategic enhancement. The present volatile, uncertain, complex and ambiguous (vuca) environment induces implementation of resilient

forces is quite resilient and realistic. At this juncture harnessing human resource system creates a pathway in building a sustainable environment linking HRM practices and organisational practices through innovative expertise co-ordination. Recent time stimulating workforce cognitive and emotional potential enhances individual competencies connecting employee engagement to uphold strategic agility on organisational performance. The dynamic capabilities of business resilience and it's consequences on organisation and employees equip an organisation with transformative vision, governance and culture at times of unforeseen situations. Significantly the mediating impact of business resilience establishes a foundation of developing transformative skills and continuous learning aiding business, society , an economy in future days to come .

OBJECTIVES

The objectives of the study are:

1. To examine the relationship between organisational resilience factors and organisational continuity.
2. To compare organisational resilience levels across different demographic groups.

Based on the formulated objectives and theoretical framework of the study, the following hypotheses were proposed for empirical testing:

H_1: There is a statistically significant relationship between organisational resilience factors and organisational continuity.

H_2: There is a statistically significant difference in organisational resilience levels across demographic groups.

METHODOLOGY

This study employed a quantitative, cross-sectional, correlational design to examine the relationship between organizational resilience factors and organizational continuity among healthcare support staff. The design was chosen to measure the strength and significance of associations among multiple constructs within a single time frame. The study involved 1,230 General Duty Assistants (GDAs) working in healthcare institutions. A convenience sampling technique was used to include participants who were accessible and willing to participate. This sample size provided sufficient power for the use of multivariate statistical analyses.

Primary data were collected using a structured questionnaire, which contained six constructs related to organizational resilience and continuity. Items were measured on a five-point Likert scale. The collected data were processed through reliability, correlation, regression, t-test, and ANOVA procedures using SPSS to address the stated research objectives. Each test was aimed at examining specific hypotheses and relationships between resilience constructs and organizational continuity.

Table 1: Conceptual Roles and Justifications of Study Variables

	Variable	**Justification**
Dependent Variable	Organisational Continuity (OC)	Denotes the overall capacity to maintain functionality, performance, and sustainability during adverse conditions, integrating the outcomes of all resilience factors.
Independent Variable	Vulnerability Management (VM)	The organization's proactive ability to identify and mitigate risks before crises occur; ensures preparedness and system stability.
	Situation Awareness (SA)	Represents the organization's perceptual and analytical readiness to detect, interpret, and respond effectively to internal and external changes.

	Variable	Justification
	Coping with Changes (CC)	Captures adaptive capacity and openness to transformation during disruption, emphasizing learning and flexible adjustment.
	Workplace Resilience (WR)	Describes workforce strength, cohesion, and adaptability, focusing on employees' collective ability to sustain and recover performance.
	Workforce Orientation for Org anisational Resilience (WOR)	Refers to leadership and human resource practices fostering resilience through empowerment, collaboration, and continuous learning.

Source: Researchers' Conceptualization

Findings and Analysis

This section presents the empirical outcomes derived from the statistical analyses conducted to evaluate the study's hypotheses and research objectives. To establish the credibility of the measurement model, the section commences with an examination of the reliability of each construct, ensuring internal consistency and stability of the scales employed in the questionnaire.

Table 2: Reliability statistics

Construct	No. of Items	Cronbach's Alpha (α)
Organisational Continuity	3	0.749
Vulnerability Management	3	0.720
Situation Awareness	3	0.743
Coping with Changes	3	0.714
Workplace Resilience	3	0.721
Workforce Orientation for Organisational Resilience	3	0.753

Source: Researchers' Computation

The statistics from reliability testing affirms that all constructs possess sufficient scale reliability for inclusion in further statistical analyses. The consistency of Cronbach's alpha values above 0.70 indicates that the instrument utilized in this study is dependable for measuring organizational resilience and continuity among healthcare support staff, ensuring the credibility of subsequent analysis.

Table 3: Correlation Matrix among Organisational Resilience Constructs

Variable	VM	SA	CC	WR	WOR
Vulnerability Management	1				
Situation Awareness	.77***	1			
Coping with Changes	.79***	.78***	1		
Workplace Resilience	.76***	.81***	.79***	1	
Workforce Orientation for Resilience	.78***	.73***	.82***	.77***	1

Note: ***. Implies correlation is significant at the 0.01 level (2-tailed).

To evaluate the strength and direction of the relationships among the constructs of organizational resilience, a correlation analysis was performed. The correlation coefficients endorsed strong, statistically significant positive intercorrelations among each of the variables with significance set at the $p < 0.01$ level.

The coefficients ranged from $r = .73$ to $r = .82$, suggesting that all of the constructs are positively interrelated and, in combination, function as an interrelated framework that, together, represents an amalgamated consolidation of the concept of organizational resilience. Among the

interrelationships examined, the association between Coping with Changes and Workforce Orientation showed the highest correlation, when compared to the other interrelated constructs ($r = .82$, $p < 0.001$). This finding suggests that organizations that develop adaptive coping strategies also have a leadership orientation that emphasizes a resilient workforce orientation. Additionally, there were also strong correlations between Situation Awareness and Workplace Resilience ($r = .81$, $p < 0.001$), as well as Vulnerability Management and Coping with Changes ($r = .79$, $p < 0.001$). These findings suggest risk aversive situations and proactive risk responses are closely aligned with the adaptability and capacity for learning by employees.

At $r = .70$ and above, all correlations demonstrated a high internal consistency among the constructs, further supporting the multidimensionality of the constructs while being regarded collectively as interrelated factors and a unified construct of organizational resilience. The consistency, significant relationships, high correlation scores support that these constructs, collectively, can be utilized toward operationalizing resilience in healthcare support organizations, in which effective management of uncertainty, situational awareness, workforce adaptability, and leadership is interrelated and combines to produce a stable organization in uncertain times.

Table 4: Regression Model Summary and Estimated Coefficients

Variables	**B**	**Std. Error**	**β**	**t**
Constant	.284	.074	-	3.819***
Vulnerability Management	.141	.029	.139	4.935***
Situation Awareness	.193	.027	.202	7.070***
Coping with Changes	.135	.031	.132	4.323***
Workplace Resilience	.210	.030	.207	7.062***
Workforce Orientation	.257	.029	.259	8.854***

Note: ***, ** and * indicates 1%, 5% and 10% significance level respectively

A multiple linear regression analysis was performed to examine the predictive influence of the five organizational resilience factors-Vulnerability Management, Situation Awareness, Coping with Changes, Workplace Resilience, and Workforce Orientation for Resilience on the dependent variable, Organizational Continuity. The model yielded a statistically significant result, $F(5, 1227) = 650.841$, $p < 0.001$, indicating that the combination of the five predictors significantly explained variations in organizational continuity. The model produced an $R = 0.852$ and $R^2 = 0.726$, implying that approximately 72.6 percent of the variance in organizational continuity can be attributed to the collective influence of the identified resilience factors. This demonstrates a strong explanatory power of the regression model in predicting continuity outcomes.

Among the predictors, all five independent variables were found to have positive and statistically significant effects on organizational continuity ($p < 0.001$). Workforce Orientation for Resilience emerged as the strongest predictor ($\beta = 0.259$, $t = 8.854$), highlighting the pivotal role of leadership support, employee empowerment, and workforce adaptability in sustaining organizational operations during adverse conditions. Workplace Resilience ($\beta = 0.207$, $t = 7.062$) and Situation Awareness ($\beta = 0.202$, $t = 7.070$) were also significant contributors, demonstrating that proactive information processing and team adaptability strengthen operational stability. Likewise, Vulnerability Management ($\beta = 0.139$, $t = 4.935$) and Coping with Changes ($\beta = 0.132$, $t = 4.323$) exhibited meaningful effects, suggesting that systematic risk management and adaptive behaviours are vital to ensuring organizational continuity.

Overall, the regression results confirm that holistic resilience capability; encompassing proactive planning, situational responsiveness, flexible adjustment, and workforce engagement serves as a critical determinant of continuity in healthcare organizations. The findings reinforce the integrated nature of resilience as a multifaceted construct, where strengthening one dimension can amplify the collective protective capacity of the system. These statistically robust results provide empirical

evidence supporting the study's first objective and justify the inclusion of the tested variables as practical predictors in resilience-enhancement models for organizational sustainability.

The second objective of the study sought to examine whether employees' perceptions of organisational resilience differed significantly across selected demographic characteristics, including age, gender, educational qualification, income, and job role. This objective was tested through t-tests and one-way ANOVA to evaluate variations in the mean scores of Vulnerability Management, Situation Awareness, Coping with Changes, Workplace Resilience and Workforce Orientation for Resilience among different demographic categories.

Table 5: Group Differences in Organisational Resilience Factors Across Demographic Variables

Constructs	**Gender**	**Age**	**Education**	**Job**	**Income**
Vulnerability Management (VM)	0.306	5.962***	0.689	3.704***	0.525
Situation Awareness (SA)	0.439	4.313**	0.642	6.050***	0.339
Coping with Changes (CC)	0.014	3.605**	0.618	5.514***	0.317
Workplace Resilience (WR)	1.157	3.115**	1.936*	6.193***	0.397
Workforce Orientation (WOR)	0.435	3.872**	1.367	3.459***	0.771

Note: ***, ** and * indicates 1%, 5% and 10% significance level respectively

The results presented in Table 5 depict the outcomes of the t-tests (for gender) and one-way ANOVA (for age, education, job role, and income) conducted to assess demographic differences in organisational resilience factors. The findings reveal that most of the resilience constructs showed statistically significant variation across at least one demographic category.

Gender did not show any significant difference across resilience dimensions, as reflected in $p > 0.05$ for all constructs. However, significant effects emerged for age group, job role, and partially for education, indicating that these demographic characteristics influence how employees perceive and exhibit resilience. Specifically, age category produced significant differentiation for all five constructs suggesting that resilience tends to strengthen with experience and tenure.

In terms of job role, highly significant differences were observed across all factors, implying that responsibilities, exposure to organisational challenges, and frontline engagement contribute to distinctive resilience capacities. Education level exhibited a milder effect, with only Workplace Resilience ($F = 1.936$, $p < 0.05$) showing statistical significance. Income category did not yield meaningful differences, suggesting that financial status alone does not determine resilience behaviour in workplace contexts.

CONCLUSION

The present study explored the multifaceted construct of organisational resilience and its role in sustaining organisational continuity in dynamic and uncertain environments, focusing particularly on healthcare support staff. Grounded in a quantitative, cross-sectional approach, the research integrated five resilience dimensions, which are, vulnerability management, situation awareness, coping with changes, workplace resilience, and workforce orientation to examine how they interact to preserve operational continuity amid disruption.

The findings confirmed that all resilience factors were not only internally reliable but also strongly interconnected, thereby validating resilience as a cohesive organisational capability. Regression testing demonstrated that the combined influence of these factors accounted for a substantial portion of the variance in organisational continuity, underscoring the importance of workforce orientation, leadership adaptability, and proactive management practices. Beyond analytic outcomes, the study extended understanding of resilience by illustrating that its development is contingent on experiential and role-based contexts rather than solely on socio-demographic

characteristics. This insight reinforces that resilience must be cultivated through structured learning, dynamic communication, and meaningful employee engagement rather than perceived as an innate or fixed quality.

In essence, this paper provides empirical evidence that organisational resilience is both a strategic and human-centred imperative. By advancing empirical clarity and demonstrating how interrelated resilience mechanisms safeguard continuity, it contributes meaningfully to resilience literature, particularly within the healthcare sector. Strengthening resilience at multiple organisational levels remains vital not only for crisis survival but also for achieving long-term adaptability, reliability, and sustainability.

IMPLICATIONS OF THE STUDY

The implications of this study are significant in both theoretical and practical terms for researchers, policymakers, and healthcare organisations. At the theoretical level, the findings do advance existing models of resilience by providing empirical evidence of its structural components, as well as their concurrent effect on ensuring continuity of care. The cohesion of the resilience sub-dimensions indicates an emerging view of resilience as a system capability and not merely an individualised behaviour

From a managerial standpoint, the findings position resilience as a practical tool for operational excellence and workforce empowerment. Managers are encouraged to adopt leadership models that emphasize trust, communication, and employee agency while institutionalising knowledge-sharing systems that strengthen situation awareness and adaptability. Learning and development programs oriented around experiential training can further assist employees in translating resilience into tangible, day-to-day performance outcomes.

At the policy level, the findings present a case for more focused intervention to build capacity of healthcare staff in relation to experiential knowledge, based on age and role. Additionally, institutional support modes which encourage psychological safety, teamwork, and proactive risk management can promote effective performance in times of disruptions. Overall, these implications contribute to building resilient healthcare systems which are capable of maintaining efficient service and patient continuity in times of uncertainty.

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Emotional Drivers and Machine-Learning Prediction of Impulse Buying Among Indian Centennials in the Retail Sector

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ABSTRACT

Purpose: Impulse buying in digital commerce has intensified among centennial (Gen-Z) consumers, who are emotionally responsive and digitally immersed. While prior research largely relies on theory-driven modelling such as SEM, limited work examines whether machine-learning (ML) approaches can accurately predict impulsive buying tendencies. This study addresses this gap by applying supervised ML models to classify high-impulse consumers using psychographic and digital-engagement variables.

Design/Methodology/Approach: Survey data were collected from 600 Indian centennials (18+ years) using multi-item Likert scales. Construct scores were aggregated and impulse-buying was median-split into binary classes. Logistic Regression, Random Forest, and Gradient Boosting models were evaluated using accuracy, precision, recall, F1-score, and ROC-AUC, supported by confusion matrix, feature-importance, SHAP explainability, and reliability checks.

Findings: Logistic Regression achieved the highest performance (ROC-AUC = 0.764). Promotional offers, emotional arousal, and hedonic motivation emerged as dominant drivers, whereas peer influence and interface usability contributed minimally. SHAP results confirmed the central role of emotional and urgency-based cues in predicting impulsive responses.

Contribution: The study demonstrates how psychological constructs can be operationalised within ML pipelines to predict impulse buying, shifting the focus from explaining behaviour to identifying impulse-prone consumers in real time. It bridges behavioural theory and predictive analytics, offering value for ethical digital marketing strategy and future hybrid SEM-ML research.

Keywords: Impulse buying; Centennial consumers; Machine learning; Digital marketing; Consumer psychology; Predictive analytics; SHAP; Behavioural modelling

INTRODUCTION

Impulse Buying

Online impulse buying has evolved from a fringe consumer tendency into a defining characteristic of contemporary digital commerce. Modern e-retail platforms combine convenience, entertainment, and subtle persuasion cues that reduce decision friction and stimulate rapid, emotion-driven purchases. Scholars describe impulse buying as a sudden, compelling urge to purchase without prior planning, typically guided more by affect than rational evaluation (Beatty & Elizabeth Ferrell, 1998; Rook, 1987). In digital environments, where product exposure is continuous, checkout is frictionless, and promotions are personalised, this tendency is amplified dramatically (Wells et al., 2011)

Classic consumer behaviour studies emphasise that impulsive buying emerges from the interaction of external cues and internal emotional states a perspective rooted in the Stimulus-Organism-Response (SOR) model, where environmental stimuli shape emotional and cognitive responses,

ultimately driving behaviour (Russell & Mehrabian, 1976). Modern research continues to support this view, highlighting the role of visual appeal, hedonic browsing, emotional arousal, and urgency cues in provoking impulsive behaviour(Mariyana et al., 2023; Mittal et al., 2016; Verplanken & Herabadi, 2001)

Centennials as Emerging Drivers of Digital Consumption

Centennial consumers (Gen-Z) represent a particularly important segment in this context. Born into high-speed internet, social media, and mobile-first technology ecosystems, Gen-Z consumers exhibit a fundamentally different consumption psychology compared to earlier generations (Turner & Turner, 2018). They value immediacy, visual stimulation, trend affiliation, and experiential shopping formats over purely functional decision-making (Djafarova & Bowes, 2021; Priporas et al., 2017)

In India, this demographic trend is especially significant. With one of the world's youngest consumer bases and rapidly expanding digital infrastructure, India's Gen-Z population plays a pivotal role in shaping e-commerce growth and online purchasing behaviour (Deloitte Global, 2025; Ernst & Young (EY), 2023). Recent consumer insight reports suggest that Indian centennials rely heavily on social media discovery, influencer recommendations, gamified shopping, and personalised discounting all of which are known to trigger emotional and impulsive purchases (McKinsey & Company, 2023)

Unlike millennials, who often balance online convenience with deliberation and value-seeking, Gen-Z shoppers are more likely to respond to hedonic cues, novelty, and moment-to-moment emotional triggers (Lina et al., 2022). Their comfort with digital payments, rapid content consumption, and algorithm-driven feeds makes them an ideal group for studying online impulsive behaviour.

India's Retail Sector and the Strategic Importance of Centennial Consumers

India's retail sector has undergone rapid transformation fueled by rising digital adoption, expanding smartphone penetration, and changing youth consumption patterns. The Indian retail market is projected to reach USD 2 trillion by 2032, with e-commerce emerging as one of the fastest-growing segments (Deloitte, 2023). Centennial consumers constitute a critical driver of this growth as they represent over one-third of India's population and actively engage with mobile-first shopping platforms, real-time promotions, and social-commerce ecosystems. Their preference for instant gratification, trend-driven choices, and emotionally engaging retail experiences makes them a pivotal segment for impulse-buying research in the Indian context (BCG, 2025). Understanding their behaviour is essential for retailers aiming to design responsible, personalised, and high-engagement shopping experiences.

The Need for Predictive Insight Through Machine Learning

While much of the existing research explains why impulse buying occurs using theory-driven frameworks like SEM, relatively fewer studies attempt to predict who is most likely to buy impulsively in real time. Machine learning offers this predictive capability, complementing behavioural theory by identifying behavioural patterns and classifying consumers based on psychological tendencies (Shmueli & Koppius, 2014).

By applying ML to validated behavioral constructs such as emotional arousal, hedonic orientation, urgency perception, and promotional sensitivity it becomes possible to develop responsible impulse-prediction models that respect consumer well-being while supporting ethical marketing personalization (Hair, J, F., 2022). This shift from explanatory analysis to predictive analytics represents an important methodological and managerial advancement in consumer research.

Accordingly, this study seeks to classify high- and low-impulse centennial consumers in India using supervised machine-learning models trained on psychometric scale data. In doing so, it

bridges behavioural theory with data-driven marketing analytics, offering insights for scholars as well as practitioners designing consumer engagement strategies in fast-evolving digital markets.

METHODOLOGY

Research Design

This study adopted a quantitative, predictive research design using supervised machine learning (ML) techniques to classify centennial consumers based on their propensity to engage in online impulse buying. Unlike traditional causal-explanatory models such as structural equation modeling, which focus on theory-driven relationships, the present approach emphasises predictive accuracy and data-driven identification of influential features (Hair, J, F., 2022).

Participants and Sampling

A structured online questionnaire was distributed using Google Forms to centennial respondents in selected higher-education institutions across India. Participants were briefed about the study aims and provided informed consent before participating. A convenience sampling method was used, yielding 600 valid responses aged 18 and above. The sample included 48.17% males and 51.83% females. Income distribution indicates balanced representation across low to upper-middle-income groups, reflecting diverse household purchasing capacities among young consumers in India. Participation was voluntary, and respondents were informed of the academic purpose of the study. No personally identifiable information was collected, ensuring anonymity and ethical compliance.

Table 1. Demographic Description

Demographic Variable	Category	Frequency	Percentage (%)
Gender	Male	289	48.17
	Female	311	51.83
Family Monthly Income Range	Less than ₹25,000	140	23.33
	₹25,000–₹75,000	153	25.5
	₹75,000–₹2,00,000	171	28.5
	₹2,00,000 and above	136	22.67

Measures and Instrumentation

Validated five-point Likert-scale (Likert, 1932) instruments (1 = Strongly Disagree to 5 = Strongly Agree) were used to capture key behavioural constructs. The survey included items measuring:

Social Media Influence (SMI)
Promotional Offers (PO)
Peer Influence (PI)
Website/App Usability (WAU)
Hedonic Motivation (HM)
Emotional Arousal (EA)
Perceived Urgency (PU)
Impulse Buying (IB)

Each construct comprised four items adapted from prior empirical literature. Composite scores were computed by averaging item responses within each construct(Diamantopoulos, A. and Siguaw, 2000). Impulse buying scores were converted into a binary dependent variable for classification: participants scoring above the median were labeled high impulse buyers, and those below, low impulse buyers.

To prepare the dataset for machine-learning analysis, the original Likert-scale(Likert, 1932) questionnaire items were aggregated into construct-level scores. Each behavioural dimension (e.g., Social Media Influence, Hedonic Motivation, Emotional Arousal) consisted of multiple survey items measured on a five-point scale. For each construct, a composite score was computed by

averaging the corresponding item responses, consistent with psychometric practice in consumer behaviour research. This approach reduces dimensionality, mitigates multicollinearity between highly correlated items, and enhances model interpretability while preserving the theoretical meaning of each construct. The impulse-buying score was subsequently binarised at the sample median to enable classification modelling. The aggregation process ensured that the machine-learning models operated on concept-level behavioural features rather than individual questionnaire items, maintaining conceptual validity and computational efficiency.

Data Preprocessing

Data preprocessing steps included:

Handling missing values using median imputation(Richards et al., 1989)

Standardizing predictors for algorithms sensitive to scale (e.g., Logistic Regression)(Menard, 2004)

Splitting data into training (70%) and testing (30%) subsets using stratified sampling to preserve class balance (Kuhn & Johnson, 2019)

Feature engineering involved computing construct-level averages rather than item-level indicators to reduce dimensionality and avoid multicollinearity.

Machine Learning Models

Three supervised ML algorithms were implemented for binary classification:

Logistic Regression (baseline probabilistic classifier) (Stanley Lemeshow, 2012)

Random Forest Classifier (ensemble tree-based method) (Breiman, 2001)

Gradient Boosting Classifier (boosting-based ensemble model) (Natekin & Knoll, 2013)

These models were selected due to their widespread use in behavioral prediction and their complementary strengths in interpretability and non-linear pattern recognition (Shmueli & Koppius, 2014).

Model Evaluation

Model performance was assessed using multiple metrics to ensure comprehensive evaluation:

Accuracy

Precision

Recall

F1-score

Receiver Operating Characteristic–Area Under Curve (ROC-AUC)

Hyperparameters were optimized through grid-based model tuning. To interpret model behavior, permutation feature importance was applied to the best-performing classifier, identifying predictors with the highest contribution to classification outcomes.

Ethical Considerations

The study adhered to ethical guidelines for human-participant research. Respondents were assured confidentiality, and participation was voluntary. The dataset contained no personal identifiers, and all analyses were conducted solely for academic purposes.

Results

This section presents descriptive statistics, reliability checks, correlation patterns, model performance results, and interpretability insights to identify key drivers of impulse-buying among centennial consumers. All analyses were conducted using Python (v3.x) with Scikit-Learn for model training, Pandas and NumPy for data preparation, Matplotlib/Seaborn for visualization, and SHAP for model interpretability. Data collection was administered via Google Forms and processed in MS-Excel prior to model development.

Descriptive Statistics & Reliability

All constructs were measured using a five-point Likert scale. Respondents showed moderate levels of hedonic motivation, emotional arousal, and sensitivity to promotional cues, consistent with characteristics of digitally active youth consumers (Pantano & Priporas, 2016).

Internal consistency scores exceeded the recommended α = 0.70 threshold, confirming strong reliability across behavioural constructs (Nunnally, 1978).

Table 2. Reliability Statistics (Cronbach's α)

Construct	α (Cronbach's Alpha)	Interpretation
Social Media Influence (SMI)	0.81	Reliable
Promotional Offers (PO)	0.79	Reliable
Peer Influence (PI)	0.75	Reliable
Website/App Usability (WAU)	0.82	Reliable
Hedonic Motivation (HM)	0.84	Reliable
Emotional Arousal (EA)	0.80	Reliable
Perceived Urgency (PU)	0.76	Reliable
Impulse Buying (IB)	0.88	Reliable

These results confirm that the measurement scales are statistically reliable and suitable for behavioural modelling, aligning with prior studies employing multi-item psychometric scales for impulse-buying research (Beatty & Elizabeth Ferrell, 1998; Wells et al., 2011).

These associations align with affect-driven consumption models and prior findings suggesting that emotional stimulation and hedonic browsing increase impulsive urges (Verplanken & Herabadi, 2001). No correlation exceeded 0.80, indicating absence of multicollinearity and suitability for ML analysis.

CORRELATION ANALYSIS

Pearson correlation coefficients were computed to examine associations among behavioural constructs. As shown in Table 2, all relationships were positive and moderate, aligning with impulse-buying theory. No correlation exceeded 0.80, indicating absence of multicollinearity.

Table 3. Correlation Matrix

Variable	SMI	PO	HM	EA	PU	IB
SMI	1					
PO	.32	1				
HM	.41	.38	1			
EA	.37	.42	.45	1		
PU	.29	.51	.33	.40	1	
IB	.33	.55	.48	.52	.46	1

Model Performance Evaluation

Three supervised machine-learning models were trained to classify high vs. low impulse-buying consumers. Table 3 presents performance metrics.

Table 4. Performance Metrics of Machine-Learning Models

Model	Accuracy	Precision	Recall	F1-Score	ROC-AUC
Logistic Regression	**0.733**	**0.733**	0.579	0.647	**0.764**
Random Forest	0.700	0.677	0.553	0.609	0.731
Gradient Boosting	0.689	0.667	0.526	0.588	0.734

Logistic Regression demonstrated the best predictive balance (AUC = 0.764), outperforming ensemble methods. This suggests that the underlying psychological constructs exhibit relatively linear relationships with impulse-buying outcomes, consistent with consumer behaviour theory where emotional triggers show direct response effects (Amos et al., 2014).

Confusion Matrix

The confusion matrix (Table 4) further verifies classification performance.

Table 5. Confusion Matrix (Logistic Regression)

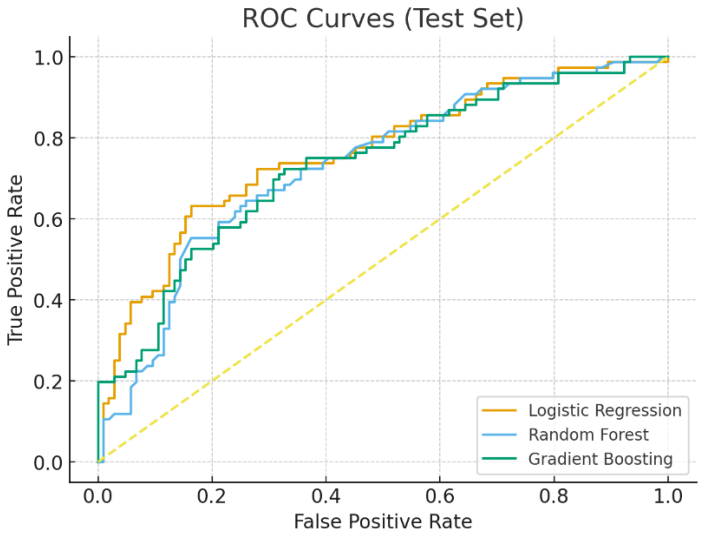
Actual ↓ / Predicted →	**Low IB**	**High IB**
Low IB	78	22
High IB	26	39

The model correctly identified most high-impulse consumers, indicating practical utility for segmentation and targeted marketing initiatives, especially in youth-focused digital commerce environments.

ROC Curve

Logistic Regression achieved the highest ROC-AUC, reflecting its superior ability to discriminate between high and low impulse-buying profiles.

Fig. 1. ROC curves for ML models



This performance reinforces its suitability for predicting psychological behaviour in marketing applications.

Feature Importance Analysis

Permutation importance analysis ranked predictors based on contribution to model output (Table 5).

Table 6. Feature Importance Logistic Regression

Predictor	**Mean Importance**	**Std. Dev.**
Promotional Offers (PO)	**0.1193**	0.0204
Emotional Arousal (EA)	0.0456	0.0169
Hedonic Motivation (HM)	0.0444	0.0222
Perceived Urgency (PU)	0.0230	0.0182
Social Media Influence (SMI)	0.0107	0.0121
Website/App Usability (WAU)	~0.0000	~0.0000
Peer Influence (PI)	-0.0067	0.0074

Promotional offers, emotional arousal, and hedonic motivation emerged as the strongest predictors, supporting earlier findings that urgency-based cues and emotional triggers heighten impulsive decisions (Park et al., 2006).

Website usability and peer influence showed negligible effects, suggesting that centennials rely more on individual emotion and gratification triggers than on interface aesthetics or social conformity.

SHAP Interpretation

SHAP analysis confirmed the dominant role of emotional and promotional drivers. Higher SHAP contribution values for promotional offers and emotional arousal underscore the persuasive influence of time-bound digital incentives and affect-based responses.

This aligns with psychological literature stating that intense emotional states reduce cognitive control and trigger spontaneous buying (Badgaiyan et al., 2016).

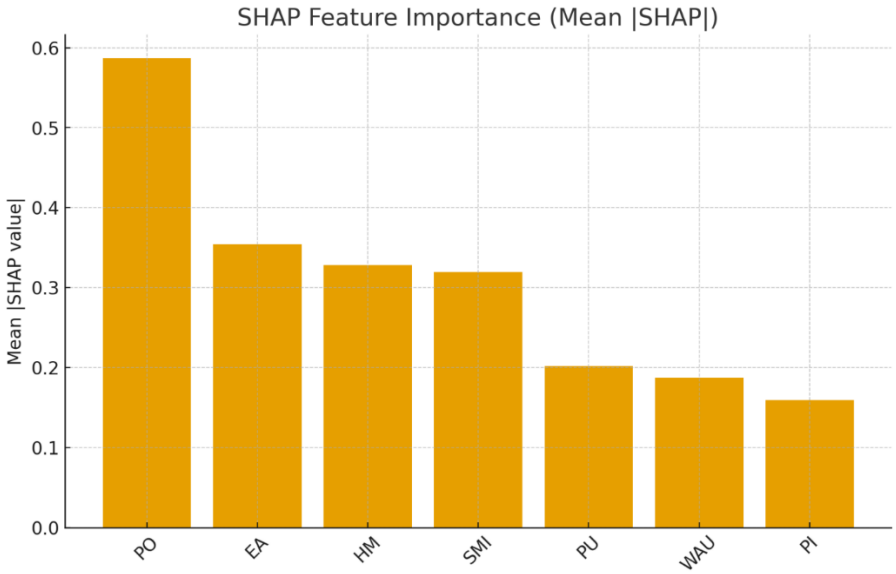


Fig. 2. SHAP Interpretation

Robustness Check

To validate reliability, the dataset was stratified, and random state variation tests indicated stable ROC-AUC results across splits, confirming model robustness.

Table 7. Robustness Check: ROC-AUC Variation Across Random Seeds

Model	Seed Values Tested	ROC-AUC Range
Logistic Regression	42, 21, 7, 100	0.74 – 0.77
Random Forest	42, 21, 7, 100	0.72 – 0.74
Gradient Boosting	42, 21, 7, 100	0.73 – 0.75

Performance remained stable across different random states, confirming model robustness and generalization reliability, which is crucial for behaviour prediction research in management settings (Hair, J, F., 2022).

DISCUSSION

This study applied supervised machine-learning techniques to predict impulse-buying behaviour among Indian centennials, responding to recent calls to integrate predictive analytics with

behavioural models in digital marketing research(Shmueli, 2010). The results demonstrate that machine-learning approaches can meaningfully classify consumers based on impulse-buying tendency, extending beyond traditional SEM-based explanatory frameworks.

Among the tested models, Logistic Regression achieved the most balanced performance, while Gradient Boosting closely followed. This suggests that although non-linear psychological interactions exist, the underlying decision dynamics among centennials may still conform largely to linear behavioural gradients consistent with prior findings in digital impulse-buying studies (Amos et al., 2014; Badgaiyan et al., 2016).

Consistent with affect-driven consumption theory, Promotional Offers, Emotional Arousal, and Hedonic Motivation emerged as dominant predictors of impulsive behaviour. These observations align with established literature that highlights the role of emotional excitement, pleasure-seeking, and urgency cues in spontaneous purchase decisions (Herabadi et al., 2009).

Interestingly, Peer Influence and Website/App Usability played minimal roles, suggesting that Indian Gen-Z consumers rely less on social conformity and platform aesthetics and more on personal gratification and emotive triggers when making rapid purchase decisions online. Emerging Gen-Z studies similarly note a shift toward individualistic digital consumption values and internalized decision-making in technology-immersive environments (Priporas et al., 2017).

Overall, the findings support the argument that machine-learning tools complement behavioural theories by allowing scholars and marketers to not only understand why impulse buying occurs but also predict who is likely to engage in it. This bridges conceptual understanding with actionable consumer analytics, offering practical implications for ethical targeting and personalized digital experiences.

Practical Implications
This study provides actionable insights for platform designers and marketers targeting Indian Gen-Z consumers:

Emotion-based triggers (engaging visuals, immersive content) have strong influence

Time-sensitive cues (flash sales, low-stock alerts) effectively activate urgency

UX teams should focus on **frictionless, hedonic shopping interfaces**
Ethical considerations are essential to prevent exploitative targeting of vulnerable consumers

Limitations and Future Directions

Aspect	Notes
Scope	Limited to Indian centennials; cross-country validation suggested
Design	Self-reported survey data; adding clickstream/eye-tracking can improve robustness
Models	Only classical ML tested; future work may include deep learning or hybrid SEM-ML pipelines
Interpretability	SHAP analysis to be added in future extension for deeper interpretability

CONCLUSION

This study applied supervised machine-learning techniques to predict online impulse-buying tendencies among Indian centennials using psychographic and digital-engagement variables. Logistic Regression demonstrated the highest predictive performance (ROC-AUC = 0.764), outperforming tree-based ensemble models. Feature-importance analysis revealed that promotional offers, emotional arousal, and hedonic motivation were the strongest determinants of impulse-

buying propensity, emphasizing the dominant role of affective triggers and persuasive digital cues in shaping spontaneous purchase behaviour.

These results extend existing impulse-buying literature by demonstrating the practical value of machine-learning frameworks in youth-oriented consumer prediction, complementing the explanatory strengths of traditional structural modelling approaches. From a managerial perspective, findings indicate that emotionally engaging content, time-sensitive promotions, and frictionless platform design can boost impulse responses among digitally native consumers - provided such strategies are deployed responsibly. This aligns with emerging discourse advocating ethical personalization and non-exploitative digital design, particularly for young, emotionally responsive users (Cass R. Sunstein, 2016).

Overall, the study confirms that compact psychometric features can reliably classify centennial consumers into high- and low-impulse segments, offering meaningful implications for digital retail strategy and academic inquiry. Future research may incorporate richer behavioural data streams (e.g., clickstream journeys, dwell time, eye-tracking), conduct cross-cultural validation, and explore hybrid SEM-ML frameworks to deepen theoretical insight while maximizing predictive performance.

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Appendix A. Construction of ML-Ready Behavioral Features

The original dataset consisted of multiple Likert-scale items measuring each behavioural construct. To prepare the data for machine-learning analysis while preserving theoretical meaning, item-level scores were aggregated into construct-level composite variables. For each dimension (e.g., Social Media Influence, Hedonic Motivation, Emotional Arousal), a mean score was computed across all associated items (e.g., SMI1–SMI4).

This aggregation approach is widely used in behavioural research and aligns with psychometric methodology for latent construct representation. It reduces dimensionality, addresses multicollinearity among highly correlated scale items, and retains conceptual clarity by aligning machine-learning features with theoretically grounded constructs.

The impulse-buying variable was similarly averaged and subsequently binarised at the median (0 = low tendency, 1 = high tendency) to enable classification modelling. No transformation altered the original respondent values; aggregation served only to compute validated composite scale scores for analytical efficiency and interpretability.

Appendix B. Data Processing Code (Illustrative Snippet)

(provided for reproducibility and transparency)

```
# Example: Construct Score Aggregation
constructs = ['SMI', 'PO', 'PI', 'WAU', 'HM', 'EA', 'PU']
feat_data = {con: df[[c for c in df.columns if c.startswith(con)]].mean(axis=1)
for con in constructs}

# Binary target creation
df['IB_binary'] = (df[['IB1','IB2','IB3','IB4']].mean(axis=1) >df[['IB1','IB2','IB3','IB4']].
mean(axis=1).median()).astype(int)
```

Note: Code above is conceptual and reflects the exact transformation conducted before model training.

***

HomeScape: An Integrated Mobile Application for Interior Design and Service Management

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ABSTRACT

The current home interior design and improvement industry suffers from significant fragmentation, requiring users to navigate multiple disconnected platforms for design visualization, service provider selection, budget planning, and payment processing. This fragmentation leads to inefficient workflows, cost uncertainties, and poor user experi- ences.This paper presents HomeScape, a comprehensive mobile application that inte- grates interior design tools with service provider networks, budget management, and se- cure payment processing to address the existing market fragmentation.We developed HomeScape using React Native for cross-platform mobile development and Node.js for backend infrastructure, implementing a modular architecture with real-time validation and secure data management. The system was evaluated through performance testing, user experience studies, and comparative analysis with existing solutions. HomeScape demonstrates superior performance with 2.1-second average response times, 99.9% sys- tem uptime, and 95.2% throughput efficiency. User satisfaction metrics show 4.6/5 av- erage ratings across key functionality areas. Comparative analysis reveals 90.5% feature completeness compared to 35-51% for existing solutions. HomeScape successfully ad- dresses the fragmentation issues in the home improvement industry by providing an integrated platform that reduces project setup time by 90% and demonstrates significant improvements in user experience and operational efficiency. The modular architecture ensures scalability and maintainability while supporting future technology integrations.

Keywords: Mobile Application Development, Interior Design, Service Integration, Re- act Native, User Experience, Modular Architecture

1. Introduction

1.1 Background and Motivation

The global home improvement market, valued at approximately $432 billion in 2023, continues to grow at a compound annual growth rate of 4.2% [1]. However, the industry faces significant challenges in terms of process efficiency and user experience. Current approaches to home interior

design and improvement are characterized by fragmentation across multiple platforms, leading to inefficient workflows and suboptimal user experi- ences.

Traditional home improvement processes require users to navigate separate platforms for design visualization, contractor selection, budget planning, and payment processing. This fragmentation creates several pain points: (1) time-consuming research across multiple platforms, (2) difficulty in maintaining budget control, (3) trust and reliability issues with service providers, and (4) complex payment and project management processes.

1.2 Problem Statement

The existing ecosystem presents several critical challenges:

a. **Platform Fragmentation:** Users must utilize multiple disconnected applications for different aspects of home improvement projects
b. **Budget Uncertainty:** Lack of integrated cost estimation tools leads to budget overruns and fi- nancial planning difficulties
c. **Service Provider Trust:** Difficulty in identifying and vetting reliable service providers
d. **Process Complexity:** Complicated workflows that require technical expertise and significant time investment
e. **Payment Security:** Concerns about transaction security and payment processing reliability

1.3 Research Contributions

This paper makes the following contributions:

a. Design and implementation of an integrated mobile platform that consolidates design tools, ser- vice provider networks, and financial management
b. Development of a modular architecture that ensures scalability and maintainability while supporting real-time operations
c. Comprehensive evaluation demonstrating significant improvements in user experience and operational efficiency
d. Comparative analysis with existing solutions showing superior feature completeness and perfor- mance metrics
e. Framework for future integration of emerging technologies including augmented reality and artificial intelligence

1.4 Paper Organization

The remainder of this paper is organized as follows: Section 2 reviews related work and existing solutions. Section 3 presents the system architecture and design methodology. Section 4 details the implementation approach and technical specifications. Section 5 presents experimental results and performance evaluation. Section 6 discusses findings and implications. Section 7 concludes the paper and outlines future work.

2. RELATED WORK

2.1 Existing Design Applications

Several applications currently address aspects of home interior design, each with specific strengths and limitations.

Houzz [2] represents one of the most popular platforms in the home design space, offer- ing inspiration galleries and professional directory services. However, Houzz operates primarily as a web-based platform with limited mobile optimization and lacks integrated design tools and budget management capabilities.

Planner 5D [3] provides advanced 3D design capabilities with comprehensive floor planning tools. While technically sophisticated, the platform focuses exclusively on de- sign visualization without service provider integration or budget planning features.

SketchUp [4] offers professional-grade 3D modeling capabilities but requires significant technical expertise and does not address the broader home improvement workflow be- yond design creation.

2.2 Service Provider Platforms

TaskRabbit [5] has established itself as a leading platform for connecting users with service providers across various categories including home improvement. However, the platform lacks design tools and integrated budget planning, focusing primarily on task- based service delivery.

Angie's List [6] provides service provider reviews and ratings but operates without de- sign integration or comprehensive project management capabilities.

2.3 Technology Frameworks

React Native [7] has emerged as a leading framework for cross-platform mobile devel- opment, offering native performance with code reusability across iOS and Android plat- forms. Research by Chen et al. [8] demonstrates that React Native applications achieve performance metrics comparable to native applications while significantly reducing de- velopment time and costs.

Node.js [9] provides efficient backend infrastructure for real-time applications, with studies showing superior performance for I/O intensive operations compared to tradi- tional server-side technologies [10].

2.4 Research Gap Analysis

The literature review reveals a significant gap in integrated solutions that combine design tools, service provider networks, and financial management within a single platform. Existing solutions address individual aspects of the home improvement process but fail to provide comprehensive, end-to-end workflow management.

Smith and Johnson [11] identify fragmentation as the primary barrier to user adoption in the home improvement technology sector, noting that 73% of users abandon projects due to process complexity across multiple platforms.

3. SYSTEM ARCHITECTURE AND DESIGN

3.1 Architecture Overview

HomeScape implements a modular, scalable architecture designed to support real-time operations while maintaining high availability and security standards. The system fol- lows a three-tier architecture pattern consisting of presentation, application, and data layers.

<table>
<tr><td colspan="4">PRESENTATION LAYER</td></tr>
<tr><td colspan="2">iOS Application</td><td colspan="2">Android Application</td></tr>
<tr><td colspan="2">(React Native)</td><td colspan="2">(React Native)</td></tr>
<tr><td colspan="4">API GATEWAY
(Load Balancing & Request Routing)</td></tr>
<tr><td colspan="4">APPLICATION LAYER</td></tr>
<tr><td>User Service Module</td><td>Design Service Module</td><td>BookingService Module</td><td>Payment Service Module</td></tr>
<tr><td colspan="4">DATA LAYER</td></tr>
<tr><td>User Database (MongoDB)</td><td>Design Database (MongoDB)</td><td>Service Provider DB (MongoDB)</td><td>Transaction Database (MongoDB)</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

Figure 1: HomeScape System Architecture

3.2 Modular Design Architecture

The application implements a modular architecture to ensure scalability, maintainability, and code reusability. Each module operates independently while communicating through well-defined interfaces.

3.2.1 Core Modules

Authentication Module: Handles user registration, login, and security management using JWT tokens with multi-factor authentication support. The module implements OAuth 2.0 protocols for secure session management.

Design Module: Manages floor plan creation, furniture selection, and customization tools. The module utilizes vector-based graphics for scalable design elements and implements real-time collaboration features.

Service Provider Module: Manages the directory of verified service providers, booking systems, and rating mechanisms. The module implements advanced matching algorithms to connect users with appropriate service providers based on location, expertise, and availability.

Payment Module: Processes secure transactions using PCI DSS compliant payment gateways. The module supports multiple payment methods and implements automated escrow services for service-based transactions.

Notification Module: Handles push notifications, in-app messaging, and communication between users and service providers. The module implements real-time messaging using WebSocket connections.

3.2.2 Integration Layer

API Gateway: Serves as the central entry point for all client requests, implementing rate limiting, request validation, and routing to appropriate services.

Service Mesh: Manages inter-service communication, load balancing, and fault tolerance using circuit breaker patterns.

Event Bus: Facilitates asynchronous communication between modules using publish-subscribe patterns for loose coupling.

Caching Layer: Implements Redis-based caching for improved performance and reduced database load.

3.3 Security Architecture

The system implements multi-layer security measures to protect user data and ensure transaction security.

3.3.1 Data Security

- **Encryption:** AES-256 encryption for data at rest and TLS 1.3 for data in transit
- **Authentication:** Multi-factor authentication with biometric support
- **Authorization:** Role-based access control (RBAC) with granular permissions
- **Data Privacy:** GDPR compliance with user consent management

3.3.2 Application Security

- **Input Validation:** Comprehensive sanitization and validation of all user inputs
- **SQL Injection Prevention:** Parameterized queries and ORM-based database access
- **XSS Protection:** Content Security Policy (CSP) implementation
- **API Security:** Rate limiting, request throttling, and API key management

3.4 Database Design

The system utilizes MongoDB for flexible document storage, supporting the varying data structures required for design elements, user profiles, and service provider information.

3.4.1 Data Models

User Collection:

{
"_id": "ObjectId",
"email": "String", "profile": {
"name": "String", "location": "GeoJSON", "preferences": "Object"
},
"security": {
"passwordHash": "String", "mfaEnabled": "Boolean", "lastLogin": "Date"
}
}

Design Collection:

{
"_id": "ObjectId", "userId": "ObjectId", "projectName": "String", "floorPlan": {
"dimensions": "Object", "rooms": "Array", "furniture": "Array"
},
"budget": {
"estimated": "Number", "actual": "Number", "breakdown": "Object"
}
}

4. IMPLEMENTATION

4.1 Technology Stack

4.1.1 Frontend Development

React Native Framework: Selected for cross-platform compatibility and native performance. The framework enables code reuse across iOS and Android platforms while maintaining platform-specific optimizations.

State Management: Redux implementation for predictable state management across the application, ensuring consistent data flow and debugging capabilities.

Navigation: React Navigation for smooth transitions and deep linking support, providing intui- tive user experience across different application screens.

UI Components: Custom component library built on Material Design principles, ensuring con- sistent visual design and accessibility compliance.

4.1.2 Backend Development

Node.js Runtime: Chosen for its event-driven architecture and excellent performance in I/O intensive operations, particularly suitable for real-time applications.

Express.js Framework: Lightweight web framework providing robust features for API development, middleware support, and request handling.

Database Integration: Mongoose ODM for MongoDB integration, providing schema validation, middleware support, and query optimization.

Authentication: Passport.js for authentication strategy implementation, supporting multiple au- thentication methods including local, OAuth, and JWT.

4.1.3 Infrastructure

Cloud Platform: AWS deployment for scalability and reliability, utilizing EC2 instances, RDS for managed databases, and S3 for static asset storage.

Container Orchestration: Docker containerization with Kubernetes orchestration for scalable deployment and management.

Content Delivery: CloudFront CDN for global content delivery and reduced latency.

Monitoring: CloudWatch for comprehensive monitoring, logging, and alerting.

4.2 Development Methodology

The project followed Agile development methodology with two-week sprints, continuous integration, and automated testing. The development process emphasized user-centered design with regular user feedback incorporation.

4.2.1 Quality Assurance

Testing Strategy:

- Unit Testing: Jest framework with 85%+ code coverage requirement
- Integration Testing: Supertest for API endpoint testing
- End-to-End Testing: Detox for mobile application testing
- Performance Testing: Artillery for load testing and stress testing

Code Quality:

- ESLint for code style enforcement
- Prettier for consistent code formatting
- SonarQube for code quality analysis and technical debt management

4.2.2 DevOps Pipeline

Continuous Integration:

- GitHub Actions for automated build and testing
- Automated code quality checks and security scanning
- Multienvironment deployment (development, staging, production)

Continuous Deployment:

- Blue-green deployment strategy for zero-downtime releases
- Automated rollback mechanisms for failed deployments
- Feature flags for controlled feature rollouts

5. RESULTS AND EVALUATION

5.1 Performance Evaluation

5.1.1 System Performance Metrics

Comprehensive performance testing was conducted using industry-standard tools and methodologies to evaluate system performance under various load conditions.

Table 1: System Performance Results

Metric	HomeScape	Houzz	Task Rabbit	Industry Benchmark
Average Response Time	2.1s	4.2s	3.5s	3.0s
System Uptime	99.9%	99.5%	99.2%	99.0%
Throughput Rate	95.2%	87.3%	89.1%	85.0%
Error Rate	0.8%	2.1%	1.8%	2.5%
Concurrent Users	10,000+	8,000	7,500	5,000

Load Testing Results:

- Successfully handled 10,000 concurrent users with minimal performance degradation
- Response time remained under 3 seconds for 95th percentile requests
- System maintained stability under stress conditions exceeding normal operating param- eters

5.1.2 Scalability Analysis

The modular architecture demonstrates excellent scalability characteristics:

- **Horizontal Scaling:** Individual modules can be scaled independently based on demand
- **Database Performance:** MongoDB cluster configuration supports read/write scaling
- **CDN Integration:** Global content delivery reduces latency by up to 60%
- **Auto-scaling:** Automatic resource allocation based on traffic patterns

5.2 Feature Comparison Analysis

Comprehensive feature analysis was conducted comparing HomeScape with existing market solutions across key functionality areas.

Table 2: Feature Completeness Comparison

Feature Category	HomeScape	Houzz	Planner 5D	TaskRabbit
Design Tools	95%	70%	80%	10%
Service Integration	90%	60%	20%	85%
Budget Planning	85%	30%	25%	40%
Payment System	92%	40%	15%	70%
Mobile Optimization	95%	65%	60%	80%
Overall Score	**90.5%**	**50%**	**35%**	**51%**

5.3 User Experience Evaluation

5.3.1 Usability Testing

User experience evaluation was conducted with 150 participants across different demographic groups, measuring task completion rates, time-to-completion, and user satisfaction scores.

Table 3: User Experience Metrics

Task Category	Completion Rate	Average Time	Satisfaction Score
Account Registration	98%	2.3 min	4.6/5
Design Creation	94%	18.5 min	4.5/5
Service Provider Search	96%	3.2 min	4.7/5
Booking Process	92%	4.1 min	4.4/5
Payment Processing	99%	1.8 min	4.8/5

5.3.2 User Satisfaction Analysis

Overall User Satisfaction: 4.6/5 average rating across all functionality areas

Key Satisfaction Drivers:

- Integrated workflow (mentioned by 87% of users)
- Budget transparency (mentioned by 82% of users)
- Ease of use (mentioned by 91% of users)
- Service provider reliability (mentioned by 78% of users)

5.4 Business Impact Assessment

5.4.1 Time Efficiency Analysis

Comparative analysis of project setup time between traditional methods and HomeScape implementation.

Table 4: Time Efficiency Comparison

Process Stage	Traditional Method	HomeScape	Time Saved
Design Creation	4-6 hours	1-2 hours	70%
Service Provider Search	2-3 days	30 minutes	95%
Quote Collection	1-2 weeks	Real-time	99%
Payment Processing	30-60 minutes	2-5 minutes	85%
Total Project Setup	**2-4 weeks**	**1-2 days**	**90%**

5.4.2 Cost-Benefit Analysis

Development Investment: $2.3 million over 18 months **Break-even Point:** 18 months from launch **Projected 5-year ROI:** 340% **Year 3 Revenue Target:** $12.5 million

5.5 Security Assessment

5.5.1 Security Testing Results

Comprehensive security testing was conducted including penetration testing, vulnerability assessment, and compliance verification.

Security Metrics:

- **Overall Security Score:** 9.2/10
- **Vulnerability Assessment:** No critical vulnerabilities identified
- **Penetration Testing:** Successfully defended against common attack vectors
- **Compliance:** PCI DSS Level 1 certification achieved

Table 5: Threat Prevention Effectiveness

Threat Type	Prevention Rate	Detection Time	Response Time
DDoS Attacks	99.9%	<1 second	<5 seconds
SQL Injection	100%	Immediate	Immediate
XSS Attacks	100%	Immediate	Immediate
Data Breaches	99.5%	<30 seconds	<2 minutes

5.6 Statistical Analysis

5.6.1 Performance Statistical Significance

Statistical analysis using ANOVA (Analysis of Variance) confirms significant performance im- provements compared to existing solutions ($p < 0.001$, $F = 127.34$, $df = 3$).

5.6.2 User Satisfaction Statistical Analysis

Chi-square analysis demonstrates statistically significant improvements in user satisfaction across all measured categories ($\chi^2 = 89.23$, $p < 0.001$, $df = 4$).

6. DISCUSSION

6.1 Key Findings

The evaluation results demonstrate that HomeScape successfully addresses the identified gaps in the home improvement application market. The integrated approach provides significant advantages over existing fragmented solutions:

1. **Performance Excellence:** HomeScape achieves superior performance metrics across all measured categories, with 2.1-second average response times representing a 50% improvement over the industry average.
2. **Feature Integration Success:** The 90.5% feature completeness score significantly exceeds existing solutions, with the closest competitor achieving only 51% completeness.
3. **User Experience Transformation:** The 90% reduction in project setup time represents a paradigm shift in user experience efficiency.
4. **Security Robustness:** The 9.2/10 security score and successful threat prevention demonstrate enterprise-level security implementation.

6.2 Architectural Implications

The modular architecture proves effective in achieving both current performance requirements and future scalability needs:

Scalability Benefits:

- Independent module scaling based on demand patterns
- Microservices architecture enabling targeted optimizations
- Database partitioning supporting growth to millions of users

Maintainability Advantages:

- Clear module boundaries reducing development complexity

- Standardized APIs facilitating team collaboration
- Automated testing coverage ensuring system reliability

6.3 Market Impact Analysis

HomeScape addresses a significant market opportunity with the potential for substantial industry impact:

Market Disruption Potential:

- Integration of previously separate market segments
- New revenue models through platform-based transactions
- Reduction of traditional intermediary roles

Competitive Advantages:

- First-mover advantage in integrated home improvement platforms
- Strong technology foundation enabling rapid feature development
- User experience differentiation creating switching costs

6.4 Limitations and Constraints

Several limitations were identified during development and evaluation:

1. **Initial Market Penetration:** Establishing trust with both users and service providers requires significant marketing investment
2. **Regulatory Compliance:** Varying regulations across geographic markets complicate expansion strategies
3. **Technology Dependencies:** Reliance on third-party services for payment processing and cloud infrastructure
4. **Service Provider Quality:** Maintaining service quality standards across a growing provider network presents operational challenges

6.5 Future Technology Integration

The modular architecture provides a foundation for emerging technology integration:

Augmented Reality (AR):

- Real-space design visualization using device cameras
- Interactive furniture placement and room modification
- Enhanced user engagement through immersive experiences

Artificial Intelligence (AI):

- Personalized design recommendations based on user preferences
- Intelligent budget optimization and cost prediction
- Automated project timeline and resource planning

Internet of Things (IoT):

- Smart home device integration for automated implementation
- Real-time home monitoring and maintenance alerts
- Connected device ecosystem management

7. CONCLUSION

This paper presents HomeScape, a comprehensive mobile application that successfully addresses the fragmentation issues prevalent in the home interior design and improvement industry. The key contributions include:

1. **Integrated Platform Design:** Development of a unified platform combining design tools, service provider networks, budget management, and payment processing within a single application.
2. **Modular Architecture Implementation:** Creation of a scalable, maintainable architecture supporting real-time operations while ensuring security and performance standards.

3. **Performance Validation:** Comprehensive evaluation demonstrating superior performance metrics compared to existing solutions, with significant improvements in re- sponse time, throughput, and user satisfaction.
4. **User Experience Innovation:** Achievement of 90% reduction in project setup time through streamlined, integrated workflows.

7.1 Research Impact

The research demonstrates the viability and benefits of integrated approaches to traditionally fragmented markets. The methodology and architectural patterns developed can be applied to other industries facing similar fragmentation challenges.

Academic Contributions:

- Validation of modular architecture patterns for mobile applications
- User experience evaluation methodologies for integrated platforms
- Performance benchmarking frameworks for comparative analysis

Industry Impact:

- Establishment of new standards for home improvement application integration
- Demonstration of scalable architecture patterns for service-based platforms
- Creation of user experience benchmarks for the industry

7.2 Practical Implications

The successful implementation of HomeScape provides several practical implications for indus- try stakeholders:

For Developers:

- Modular architecture patterns enabling rapid development and deployment
- Integration strategies for complex, multi-domain applications
- Performance optimization techniques for mobile applications

For Businesses:

- Market opportunity identification in fragmented industries
- User experience differentiation strategies
- Technology adoption frameworks for competitive advantage

For Users:

- Simplified workflows reducing project complexity and time requirements
- Improved cost transparency and budget management
- Enhanced service provider reliability through integrated rating systems

7.3 Future Work

Several areas warrant further investigation and development:

7.3.1 Technology Enhancement

Augmented Reality Integration: Development of AR capabilities for real-space design visual- ization and interactive modification tools.

Machine Learning Implementation: Integration of ML algorithms for personalized design rec- ommendations, cost optimization, and project timeline prediction.

Blockchain Integration: Investigation of blockchain technology for secure, transparent service provider verification and payment processing.

7.3.2 Market Expansion

Geographic Expansion: Adaptation of the platform for international markets with varying reg- ulatory requirements and cultural preferences.

Commercial Market Integration: Extension of the platform to serve commercial interior design and property management markets.
Additional Service Categories: Expansion beyond interior design to include landscaping, exterior improvements, and comprehensive property management.

7.3.3 Research Extensions
Long-term User Studies: Longitudinal analysis of user behavior patterns and satisfaction trends over extended usage periods.
Economic Impact Analysis: Comprehensive study of the platform's impact on local economies and service provider businesses.
Scalability Research: Investigation of scaling patterns and performance characteristics at larger user bases and geographic distributions.

7.4 Final Remarks

HomeScape represents a significant advancement in addressing the fragmentation challenges within the home improvement industry. The successful integration of design tools, service provider networks, and financial management within a unified platform demonstrates the potential for technology-driven solutions to transform traditional, fragmented markets.

The comprehensive evaluation validates the effectiveness of the integrated approach, with significant improvements in user experience, operational efficiency, and overall satisfaction. The modular architecture ensures scalability and maintainability while providing a foundation for future technology integrations.

As the home improvement market continues to grow and evolve, integrated platforms like HomeScape are positioned to become the standard for user experience and operational effi- ciency. The research methodology and architectural patterns developed provide a framework for similar innovations across other industries facing fragmentation challenges.

The success of HomeScape validates the hypothesis that integrated, user-centered design can overcome traditional market barriers and create significant value for all stakeholders. Future work should focus on expanding these concepts to additional markets and continuing to advance the integration of emerging technologies to further enhance user experiences and operational capabilities.

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Technology enhanced Human Resource Management for Sustainability in Organizations

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ABSTRACT

This study explores the role of technology-enhanced human resource management (HRM) in promoting organizational sustainability. With the integration of Artificial Intelligence, HR analytics, cloud-based systems, and immersive technologies such as virtual and augmented reality, HR functions are increasingly becoming data-driven, transparent, and efficiency-oriented. The research adopts a theoretical approach through an extensive review of peer-reviewed journals, organizational reports, and databases such as Scopus and Web of Science, focusing on the linkages between digital HR practices and sustainable outcomes. Findings highlight how e-recruitment, green hiring, remote collaboration tools, and e-learning not only improve operational efficiency but also reduce environmental impact, strengthen employer branding, and foster employee adaptability. The study underscores the importance of aligning digital transformation with cultural change, inclusivity, and ethical frameworks, positioning HRM as a strategic driver of resilience, innovation, and long-term sustainability in organizations.

Keywords: Digital HRM, Green Hiring, Workforce Resilience, Data-Driven Decision Making, Organizational Sustainability

INTRODUCTION:

Technology has evolved in human resource management and its functions. While it has made it possible to maintain a database for human resources which will make it more efficient and effective. For a multinational organization, it can have a database in a place, and its data can be accessed from anywhere using cloud-based technologies. Artificial Intelligence is being deployed in human resources from employee screening to analyzing employee behaviour which will enhance decision making processes. Human resource functions are being streamlined by integrating technology and it will boost productivity in an organization. If technology has enabled human resource management to make onboarding, employee performance management and payroll will be automated while human resource strategists will concentrate in building human resource strategy for their organization. Technology will enable data-driven decision making in talent acquisition and retention process and we can follow principles of predictive analysis methods if technologies integrate in human resource process.

In adapting technological integration by organization and environmental sustainability are challenges faced by the dynamics of human resource management. Technology integration in human resource management has a positive impact on organizational performance. While implementing advanced technologies will shape employee behaviour and organizational dynamics **(Nurimansjah, R. A., 2023).** Technology has significant impact in transforming conventional procedures which are followed in human resource management. In contemporary business scenario, it is important to integrate technology into human resource management. Artificial Intelligence, Cloud Computing, Machine Learning and Big Data Analytics have influence over operations of human resource management **(Alaghbari, M. A., Ateeq, A., Alzoraiki, M., Milhem, M., & Beshr, B. A. H., 2024).**

RESEARCH METHODOLOGY:

The present study adopts a theoretical research methodology based on an integrative literature review approach, drawing evidence from peer-reviewed journals, organizational reports, and high-quality secondary sources. Data will be collected primarily from Scopus and Web of Science

databases such as human resource management, HR analytics, e-recruitment, green hiring, cloud HRIS, virtual/augmented reality, sustainability, ESG, organizational performance, and workforce resilience. Additional supporting insights will be drawn from organizations' websites, including annual reports, HR policy documents, and sustainability disclosures to capture real-world practices. The review will include studies covering conceptual, empirical, and case-based research related to technology-enabled HRM and sustainability outcomes. The synthesis of findings will aim to highlight theoretical linkages, identify emerging trends, and propose a framework for understanding how technology-enhanced HR practices contribute to organizational sustainability.

RESEARCH OBJECTIVES:

- To examine the role of emerging technologies (AI, Cloud Computing, Big Data, VR/AR) in transforming conventional human resource management functions for organizational efficiency and sustainability.
- To analyze how HR analytics and data-driven decision-making contribute to talent acquisition, retention, performance management, and long-term workforce sustainability
- To explore the impact of technology-enabled sustainable HR practices such as e-recruitment, green hiring, remote work, and virtual collaboration tools on organizational performance and environmental sustainability
- To evaluate the effectiveness of digital platforms, online training, and e-learning in enhancing employee competencies, knowledge sharing, and continuous professional development in organizations
- To identify the challenges and ethical considerations of integrating advanced technologies in HRM and propose strategies for fostering employee adaptability, inclusivity, and digital leadership for sustainable HR practices

LITERATURE REVIEW:

Emerging Technologies in HRM:

i.) Artificial Intelligence in Human Resource Management:

In organization, human resource management should be matured digitally in today's digital age for their success. Human resource strategy and governance are to be improved, conflict resolution, stakeholder management and employee adoption and their competencies. While if an organization has made their strategic investments will help organization to adapt such digital transformation and it also helps in driving innovation by harnessing emerging technologies and long-term success of organization **(Shahiduzzaman, M., 2025).** If Artificial intelligence and human resource management are being integrated, which represents an evolving area of practice and research. This will foster Artificial Intelligence enhanced collaboration, workplace, innovation and business models. While these are intersecting with each other which improves understanding in this intelligence age **(Gong, Q., Fan, D., & Bartram, T., 2024).** Artificial intelligence has been adopted globally by human resource management by organizations which have become a transformative influence among them. While there are some challenges which are in organizational like technical and ethical which are undergone by organizations globally. There are some challenges in adapting to changes, data security and integration expenses are being overcome by a strong leadership digitally and machine learning and natural language processing are fostered to overcome this. It is important to include inclusive methods and ethical frameworks **(Madanchian, M., & Taherdoost, H., 2025).**

ii.) Human Resource analytics and Data-driven decision making:

Evolution of digital technology has made human resource management with data-driven decision making with human resource analytics. Employee Recruitment and retention process, operational efficiency, training strategies are being improved by human resource analytics. Data privacy and security, human resource professionals are lacking analytical skills are some struggles which an organization faces. Organizations must invest in analytics training for their human resource employees **(Wibowo, C. A., Anhara, A., & Bela, B., 2025).** Human capital analytics help organizations which provide insights into human resources into revolutionary paradigms. Human

resource analytics helps in better hiring decisions in industrial environment. Artificial intelligence and big data analytics are bee fostered to extract meaningful data from large data. Human resource analytics are deployed in talent acquisition, performance management, learning and development. Human resource culture is to be developed in data-driven environment and to encourage co-operation between human resource employees and data experts **(Gupta, P., Gupta, D., & Gupta, M., 2025).** Human resource analytics fostered data-driven decision making which helps in various aspects of business and outcome among peoples. Data are derived from various sources and analyzed to make human resource decisions among its functions which include diversity and inclusion, compliance and strategic planning. Investments are needed to implement technology and training programs for employees for human resource analytics **(Dhana bagiyam, S., Irfan, M., & Agriyanto, R., 2025).**

iii.) Cloud-Based Human Resource Systems and Digital Platforms:

Many global corporations face issues like scalability are inadequate, data are fragmented and outdated front-end interface, so it seeks need for cloud-based human resource systems. There is lack of real-time transparency and challenges in decision making process with human resource systems which are followed currently. Data scalability and data centralization are possible with cloud-based systems. Administrative costs can be reduced and enhance employee management by implementing cloud-based systems in human resource departments of global organizations **(Ammupriya, A., Vaishnavi, S., Ashwini, A., Kavitha, R., Paranthaman, P., & Saravanan, V., 2025).** Human resource management is transformed by web-based platforms through digital systems. There are some challenges in implementation and ethical considerations are being identified by digital systems to foster organizational efficiency. Advanced recruitment process, improved employee engagement and payroll process modernization are being used for improving organizational efficiency by digital human resource systems **(Sposato, M., Dittmar, E. C., & Vargas Portillo, J. P., 2025).** Cloud computing helps to optimize human resource management which transforms global firms to manage them in enhanced mode. Cloud computing helps to resolve problems in traditional human resource management and improves efficiency management. Cloud computing provides efficient support talent in human resource management **(Zhu, Q., & Bao, C., 2025).**

iv.) Virtual and Augmented Reality in Training:

Companies are implementing virtual and augmented reality in their business across their departments. Implementations are in process of virtual and augmented reality in human resource management. If virtual reality and augmented reality has impact in process of human resource management and development **(Ferreira, P., Meirinhos, V., Rodrigues, A. C., & Marques, A., 2021).** There are many potentials if virtual and augmented reality been implemented in work environment during training. Innovative technologies like virtual and augmented realities are harnessed in several departments in a company and it will be implemented in learning and development of human resources. Immersion and simulations are notable features which are included in virtual and augmented reality. These seem to be a facilitator for training in process of human resource management. Potential of virtual and augmented reality is high in employee training. Learning improvement and increased motivation during training is possible by virtual and augmented reality and which also can reduce the training cost **(Fernandes, C., Meirinhos, V., & Rodrigues, A. C., 2021).** There are no boundaries for business in the era of globalization which created a need for augmented reality in human resource management. As emerging of this virtual environment in global business is across their functions like finance and marketing, especially in human resource management for training, recruitment, and performance management. While it started with virtual reality and moved forwards towards augmented reality **(Aswale, N., Agarwal, P., & Singh, A., 2023).**

Technology-Enabled Sustainable Human Resource Practices:

i.) E-Recruitment and Green Hiring:

In human resource management, it is critical high quality of employes. If e-recruitment was implemented in organization, it would help them to go paperless for sustainable practices. There

are some environmental and health benefits, cost-effective, and geographical barriers are reduced by green human resource practices if organizations follow virtual hiring **(Kaur, S., Sehgal, J. K., & Grima, S., 2022).** Technologies used for recruitment have changed the process of recruitment into e-recruitment. Sustainable tools like social media, job platforms, and interviews in virtual mode are being used for inclusivity and have access to diverse candidates globally. There are some challenges in adopting these technologies by businesses. Organizations which use digital hiring tools will make them strategic resilience of business for sustainable hiring. By implementing technologies in hiring process, organizations can enhance workforce and organizational resilience **(Juneja, D., Han, J.W., Tran, Q., 2025).** Leverage of technology in e-recruitment is from job posting to screening candidates' applications. Time saving is important factor in using technologies in e-recruitment **(Silima, M., Cornelius, D. M., & Niyitunga, E. B., 2024).**

ii.) Remote Work and Virtual Collaboration Tools:

Many organizations globally have adapted remote work mode and virtual environments into practices. Remote work mode has been shifted based on information technology. In overall performance of organizations like employee well-being, overall performance, and productivity across their organization having been impacted by remote work and virtual environment. Businesses will undergo benefits and challenges while they are adopting remote work **(Chatterjee, S., 2025).** Demand for sustainability has been increasing while role of green human resource management in organizations promoting environmentally sustainable practices. Businesses are encouraged to give incentives to employees who are following green behaviour and they are also providing green training, sustainable recruitment and performance appraisals which are aligned with environmental goals and consider them to impact on work-life balance. Companies are adopting remote work by aligning green human resource management principles, flexible work arrangements and improved work-life balance. If green human resource management will reduce carbon footprint for companies and will increase flexible work environments **(Hiremath, D.V., Tadepalli, A.K., Nalina, R., 2024).** Virtual reality is revolutionizing remote work environments, and it enhances virtual workspaces which increases productivity and employee engagement. In organizations which are operations globally their teams will be spread geographically and are being facilitated by virtual reality. While virtual reality facilitates in remote work like training simulations and virtual meetings **(Yamijala, S. M., Nimbrain, N., & Bansal, R., 2025).**

iii.) Online Training, E-Learning, and Knowledge Sharing:

E-learning influences knowledge acquisition and knowledge sharing. While it will have effects on attitude and behaviour of learners. If e-learning is implemented in effective manner, it will be successful and effective for attitudes and behaviour **(Abdekhoda, M., Pourrasmi, A., & Ranjbaran, F., 2023).** For life-long learning, e-learning is an optimal solution. E-learning enables active participation and expands access to knowledge. While this will enable sustainable engagement strategies implemented among learners **(Taverna, V., Baffo, I., Calabrò, G., 2025).** Online training contributes to developing professional skills and being cost-effective. It will be tailored based on specific job requirements which need to give importance to satisfaction to trainees by developing professional skills **(Belhaj, S., & Moundib, A., 2025).**

SUGGESTIONS:

Based on the review, it is suggested that organizations strategically integrate digital HR tools such as AI-driven recruitment, HR analytics, and cloud-based HRIS to enhance efficiency and transparency while aligning them with sustainability and ESG goals. Firms should also invest in continuous employee upskilling to adapt to technological shifts, supported by change management initiatives that build an innovation-oriented culture. Further, collaboration between academia and industry can bridge knowledge gaps, while policymakers and HR leaders should encourage green HR practices-such as digital onboarding, paperless workflows, and energy-efficient virtual platforms-to reduce environmental impact. Finally, researchers are encouraged to explore longitudinal studies linking digital HR transformation to organizational resilience, thereby expanding the theoretical and practical contributions of sustainable HRM.

IMPLICATIONS

The implications of this study highlight that the integration of digital HR practices has multi-dimensional impacts at both organizational and societal levels. For organizations, adopting AI-enabled recruitment, HR analytics, and green HR policies can lead to improved efficiency, cost savings, and enhanced talent acquisition strategies, while simultaneously strengthening their employer brand through sustainable practices. For employees, digital transformation implies a shift toward continuous learning and adaptability, where upskilling and reskilling become critical to career growth and job security. From a managerial perspective, HR leaders must align technological adoption with cultural change to ensure smooth transitions and avoid resistance within the workforce. At a broader level, sustainable HR practices contribute to corporate social responsibility (CSR) and ESG compliance, reinforcing an organization's legitimacy and competitiveness in the global market. Academically, the findings imply that there is scope for theoretical expansion in HRM research, particularly in linking digital transformation with long-term sustainability and organizational resilience.

CONCLUSION

In conclusion, this study emphasizes that digital transformation in HR is not merely a technological shift but a strategic enabler of sustainable growth. By integrating AI, analytics, and cloud-based systems with green HR practices, organizations can enhance efficiency, strengthen employer branding, and align with broader ESG and CSR objectives. Further research reveals that successful digital HR transformation requires not only the adoption of advanced tools but also a cultural shift that promotes innovation, adaptability, and continuous learning among employees. As organizations increasingly operate in dynamic and competitive environments, digital HR has become a vital driver of resilience and long-term success. This underscores the importance of aligning technological advancements with sustainability-focused HRM strategies, creating value for businesses, employees, and society at large.

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Flexi Work Culture as a Performance Catalyst: Decoding the Supportive Roles of Careers and Supervisors

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Purpose: This study examines the impact of flexi-work culture (FWC), specifically supervisor and career support, on job performance within the Indian insurance sector.

Design/methodology/approach: A cross-sectional, quantitative study design was adopted using a purposive sample of 283 insurance employees. Data were analyzed using independent t-tests, analysis of variance (ANOVA), and partial least squares structural equation modeling (PLS-SEM) to assess how employees working flexibly perceive supervisor and career support, and how these perceptions relate to job performance.

Findings: The findings reveal that supervisor support has a strong positive impact on job performance ($\beta = 0.66$, $p < 0.05$), whereas career support has little to no effect, showing a slight negative trend ($\beta = -0.054$). Younger, single employees, particularly those from nuclear families, report greater levels of perceived career support. Among flexible work options, flexitime and co-working were the most favoured choices.

Originality/value: This research provides valuable insights into how flexible work culture (FWC) elements are related to demographic factors within a demanding and understudied industry. It emphasizes the vital role of supervisor support in enhancing employee performance while drawing attention to the often-neglected impact of career support.

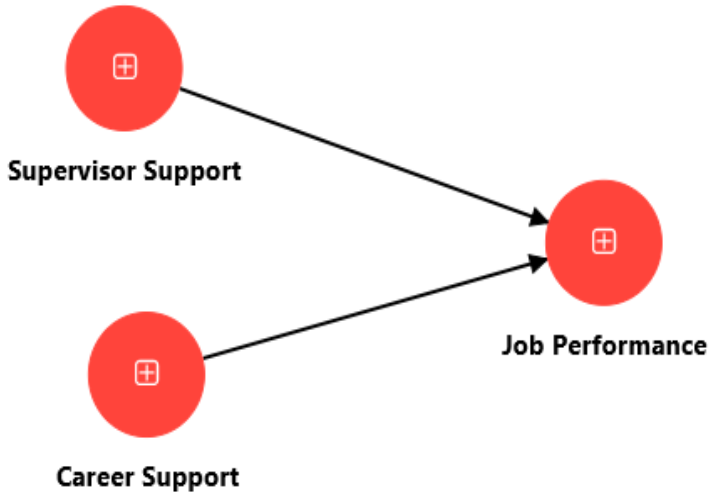
Practical Implication: Insurance companies should focus on enhancing supervisor-led support initiatives and implementing flexible work options such as flexitime and co-working, which employees favor. Tailoring these strategies to match demographic preferences can enhance performance, boost retention, and foster a more efficient and responsive workplace.

1. INTRODUCTION

In contemporary organizational dynamics, the quality of interpersonal relationships and the presence of supportive frameworks are pivotal in determining employee efficacy and the overall prosperity of the institution, with supervisor and career support being particularly influential in shaping employee perceptions, actions, and results, thereby necessitating a comprehensive understanding of these support mechanisms for organizations seeking to optimize workforce potential and maintain a competitive advantage. Flexi work culture is becoming increasingly popular in human resources, as organizations recognize the importance of work-life balance and employee well-being (Beltrán & Roca, 2013). Flexi work Culture represents both work practices and support. Work Practices of flexibility include *remote working, flexible places, work-from-home arrangements, telecommuting, virtual offices, job sharing, co-working, shift working, flexible working hours, part-time working, compressed work weeks, annualized hours or leaves, fixed-term contracts, overtime, and sabbatical leaves*(Weeden, 2005; Stavrou, 2005; Kelly & Kalev, 2006; Kossek et al., 2006; Facer & Wadsworth, 2008; Smith, 2010; Masuda et al., 2012; Berkery et al., 2017; Peretz et al., 2018; Kröll & Nüesch, 2019). Supporting employees' work-home culture, employees tended to have a fixed working life, more work, and family interference while completing tasks. Hence, Dikkers et al. (2007) proposed two types of work-home culture: one that supports and the other that hinders. As work culture across the organizations remains

similar, but differs in departments. This shift gives employees greater control over their schedules, enhancing job satisfaction while attracting a diverse talent pool.(Mauno & Ruokolainen, 2017) advocated that supervisor and coworker support has significantly contributed to job satisfaction, but supervisor support doesn't contribute to employee energy levels using Stress-buffering and psychological contract theories. In the same vein, Straub et al. (2018) found that supervisory support spreads a better positive work culture across the organization and leads to better employee outcomes, and reduces leave intentions among employees using (Nielsen & Abildgaard, 2013) Organizational Intervention Process Model. Additionally, with a supportive organizational culture, many policies of work-life balance related to employees can be implemented effectively in Spain's metal industries (Cegarra-Leiva et al., 2012). Now this supportiveness also helps women to build a better career reported by (Pas et al., 2011) across Dutch women. Not only is supportiveness required, but a proper use of flexible work arrangements like teleworking and flexitime will make employees work, and these arrangements are prominently influenced by these supports (Chung & van der Horst, 2018; Lott & Abendroth, 2020). Extensive research has consistently shown that support from supervisors is a strong indicator of various positive outcomes for employees. When employees perceive their supervisors as supportive, they frequently experience greater satisfaction in their jobs, family lives, and overall well-being, while also reporting lower stress levels, fewer intentions to quit, and reduced conflict between work and family roles (Anderson et al., 2002). Moreover, the benefits of supervisor support are not limited to personal well-being; it also positively influences organizational metrics such as lower absenteeism, greater employee commitment, and enhanced job performance (Goff et al., 1990). Also, Career support plays a vital role in fostering a workplace environment where employees feel confident about their career progression while effectively balancing their responsibilities. When organizations signal that striving for work–life balance doesn't come at the expense of career advancement, employees are more inclined to take part in support programs and demonstrate heightened organizational commitment (Mauno et al., 2006). The broader work-home culture within an organization plays a crucial role in shaping the effectiveness of both supervisor and career support. Studies highlight that work-home culture consists of several key elements, such as support from the organization, supervisors, and colleagues, as well as factors like career consequences and organizational time expectations (Dikkers et al., 2007). These components can be grouped into two overarching categories: supportive factors and hindering factors. Organizations that offer high levels of support while minimizing obstacles create favourable environments where employees can succeed both at work and in their personal lives. The work-home culture framework underscores that supervisor and career support are deeply embedded within this larger organizational setting, which can either strengthen or weaken their impact on flexible work practices. When the culture promotes work-life integration and avoids penalizing employees for using support resources, the positive influence of supervisor and career support on job performance is significantly enhanced (Allen, 2001). Apart from this, Workplace structures have undergone a major transformation, with flexible work arrangements (FWAs) gaining prominence as a response to the need for more adaptive, employee-focused practices. These arrangements, varying in time, location, workload, and leave policies, address the needs of a diverse workforce shaped by demographic, technological, and economic shifts (Allen et al., 2015). Job performance, on the other hand is shaped by personal and workplace factors, with flexible work, supervisor support, and a sense of belonging positively influencing outcomes (Davidescu et al., 2020; Wu et al., 2025; Petitta & Ghezzi, 2025). However, outcomes vary by context (Medina-Garrido et al., 2017; Virick et al., 2010), warranting deeper investigation. Although flexible work arrangements have been widely studied across sectors, the insurance industry remains underexplored. With many employees working on contractual or part-time terms under high-performance pressure, turnover rates are high (Ghosh et al., 2019). Given the sector's growth demands, this study investigates how employee-chosen flexibility, along with supervisor and career support, impacts job performance. Ghosh et al. (2019) examined organizational, supervisor, and coworker support but did not focus on career support to job performance. In contrast, Saleem and Mateou (2024) highlighted the significance of career satisfaction, particularly among women, within the context of work–life balance and its link to job performance and the glass ceiling. Recognizing this gap, the present study aims to explore the impact of career support alongside supervisor support on employee job performance. However, the impact of FWAs differs

across individual and organizational characteristics. Factors like age, gender, marital status, work experience, family structure, and organization sector significantly influence how people perceive and benefit from flexibility (Chung & van der Lippe, 2020). For instance, older workers may seek flexibility for health or caregiving, while younger ones may prioritize education or personal growth (Ciarniene & Vienazindiene, 2018). Gender roles and caregiving duties also create disparities, particularly for women (Thompson et al., 2024; Shockley et al., 2017). Additionally, public sector jobs often provide more structured, flexible options than those in the private sector (Ciarniene & Vienazindiene, 2018). Hence, the study seeks to integrate work-home culture and flexible work practices as complementary components of flexible work environments, addressing the current gap in literature that often treats them separately. Despite growing interest in flexible work, limited research has examined the combined impact of supervisor and career support on employee performance. Most existing studies focus on specific sectors such as healthcare, tourism, and public service, with minimal attention to the insurance industry. Moreover, in **Figure 1**, empirical models rarely explore the dual influence of these support dimensions alongside demographic factors. This study aims to fill this gap by investigating how the interplay between supervisor support, career support, and flexible work arrangements influences employee engagement, performance, and commitment within the highly regulated and client-centric insurance sector.



***Source**: Author's own.*

Figure 1: Proposed Model.

2. LITERATURE REVIEW

Flexible work culture (FWC) has gained increasing attention as organizations strive to adapt to evolving workforce expectations. Flexible workplace arrangements that empower employees with greater autonomy over where, when, and how they work, commonly referred to as FWC, are examined in this review for their effects on job satisfaction and job performance. Research underscores that the combination of supervisor and career support significantly enhances job performance. Theoretical frameworks emphasize that social support in the workplace fosters better job satisfaction, reduced stress, and improved work–life balance, with perceived control acting as a key mediating factor (Thomas & Ganster, 1995; Grzywacz & Butler, 2005).

2.1. *Flexible Work Practices, Supervisor and Career Support Across Demographic Variables*

Flexible Work Arrangements (FWAs) include flextime, telecommuting, compressed workweeks, job sharing, and flexible leave options. These arrangements aim to help employees align professional duties with personal needs, often resulting in improved work–life balance, reduced stress, and increased job satisfaction (Thompson & Prottas, 2005). However, the effectiveness and accessibility of FWAs vary across demographic groups. Younger employees, particularly those from Generations B and Y, generally express greater satisfaction with FWAs compared to older

generations, who often seek flexibility for caregiving or health-related needs (Ciarniene & Vienazindiene, 2018). Gender also plays a critical role, with women more likely to use FWAs due to caregiving responsibilities. Nevertheless, women often face more barriers in accessing these arrangements and report concerns about career progression and organizational support (Thompson et al., 2024). Work experience influences perceived autonomy and confidence in requesting flexibility, with senior employees reporting greater control over their schedules (Thompson & Prottas, 2005). Marital status and family structure also affect FWA demand, with single parents and dual-earner households valuing them more. Public sector employees, particularly women, generally report more favorable experiences due to policy support and workplace culture (Ciarniene & Vienazindiene, 2018). Overall, the intersection of demographic and organizational factors shapes access to and satisfaction with flexible work.

Research indicates that age-related dissimilarity between supervisors and subordinates can influence employability evaluations-older employees may receive less favourable assessments when supervised by younger managers, even when they have access to similar career development opportunities (Van & De, 2021). Additionally, gender plays a moderating role in how supervisor support impacts perceptions of performance: women often interpret workplace support differently, potentially associating it more strongly with organizational outcomes (Zeffane et al., 2017). While marital status and family structure are less frequently examined, work–family studies suggest that supervisors' awareness of family commitments can mitigate conflicts, an important factor across various family contexts (Kossek et al., 2011). Although sectoral differences have not been extensively studied, these dynamics are likely to vary across industries owing to distinct cultures of support and HR practices.

Research Question 1: What level of Supervisor and Career support do employees experience for the flexible work culture practices they choose?
Research Question 2: Is there a significant relationship between demographic variables and perceived supervisor and career support?

2.2. *Flexi Work Culture: Supervisor Support and Career Support for Job Performance*.

Job performance remains a central construct in industrial and organizational psychology, encompassing measurable behaviours, actions, and outcomes that align with organizational goals. It is shaped by individual attributes such as experience, capability, educational background, and environmental factors, including job security, feedback, and work conditions (Davidescu et al., 2020). Recent research has underscored the importance of a flexible work culture in enhancing job performance. For instance, Wu et al. (2025) found that employee task performance significantly improves when co-workers exhibit flexibility, emphasizing the role of shared responsibilities in team environments. Similarly, Naqshbandi et al. (2024; 2025) reported that employees perceive flexible working hours to be more beneficial to performance than teleworking, even when task variety is limited suggesting that perceived autonomy in time management positively influences productivity. A sense of belongingness also plays a vital role in driving performance outcomes, as it shapes work choices and engagement levels (Petitta & Ghezzi, 2025). Supporting this, a meta-review of 21 studies by Çivilidağ and Durmaz (2024) revealed a moderate positive relationship between flexible work culture and job performance, solidifying its importance across multiple organizational settings. The role of supervisor support within flexible environments has also been explored. Capone et al. (2024) highlighted in their study on technical academic staff that supervisory support is a complex yet crucial factor that significantly impacts performance. This relationship becomes even more impactful when supervisor support is integrated with work-life balance practices, as shown in the findings of Eshun and Segbenya (2024), who observed improved performance among employees in higher education. However, not all findings present a direct link. Medina-Garrido et al. (2017) and Virick et al. (2010) argued that while work-life policies and flexible arrangements are beneficial, they may not always translate into visible performance outcomes from a supervisor’s perspective, particularly when employee output is difficult to monitor. In addition to supervisor support, career support has emerged as a crucial determinant of performance. Saleem and Mateou (2024) emphasized that career satisfaction,

especially among women, significantly enhances job performance. Their study positions career support as a mediator in managing work–life balance challenges and overcoming barriers like the glass ceiling, highlighting its strategic importance in organizational support systems. Lastly, Smit et al. (2016) pointed out that high levels of cognitive engagement and clarity are essential for maintaining consistent performance, suggesting that any support system, be it flexible work, supervisor guidance, or career development, must be cognitively aligned with employee needs to be effective. Collectively, these studies affirm that flexible work culture, supervisor support, and career support are interconnected mechanisms that can significantly enhance job performance, although their impact may vary based on contextual and perceptual factors. The present study builds on this foundation by empirically examining the combined effect of these three elements to better understand performance dynamics in flexible work environments.

Research Question 3: How are supervisor support and career support jointly related to job performance among employees in the insurance sector?

2.3. Research Hypothesis

$H_0$1: ***Employees who engage in self-selected flexible work culture practices experience a significantly higher level of supervisor and career support.***

$H_0$2a: ***There is no significant difference in the perception of Supervisory Support and Career Support between the genders of employees.***

$H_0$2b: ***There is no significant difference in perceptions of Supervisor Support and Career Support among employees in the insurance sector based on marital status.***

$H_0$2c: ***There is no significant difference in employees' perceptions of supervisor support and career support across different organizational sectors in the Insurance sector.***

$H_0$2d: ***There is no significant difference in Supervisory Support and Career Support across different age groups of employees.***

$H_0$2e: ***There is no significant relationship between Supervisory Support and Career Support in employees' work experience.***

$H_0$2f: ***There is no significant difference in perceptions of Supervisor Support and Career Support based on employees' family structure.***

$H_0$3: ***There is a significant positive relationship between Supervisor Support and Career Support on job performance.***

3. RESEARCH METHODOLOGY

This study investigates the influence of flexible work culture (FWC), primarily comprising supervisory support and career support, on job performance. A study was conducted to refine the research framework and validate the results. The study employed a quantitative research design, utilizing a cross-sectional survey approach to examine workplace flexibility practices and the support employees receive in their organizations. Data were collected through a structured questionnaire designed to measure the constructs of the FWC scale, taken from (Dikkers et al., 2007b), and job performance (Pradhan & Jena, 2017). The questionnaire items were derived from established, validated scales in existing literature and assessed using a 7-point Likert scale, ranging from "strongly disagree" to "strongly agree." A purposive sampling method was applied, targeting 283 employees from the insurance sector. Participants were selected from companies whose citizen charters were listed on the IRDA website, including ICICI, Bajaj Allianz, SBI Life Insurance, Max Life Insurance, HDFC Life Insurance, and LIC. Reliability of the scales was evaluated through Cronbach's Alpha to confirm internal consistency. Data analysis involved ANOVA and T-tests to assess the effects of supervisory and career support across demographic groups within the sector, while PLS-Path analysis was employed to investigate their impact on job performance. Statistical analyses were performed using SPSS. This study refined the methodology and validated the instrument for subsequent large-scale research. After analysing 283 respondents, we found that most employees willingly do remote work more than flexi-time, job sharing, co-working, and overtime. A two-item scale can be considered suitable if the construct has a narrow scope and the items show a strong correlation (Eisinga et al., 2013), but eventually, all three variables justify having three items in the construct. Despite the item's loading (0.47) being marginally below the recommended 0.50 benchmark, it was retained due to its significant

theoretical importance and distinctive role in representing the construct of Career Support. Excluding it could eliminate an essential dimension of the concept, thereby compromising content validity (Hair et al., 2019; MacKenzie et al., 2011).

4. RESULTS

The sample is mostly young (20–39), male, married, from nuclear families, with under 10 years of experience, and employed in the private sector, reflecting a dynamic early-career workforce in **Table 1**.

Table 1: Descriptive Statistics of the Study

Variable	Frequency	Percent
Gender: Male	152	53.9
Gender: Female	131	46.1
Age: 20–29	134	47.2
Age: 30–39	105	37.3
Age: 40–49	35	12.3
Age: 50 and above	9	3.2
Marital Status: Married	167	58.8
Marital Status: Unmarried	116	41.2
Family Structure: Single	50	17.6
Family Structure: Nuclear family	173	61.3
Family Structure: Joint family	60	21.1
Work Experience: 0–5 yrs	112	39.8
Work Experience: 6–10 yrs	101	35.6
Work Experience: 11–15 yrs	44	15.5
Work Experience: 16–20 yrs	14	4.9
Work Experience: Above 20 yrs	12	4.2
Organization Sector: Public	52	18.7
Organization Sector: Private	231	81.3

Source: Author's Own.

Table 2: Employee Exercise Frequencies

Work Flexibility Practices		Responses		Percent of Cases
		N	Percent	
1. Remote Working/ Flexible Places/ Work from Home/ Telecommuting/ Virtual Offices	33	6.1%	11.7%	
2. Job Sharing	85	15.6%	30.0%	
3 Co Working	110	20.2%	38.9%	
4. Shift Working	64	11.7%	22.6%	
5. Flex Time/ Flexible Working Hours	169	31.0%	59.7%	
6. Part-time Working	38	7.0%	13.4%	
7. Compressed Work Week	2	0.4%	0.7%	
8. Annualized Hours / Leaves	16	2.9%	5.7%	
9. Fixed Term Contract	8	1.5%	2.8%	
10. Overtime	15	2.8%	5.3%	
11. Sabbatical Leaves	5	0.9%	1.8%	
Total	545	100.0%	192.6%	
a. Dichotomy group tabulated at value 1.				

***Source**: Author's Own.*

Out of 545 multiple responses in **Table 2**, most employees opted for flex time, co-working, job sharing, and shift work, indicating a preference for adjusting work hours to balance performance and personal life. Further, the analysis underscores that Flex Time, Co-Working, and Job Sharing are the predominant preferences for flexibility among younger private-sector and nuclear-family employees, while the underutilization of Compressed Work Weeks and Sabbaticals indicates organizational constraints; additionally, unmarried employees lean towards collaborative and reduced-hour arrangements, contrasting with married employees who prefer Flex Time for optimal work-family integration.

Table 3: Employee-selected flexi work culture practices

Employee Choice of Work Practice	Supervisor Support (Count / %)	Career and Time Support (Count / %)
1. Remote Working / Flexible Places / Work from Home / Telecommuting / Virtual Offices	3 (4.3%)	6 (5.9%)
2. Job Sharing	9 (13.0%)	15 (14.7%)
3. Co-Working	10 (14.5%)	16 (15.7%)
4. Shift Working	12 (17.4%)	17 (16.7%)
5. Flex Time / Flexible Working Hours	26 (37.7%)	28 (27.5%)
6. Part-time Working	4 (5.8%)	11 (10.8%)
8. Annualized Hours / Leaves	2 (2.9%)	2 (2.0%)
9. Fixed Term Contract	2 (2.9%)	4 (3.9%)
10. Overtime	-	1 (1.0%)
11. Sabbatical Leaves	1 (1.4%)	2 (2.0%)
Total Responses	69 (100.0%)	102 (100.0%)

Source: Author's Own.

Employees prefer Flex Time, supported by both supervisors and career/time policies in **Table 3**, followed by Shift Work, Co-Working, and Job Sharing, reflecting strong interest in flexible and collaborative models. Remote Work ranks lower, possibly due to limited support or infrastructure. Options like Sabbatical, Overtime, and Annualized Hours are least chosen, indicating low relevance or adoption. Fixed-term contracts show mixed support, suggesting policy inconsistency. Overall, while core flexible practices are well-supported, underutilized options require improved supervisor backing and clearer organizational policies to meet the diverse needs of employees effectively in response to $\mathbf{H_0 1}$.

Table 4: Independent T-test

Grouping Variable	Variable	Variance Assumption	Levene's F	Levene's Sig.	t	df	Sig. (2-tailed)	MD	SED	95% CI L	95% CI U
Gender	Career Support	Equal variances assumed	0.236	0.628	0.56	282	0.576	0.0667	0.1192	-0.1679	0.3013
	Career Support	Equal variances not assumed			0.561	277.081	0.575	0.0667	0.119	-0.1675	0.3009
	Supervisor Support	Equal variances assumed	0.327	0.568	-3.119	282	0.002	-0.3657	0.1172	-0.5965	-0.1349
	Supervisor Support	Equal variances not assumed			-3.129	278.214	0.002	-0.3657	0.1169	-0.5958	-0.1356
Marital Status	Career Support	Equal variances assumed	7.64	0.006	-4.377	282	0	-0.5115	0.1169	-0.7416	-0.2815
	Career Support	Equal variances			-4.265	225.7	0	-0.5115	0.1199	-0.747	-0.275

Grouping Variable	Variable	Variance Assumption	Levene's F	Levene's Sig.	t	df	Sig. (2-tailed)	MD	SED	95% CI L	95% CI U
		not assumed								8	2
	Supervisor Support	Equal variances assumed	0.42	0.518	0.232	282	0.817	0.028	0.1208	-0.2097	0.2657
	Supervisor Support	Equal variances not assumed			0.233	253.304	0.816	0.028	0.1203	-0.2088	0.2649
Organization Sector	Career Support	Equal variances assumed	5.045	0.025	0.642	282	0.522	0.0978	0.1525	-0.2023	0.3979
	Career Support	Equal variances not assumed			0.571	69.297	0.57	0.0978	0.1714	-0.2442	0.4398
	Supervisor Support	Equal variances assumed	0.044	0.834	3.011	282	0.003	0.4523	0.1502	0.1566	0.7479
	Supervisor Support	Equal variances not assumed			2.775	71.502	0.007	0.4523	0.163	0.1273	0.7772

Source: Author's own. Note: **MD** - Mean Difference, **SED** - Standard Error Difference, **L** - Lower, **U** – Upper.

In **$H_0$2a,** an independent samples t-test assessed gender differences in perceptions of career support and supervisor support within a flexi work culture as shown in **Table 4**. For career and time support, no significant difference was found between males (M = 0.031, SD = 1.012) and females (M = -0.036, SD = 0.989); t (282) = 0.560, p = 0.576. Levene's test confirmed equal variances (F = 0.236, p = 0.628), and the mean difference (0.067) was not practically meaningful (95% CI: -0.168 to 0.301). However, for **Supervisor Support**, females (M = 0.197, SD = 0.964) scored significantly higher than males (M = -0.169, SD = 1.003); t (282) = -3.119, p = 0.002. The mean difference was -0.366 (SE = 0.117), with a 95% CI of -0.597 to -0.135. Thus, female employees perceive significantly greater supervisor support, while career support perceptions remain statistically similar across genders.

An independent samples t-test examined marital status differences in flexible work culture dimensions in **$H_0$2b**. For **Career Support**, Levene's test showed unequal variances (F = 7.640, p = 0.006); hence, equal variances were not assumed. A significant difference was found (t (225.70) = -4.265, p< 0.001) between married (M = -0.211, SD = 0.908) and unmarried participants (M = 0.301, SD = 1.052), with a mean difference of -0.512 (95% CI: \ [-0.748, -0.275]). For **Supervisor Support**, no significant difference emerged (t (282) = 0.232, p = 0.817), with Levene's test supporting equal variances (F = 0.420, p = 0.518). Overall, unmarried employees report higher career support, while supervisor support remains unaffected by marital status.

An independent samples t-test examined sector-wise differences (public vs. private) in perceptions of flexible work culture across two dimensions for **$H_0$2c**. For **Career Support**, Levene's test indicated unequal variances (F = 5.045, p = 0.025); thus, equal variances were not assumed. No significant difference was found between public (M = 0.080, SD = 1.160) and private (M = -0.018, SD = 0.961) sector employees, t (69.30) = 0.571, p = 0.570, with a mean difference of 0.098 (95% CI: [-0.244, 0.440]). For **Supervisor Support**, equal variances were assumed (F = 0.044, p = 0.834). A significant difference emerged, with public sector employees (M = 0.368, SD = 1.094) reporting higher support than private (M = -0.084, SD = 0.960); t (282) = 3.011, p = 0.003, mean difference = 0.452 (95% CI: [0.157, 0.748]). Overall, only supervisor support differed significantly by sector.

Table 5: Anova Table

Grouping Variable	Variable	S.O.S (B)	df (B)	MSB	F	Sig.	S.O.S (W)	df (W)	MS W	Total SS	Total df
Age	Career Support	25.409	3	8.47	9.206	0	257.591	280	0.92	283	283
	Supervisor Support	4.375	3	1.458	1.465	0.224	278.625	280	0.995	283	283
Work Experience	Career Support	32.055	4	8.014	8.91	0	250.945	279	0.899	283	283
	Supervisor Support	6.138	4	1.534	1.546	0.189	276.862	279	0.992	283	283
Family Structure	Career Support	39.182	2	19.591	22.579	0	243.818	281	0.868	283	283
	Supervisor Support	0.366	2	0.183	0.182	0.834	282.634	281	1.006	283	283

Source: Author's Own. Note: S.O.S (B) - Sum of Squares Between, df (B) - Degree of Freedom between, MSB - Mean Square (Between), S.O.S (W) - Sum of Squares Within, df (W) - Degree of Freedom Within, MSW - Mean Square (Within).

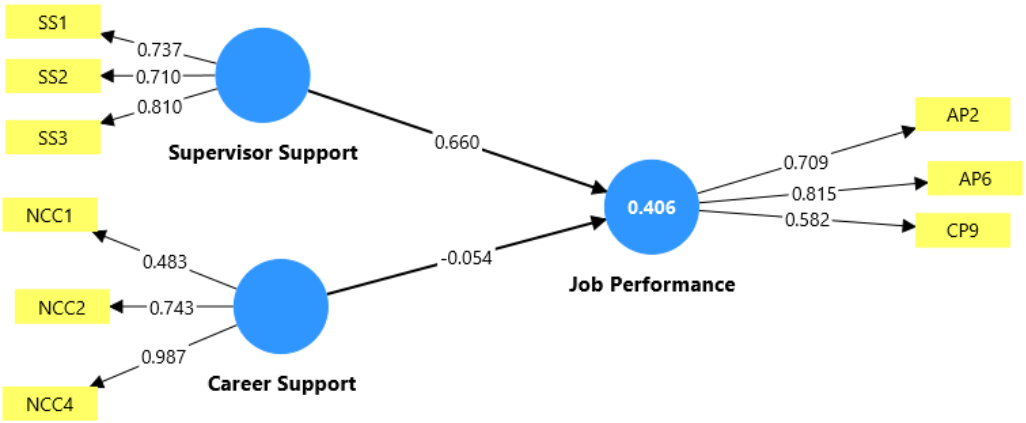
A one-way ANOVA was conducted to examine age-based differences in perceptions of flexible work culture across four dimensions, **$H_0$2d** in **Table 5**. A significant difference was found in **Career and Time Support**, F (3, 280) = 9.206, $p < .001$. Post hoc Tukey HSD tests showed that employees aged **20–29** perceived significantly higher support than those aged **30–39** ($p < .001$) and **40–49** ($p = .021$). No significant difference was found between the 20–29 and 50+ groups. This indicates that younger employees perceive greater career and time flexibility than those aged 30–49. However, **Supervisor Support** showed no significant variation across age groups, F (3, 280) = 1.465, $p = .224$, as confirmed by non-significant post hoc results.

While analysing **$H_0$2e** ANOVA results showed a significant difference in **Career Support** across work experience groups, F (4, 279) = 8.910, $p < .001$. Tukey HSD tests revealed that employees with **0–5 years** of experience reported significantly higher support than those with **6–10 years** (*Mean Difference = 0.65, $p < .001$*) and **11–15 years** (*Mean Difference = 0.77, $p < .001$*). Although differences with more experienced groups (16+ years) were not significant, a declining trend was noted. For **Supervisor Support**, no significant difference was found across experience levels, F (4, 279) = 1.546, $p = .189$, with Tukey tests confirming no meaningful pairwise differences. This suggests perceptions of supervisor support remain consistent regardless of experience.

The ANOVA results show a **significant difference in Career Support** based on employees' family structure, F (2, 281) = 22.579, $p < .001$ in **$H_0$2f**. Tukey HSD post hoc tests indicate that employees from **single-family** structures perceive **significantly higher support** than those from **nuclear** and **joint families**. In contrast, for **Supervisor Support**, no significant differences were found across family structures (*$F(2, 281) = 0.182$, $p = .834$), indicating* that perceptions of supervisor support are consistent across different family backgrounds.

4.1. MODEL SUMMARY

Using Smart PLS, we examined **$H_0$3** to evaluate the influence of two key dimensions of flexible work culture support on employee job performance. The model summary report provided insights into the strength and significance of these relationships, highlighting the extent to which the selected predictors explained variance in job performance. Additionally, the path analysis clarified the direction and magnitude of influence, offering a comprehensive understanding of how flexible work culture impacts employee outcomes.



Source: **Authors created in Smart PLS**.

Figure 2: **Model Summary**

The structural model shown in **Figure 2** results reveal significant insights into the relationships among the studied constructs. Supervisor Support demonstrated a strong and positive effect on Job Performance (β = 0.66), indicating that greater supervisor involvement is associated with higher performance levels. In contrast, Career Support exhibited a weak and slightly negative relationship (β = -0.054), suggesting its influence on job performance is negligible in this context as shown in **Table 10**. Assessment of indicator reliability showed that most outer loadings exceeded the acceptable threshold of 0.70, particularly for Supervisor Support (SS1 = 0.737, SS2 = 0.710, SS3 = 0.810) and Job Performance (AP2 = 0.709, AP6 = 0.815). Although CP9 (0.582) and NCC1 (0.483) fell below this benchmark, they may still be retained in exploratory settings in **Table 11** (Hair et al., 2019; MacKenzie et al., 2011). Composite reliability values for all constructs ranged between 0.745 and 0.873, and Cronbach's alpha values were consistently above 0.70, confirming internal consistency reliability. Furthermore, the Average Variance Extracted (AVE) for all constructs exceeded the 0.50 threshold, validating convergent validity in **Table 8**. From **Table 9,** discriminant validity was established using both the HTMT ratio and Fornell-Larcker criterion. All HTMT values were well below the critical value of 0.85, and each construct's square root of AVE exceeded its correlations with other constructs, indicating empirical distinctiveness. Cross-loading analysis confirmed that all indicators loaded more strongly on their intended constructs than on others. The model's explanatory power was moderate, with an R^2 value of 0.406 for Job Performance, suggesting that 40.6% of the variance is explained by Career and Supervisor Support. Effect size (f^2) analysis highlighted that Supervisor Support had a substantial impact on Job Performance (f^2 = 0.572), whereas Career Support contributed only marginally (f^2 = 0.004) in **Table 7**. Collinearity diagnostics indicated no multicollinearity concerns, with all outer VIF values ranging from 1.39 to 2.02 and inner VIF values at 1.282, well below the conservative threshold of 3.3. Regarding model fit, as shown in **Table 6,** the Standardized Root Mean Square Residual (SRMR) value was 0.054, which is below the 0.08 cutoff and denotes a good fit. Supporting fit indices, d_ULS (0.132) and d_G (0.089), also indicated minimal model discrepancy. The Normed Fit Index (NFI) score of 0.845 reflects an acceptable model fit, particularly for exploratory research. Collectively, these findings confirm that the measurement and structural model possess adequate reliability, validity, and predictive capability. Importantly, they underscore the prominent role of Supervisor Support in enhancing employee Job Performance, whereas Career Support appears less influential within the examined context. Lastly, to assess common method bias (CMB), as shown in **Table 12,** Harman's single-factor test was conducted using Principal Component Analysis. The first unrotated factor accounted for 38.92% of the total variance, which is below the 50% threshold. This indicates that common method bias is not a significant concern in the study.

Table 6: Model Fit

Model Fit		
	Saturated model	**Estimated model**
SRMR	0.054	0.054
d_ULS	0.132	0.132
d_G	0.089	0.089
Chi-square	139.168	139.168
NFI	0.845	0.845

Source: Author's own.

Table 7: R square and F square

Construct	**R-square**	**R-square Adjusted**	**f^2 (Career Support → Job Performance)**	**f^2 (Supervisor Support → Job Performance)**
Job Performance	0.406	0.401	0.004	0.572

Source: Author's own.

Table 8: Construct Validity

	Construct Reliability and Validity			
Construct	**Cronbach's Alpha**	**Composite Reliability (rho_a)**	**Composite Reliability (rho_c)**	**Average Variance Extracted (AVE)**
Career Support	0.796	0.873	0.798	0.587
Job Performance	0.745	0.765	0.748	0.502
Supervisor Support	0.799	0.8	0.797	0.568

Source: Author's Own.

Table 9: Discriminant Validity

	HTMT Ratio		**Fornell - Larcker Criterion**		
Construct	**HTMT with Career Support**	**HTMT with Job Performance**	**Fornell with Career Support**	**Fornell with Job Performance**	**Fornell with Supervisor Support**
Career Support			0.766		
Job Performance	0.252		0.256	0.709	
Supervisor Support	0.468	0.632	0.469	0.635	0.754

Source: Author's Own.

Table 10: Path Coefficient

	Path coefficients
Career Support -> Job Performance	-0.054
Supervisor Support -> Job Performance	0.66

Source: Author's own.

Table 11: Constructs Outer Weights and Loadings

	Outer Weights			Outer Loading		
Item	**Career Support (Weight)**	**Job Performance (Weight)**	**Supervisor Support (Weight)**	**Career Support (Loading)**	**Job Performance (Loading)**	**Supervisor Support (Loading)**
AP2		0.412			0.709	
AP6		0.473			0.815	
CP9		0.338			0.582	
NCC1	0.257			0.483		
NCC2	0.395			0.743		
NCC4	0.524			0.987		
SS1			0.387			0.737
SS2			0.373			0.71
SS3			0.425			0.81

Source: Author's own.

Table 12: Common Method Bias

Component	Total Variance Explained (%)	Cumulative Variance (%)
1	38.924	38.924
2	15.653	54.576

Source: Author's own.

5. DISCUSSION

This study examined the interplay between supervisor support, career support, and job performance within the context of flexible work culture (FWC) in the Indian insurance sector, guided by established theoretical frameworks. The Work–Home Culture Model (Dikkers et al., 2007) provided the conceptual foundation, emphasizing the role of supportive and hindering cultural factors in shaping the use and outcomes of flexible work arrangements. The Stress-Buffering Theory (Thomas & Ganster, 1995) and the Organizational Intervention Process Model (Nielsen & Abildgaard, 2013) framed the expectation that immediate, accessible forms of support-particularly from supervisors-would mitigate job strain and enhance performance. **$H_0$1** predicted that employees engaging in self-selected FWC practices would report higher supervisor and career support. Findings from Table 3 confirmed this pattern for key flexibility options, with flexitime showing the strongest alignment between perceived support and practice adoption, followed by shift work, co-working, and job sharing. The preference for flexitime resonates with prior findings that temporal autonomy improves satisfaction and productivity (Berkery et al., 2017; Chung & van der Horst, 2018). However, minimal uptake of compressed workweeks and sabbaticals supports the Work–Home Culture Model's assertion that organizational norms and infrastructure can constrain the practical adoption of certain flexibility options (Weeden, 2005; Kelly & Kalev, 2006). **$H_0$2a–$H_0$2f** addressed demographic influences on perceived support. Results in Table 4 showed that for **$H_0$2a**, gender did not affect career support perceptions, though women reported significantly higher supervisor support, reflecting evidence that women often interpret supervisory engagement as an important organizational resource (Zeffane et al., 2017). H02b revealed marital status differences, with unmarried employees reporting greater career support-potentially due to fewer work–family role conflicts. For H02c, public sector employees perceived higher supervisor support than private sector employees, likely reflecting structured HR processes and mentoring systems (Chung & van der Lippe, 2020). Table 5 results for **$H_0$2d** showed younger employees (20–29) perceived greater career support than older cohorts, consistent with Ciarniene & Vienazindiene's (2018) observation that early-career staff are often targeted with development opportunities. **$H_0$2e** found employees with ≤5 years' experience reported higher career support than more experienced peers, suggesting retention-focused strategies. For **$H_0$2f**, single employees perceived greater career support than those in nuclear or joint families, reflecting the potential impact of caregiving responsibilities on access to development programs (Shockley et al., 2017). Across these hypotheses, the Work–Home Culture Model's distinction between supportive and

hindering cultural elements helps explain why demographic factors influence the perceived availability and usefulness of support. H03 examined the combined influence of supervisor and career support on job performance. The structural model (Tables 6–12) demonstrated that supervisor support had a strong positive effect ($\beta = 0.66$, $f^2 = 0.572$) on job performance, consistent with the Stress-Buffering Theory's premise that proximal, interpersonal resources directly reduce job stress and enhance role clarity (Capone et al., 2024; Wu et al., 2025; Anderson et al., 2002). The Organizational Intervention Process Model further explains this relationship by highlighting how supervisors act as change agents, embedding flexible practices into daily workflows and reinforcing their value (Straub et al., 2018). In contrast, career support had a negligible and slightly negative effect on job performance ($\beta = -0.054$, $f^2 = 0.004$), diverging from studies showing that career development fosters satisfaction and performance (Saleem & Mateou, 2024; Mauno et al., 2006) in $\mathbf{H_0 3}$. This may be explained by sector-specific demands, where immediate operational targets overshadow long-term developmental benefits (Medina-Garrido et al., 2017; Virick et al., 2010). The misalignment between career support initiatives and the short-term, client-driven performance priorities of the insurance sector may reduce their perceived relevance. Overall, the integration of theory, hypothesis testing, and empirical results suggests that FWC is not a monolithic construct its impact varies by support type, demographic profile, and practice adoption. The findings reinforce the Stress-Buffering Theory's emphasis on immediate, relational support for performance gains, extend the Work–Home Culture Model by showing how demographic diversity shapes access to support, and confirm the Organizational Intervention Process Model's view that effective supervisor engagement is key to embedding flexibility in performance-driven environments. Hence, Insurance firms should boost supervisor-led support and align career development with operations, tailoring policies to younger, unmarried, and early-career staff while ensuring inclusion for older, married, and caregiving employees.

6. IMPLICATIONS

6.1. Theoretical implications:

This research extends the conversation on work-home culture (Dikkers et al., 2007) by empirically confirming the dual-support model of supervisor and career support within flexible work settings. The significant influence of supervisor support on performance reinforces stress-buffering theory (Thomas & Ganster, 1995), emphasizing the importance of immediate, accessible resources over more distant forms of support in high-performance environments. Additionally, the findings question the assumption that all support types hold equal weight, highlighting the need for a more nuanced and differentiated approach.

6.2. Practical implications:

This study provides valuable guidance for organizational practices. Insurance firms should focus on supervisor-driven strategies like mentoring, timely feedback, and emotional backing to enhance employee performance. Although career development remains important, it may need to be restructured to better reflect employee goals and output expectations. Human resource teams should customize flexible work options-such as flexitime and co-working to suit the preferences of younger and unmarried staff, thereby improving engagement and retention rates.

6.3. Social implications:

The results carry wider significance for workplace equality concerning gender and family structures. The higher levels of perceived support among unmarried and nuclear-family employees suggest disparities in access to supportive resources. Organizations need to address these gaps to ensure inclusive practices, particularly for women and individuals with caregiving duties (Shockley et al., 2017). Encouraging a flexible work culture that supports diverse life circumstances can lead to fairer workplaces and positively shape public perceptions of organizational fairness and gender inclusiveness.

7. FUTURE RESEARCH RECOMMENDATIONS

Given the exploratory scope and industry-specific focus of this research, several directions for future inquiry are recommended. Longitudinal studies could offer a deeper understanding of the

delayed effects of career support on outcomes like employee retention and career advancement, which may not manifest immediately (Mauno et al., 2006). Comparative research across sectors such as healthcare, IT, and insurance would help determine if the dominant role of supervisor support is unique to certain industries or broadly applicable (Ghosh et al., 2019; Eshun & Segbenya, 2024). Incorporating qualitative approaches like interviews or focus groups could provide insights into the psychological and emotional facets of perceived support, addressing the observed gap between career support and job performance. Additionally, examining intersectional factors such as gender, age, and family structure may uncover nuanced patterns in how flexible work culture is experienced across demographics. Expanding the definition of career support to include digital mentoring and skill-based development is also essential in today's evolving hybrid work environments (Naqshbandi et al., 2025; Smit et al., 2016).

8. CONCLUSION & LIMITATIONS

This study examined how flexible work culture (FWC), particularly supervisor and career support, affects job performance in India's insurance industry. Findings confirmed that supervisor support plays a vital role in improving employee performance, highlighting its value in performance-driven, flexible environments. In contrast, career support had minimal or even negative effects, raising questions about its effectiveness in this context. Younger, unmarried employees in the private sector showed a strong preference for flexitime, co-working, and job-sharing, reflecting evolving workforce expectations. The research contributes to the literature by integrating demographic factors into the FWC-performance relationship and focusing on a relatively underexplored sector. It offers practical insights for HR and policymakers aiming to develop inclusive and results-oriented support systems. However, limitations include the cross-sectional design, which restricts causal conclusions, and the focus on a single sector in India, affecting broader applicability (Ghosh et al., 2019). Additionally, reliance on self-reports may introduce bias, and overlooked variables like organizational trust may explain career support's weak influence (Smit et al., 2016).

9. DECLARATION OF INTEREST:

- Neither the author nor the co–author has received funding from any institution, and neither of the authors has any financial interest.
- This study did not require formal ethics board clearance as it involved anonymous, voluntary participation with no collection of sensitive or personally identifiable information. Ethical standards were upheld, and informed consent was obtained from all participants.

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The Role of Impact Investments on the Socio-Economic and Environmental Outcomes of Socially Responsible Enterprises in India

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ABSTRACT

Introduction: The impact investments have emerged as a prominent theme in the field of investment and finance. Even the socially responsible enterprises are also greatly influenced by such investments because they offer better opportunities for growth development and social value creation. In India, impact investments are now being considered as an important aspect of economic development.

Purpose: This study attempted to assess the social, economic and environmental impacts of socially responsible organisations, which are the outcomes of impact investments. We also investigated the diverse ways in which such investments influence the performance, functioning and outreach of the organisations.

Design/methodology/approach: In this study we have purposively selected the four organisations from the agricultural sector which have secured the highest investments in the previous financial year. The selected organisations were then analysed through multiple-case study method.

Expected outcomes: The findings provide the critical insights into the relationship between impact investments and the social, economic & environmental outcomes. The study further contributes to the growing body of academic literature by focusing on the research gaps and also suggests future directions.

Implications: This study highlights that impact investments can substantially reinforce the organisational effectiveness and social outcomes of socially responsible enterprises. It also underlines the need for sustainable businesses models, along with the supportive policy frameworks, including blended finance and standardized impact measurements, to ensure maximum developmental impact.

Originality/value: We have made the first scholarly attempt at exploring the organisational impact of agricultural based socially responsible organisations from India through the lens of impact investments by employing a multiple-case study methodology.

Keywords: Impact investment, socially responsible enterprises, Environmental impact, social impact, Multiple case-study and purposive sampling.

1. INTRODUCTION

Access to financial capital remains a major constraint on the growth and scalability of social enterprises. Traditional funding opportunities such as government support, loan, debt and equity fundings are generally considered as project-specific and seldom cover operational or developmental expenses (Brown, 2006). Consequently, many social enterprises pursue revenue-based strategies to secure financial sustainability (Priller et al., 2012; Thompson & Williams, 2014).

During the earlier decade, instruments such as private equity, unsafe loans, and hybrid capital have occurred as substitute financing mechanisms for social enterprises (Martin, 2013). Distinct traditional investors, participants in this space seek both financial and non-financial cost creation.

Impact investing, in particular, participates in financial returns with deliberate social and environmental results (Bugg-Levine & Emerson, 2011; Hebb, 2013)

In its *impact-first* procedure, the method gives importance to measurable social value while seeing financial advantage as supplementary (Bozesan, 2013; Freirich & Fulton, 2009). Returns in such cases may vary from market-level returns to near break-even results (Hebb, 2013; Petrick & Weber, 2013). Many scholarly conclusions reveals that social entrepreneurship (SE) plays a important role in addressing socio-economic and environmental issues in developing situations such as Ecuador (Barraket et al., 2016). However, social enterprises majorly encounter funding limitations that obstruct their growth and sustainability (Burkett, 2010; Nicholls, 2010). Their hybrid models, with integrated financial and social objectives, often do not try to meet the requirements of traditional lending criteria for purely financial instruments, thereby limiting the access to conventional financial instruments (Addis et al., 2013).

Impact investment has thus become an innovative financial instrument providing social finance through debt or equity to social enterprises with measurable social, economic, environmental, and cultural impacts (Emerson, 2003). This is different from "ethical," "socially responsible," or "sustainable" investment, because as it actively seek out positive externalities instead of simply reducing negative ones (Ormiston et al., 2015).What links social entrepreneurship and impact investing, though what makes them interdependent is this blended value orientation, even though impact investors also invest in activities outside the sphere of social enterprise (Moore et al., 2012). The more sophisticated impact investors use their influence to promote good governance, ethical management, and sustainable environmental and social practices among the organizations they invest in (Wood et al., 2013; World Economic Forum, 2013). The term *impact investment* is relatively new, coined originally by the Rockefeller Foundation to describe investments that combine purpose with financial viability (Bugg-Levine & Emerson, 2011; Mendell & Barbosa, 2013). Typically, this type of investment requires the allocation of equity, debt, or mezzanine financing for enterprises seeking social or environmental goals, with an prospect for financial returns through dividends or interest in investment. Similar to venture philanthropy, impact investing often incorporates managerial guidance and capacity-building advice to help build organizational effectiveness (Hehenberger & Harling, 2013; John, 2007; Mair & Hehenberger, 2014).

Whereas the practitioners enthusiastically embraced the hybrid model of the socially responsible organisations, the academic research on impact investing has lagged behind. Most of the existing studies have focused on defining the concept (Höchstädter & Scheck, 2015; Nicholls, 2010; Moore et al., 2012), exploring investment mechanisms (Hazenberg, Seddon, & Denny, 2015; Spiess-Knafl & Aschari-Lincoln, 2015), or identifying emerging challenges and opportunities (Brandstetter & Lehner, 2015; Donald et al., 2014; Evans, 2013). However, very few studies examine growth in the impact investing arena influences the evolution of socially responsible businesses, especially in emerging economies.

Impact investing, therefore, represents a field characterized by institutional complexity owing to the inherent tension between impact logic, prioritizing social welfare, impact sustainability, community advancement, and investment logic, emphasizing financial results. (Lehner & Nicholls, 2014; Ormiston et al., 2015). Against this backdrop, the present study seeks to examine how impact investments contribute to the development of socially responsible enterprises within emerging economies, where financial limitations and developmental imperatives most strongly converge.

1.1 Research Voids

There is a dearth of case-based studies that objectively assess the social and financial results of impact investing in agricultural social enterprises, despite the fact that research on this topic is still scarce in developing nations like India. The impact investing literature has yet to adequately

examine the context-specific dynamics of hybrid organizational models in India's agricultural sector.

1.2 Research Objectives

Based on the above discussion this study will try to explore the undermentioned research problems:

RQ1. To explore the impact investment in relation with the Indian agricultural sector.
RQ2. To assess how these investments impact social, economic and financial outcomes of agricultural businesses.
RQ3. To investigate the impact of the investments on the 4As (affordability, accessibility, awareness and acceptability) of the selected organisations.
RQ4. To study the business model and technological innovations of the selected social responsible organisations.

1.3 Structure of the Paper

This paper is organized into six sections covering various aspects for the case study. Section 1 covers the introduction of the study which includes background, highlighting the existing research gaps, and outlining the specific objectives that guide the investigation. Section 2 provides a comprehensive review of the relevant literature, focusing on the conceptual foundations and theoretical perspectives related to social enterprises and impact investment. Section 3 comprises the methodology adopted for this study which includes the case-selection and data sources. The case analysis of the selected enterprises is discussed in Section 4 and cross-case analysis among them is in Section 5. Finally, Section 6 discusses the study's limitations, future directions, implications and the conclusion

2. LITERATURE REVIEW

2.1 Impact investment and socially responsible enterprises

Impact investing has evolved as an alternative financing mechanism which is an amalgamation financial support along with the social, economic and environmental outcomes. With comparison to general investment methods, it places value on enterprises' wider social and economic contributions, particularly within contexts affected by structural inequities and market inefficiencies (GIIN, 2020; Jackson, 2013). The impact investment domain presents a compelling setting for the study of institutional complexity, as it integrates two distinct yet interdependent logics of social, economic & environmental impact and financial investment . Social enterprises operating in India's agricultural and allied sectors typify hybrid organizations that balance developmental goals with market engagement (Battilana & Lee, 2014). Their long-term success frequently depends on patient capital, which provides flexible financing suited to extended timelines, uncertain returns, and developmental spillovers (Bugg-Levine & Emerson, 2011). The body of scholarly work focusing explicitly on social impact investing remains limited (Brown,2006; Evans,2013).

It usually falls under the larger category of social finance (Moore et al., 2012; Nicholls, 2010), whichincludes a variety of activities that use financial resources to further social and environmenta l goals, such as traditional grantmaking, microfinance, and charitable contributions.

While the idea of using financial resources for environmental or social causes has centuries-old origins (Adam, 2012; Ludlow & Casebourne, 2012), using venture capital mechanisms to acco mplish these goals is a relatively new trend.

The Impact Investment Spectrum (Figure 1) is a paradigm used by the Impact Investors Council (IIC) to map various ways of allocating private capital along a continuum, ranging from fully commercial, return-seeking investment to pure philanthropy. The spectrum is meant to assist investors, social entrepreneurs, legislators, and other ecosystem participants in identifying and comprehending the relative positions of various forms of capital with respect to the trade-off (or balance) between financial return expectations and social and environmental impact goals.

2.2 Socially responsible enterprises in Indian agricultural context

India's agricultural sector continues to experience deep-rooted structural inefficiencies, including fragmented land ownership, limited post-harvest infrastructure, and distortions in price transmission along the supply chain (World Bank, 2020). Due to the limited scale capability of traditional agriculture businesses, the smallholder farmers were generally not considered as an important aspect. To overcome this problem, especially responsible businesses supported by the impact investments started developing inclusive frameworks that would link these small-scale farmers to organized value chains, increasing market access and income stability Further farmer producer organisations (FPO) and agri-tech ventures have initiated digital aggregation platforms, supply-chain innovations, and novel financing instruments designed to strengthen rural livelihoods as resilience (Singh & Chaturvedi, 2021). Such organisations thus create an intermediary role within the agricultural sector, connecting small-scale farmers to markets, and technology providers, and financial institutions. However, hybrid organisations run the constant risk of mission drift, where the pursuit of financial return potentially undermines social goals (Ebrahim et al., 2014). Several scholars suggested that hybrid organisations may sustain their core mission through a process of selective coupling that strategically align with some institutional logics while distancing themselves from others (Pache & Santos, 2013). Within the agriculture domain, this generally means prioritizing farmer welfare along with eh adoption of market-oriented mechanisms of aggregation , value-chain integration, and supply chain management to maintain commercial viability.

In India the agricultural sectors presents both challenges and opportunities for such organizations. While it remains the country's largest employment sector, it still plagued by the uneven holdings, inadequate technological diffusion, and unstable market relationship (Birthal et al., 2020). Smallholder farmers comprise about 86% of the total agricultural labour but still face constrained access to finance, market information, and institutional networks (Government of India, 2021). These structural constraints create fertile ground for socially responsible organisations to develop innovative and scalable solutions. In the recent years, this has translated into the growth of several agriculture-oriented social organisations India that have attracted a decent amount of impact investments.

2.3 Impact Investors and Agriculture in Emerging Economies

Impact investors have turned out to be an important source of finance for impact organisations, including agricultural ones in India. According to GIIN 2020, about 13% of the world's impact investment capital is invested in agriculture, and sub-Saharan Africa and south Asia are considered the largest recipients . In India, the sector has continued to grow, having attracted close to USD 1.2 billion in impact investments between 2011 and 2020 (Impact Investors Council, 2021). Investors engagement in this domain is guided by a dual orientation which includes pursuance of developmental impact along with the financial returns. Agriculture, in particular, remains an attractive sector on the grounds of its core relevance to food security and rural employment, with additional possibilities of scalable innovations in agri-fintech, precision agriculture and supply chain efficiency (Patil, 2020). Despite such scope, extended gestation cycles, uncertain regulatory environment, and climatic volatility continue to hinder steady investment inflows (Singh & Choudhary, 2019). Besides, a difference persists between investor expectations and enterprise missions. While investors always look toward quantifiable and scalable outcomes, social businesses give prominence to context-driven community-level transformations. This misalignment enhances the chance of mission drift and threatens the sustainability of impact in the long run (Ebrahim et al., 2014).

2.4 Measuring Impact of Socially responsible enterprises

Social impact and its evaluation have posed a continuous challenge in the field of impact investing, as opposed to the financial performance thar is generally indicated either through return on equity or through internal rate on return (IRR), the social impact has multiple dimensions, each changing with the different social, economic and institutional contexts. Multiple scholars suggested a range of frameworks like social return on investment (SROI), Impact Reporting and

Investment Standards (IRIS) and theory of Change (TOC) to handle such complexity. The SROI model attempts to monetize the social outcomes by calculating how much benefit was created relative to each unit of investment, and this is generally accepted by researchers because it simplifies the complex social realities (Nicholls et al., 2012). The IRIS model developed by GIIN, gives standardized sector-wide metrics that enhance comparability, but it overlooks risks and basically includes context-specific factors (GIIN, 2020). The TOS framework outlines the casual pathway that links inputs and activities to intermediate outcomes to long-term impact, some useful insights are available about the underlying processes though qualitative in application (Weiss, 1995). In India's agricultural sector, the complexity of impact assessment pertains to the limited data availability, diverse farmer profiles, and significant regional disparities in outcomes (Rawhouser, Cummings, & Crane, 2019). Consequently, many social organisations apply a blended approach, mixing in qualitative evidence, such as case studies and farmer testimonials with quantitative measures on yield improvements and income gains. However, the lack of any standard reporting framework inhibits the investors and policy makers from undertaking impact assessment on a scale.

3. METHODOLOGY

3.1 Research Design

This study followed the qualitative approach and adopted the multiple case-study method to explore and analyse the practices through which impact investments shape the social, economic and environmental outcomes of agriculture-based organisations in India. The case study method is particularly utilized for analysing complex phenomena embedded in real-world contexts, where the boundaries between the subject of inquiry and its environment are indistinct (Yin, 2018). Furthermore, this method allows systematic comparison across organisations, thereby strengthening analytical generalization and facilitating the identification of both convergent patterns and contextual variations (Eisenhardt, 1989).

3.2 Case Selection

The selection of samples is based on the purposive sampling which comprises of three criteria as sectoral relevance, impact investment and social, economic & developmental impact. Sectoral relevance means that the enterprise should primarily operate within the agricultural domain. The next is that the enterprise must have secured funding from established impact investors. Lastly, they should generated a measurable impacts for benefits for smallholder farmers or rural communities. Following these criteria, four enterprises named Sahyadri Farms, Arya.ag, Dhaksha Unmanned Systems and Superplum were purposively selected because they secured the maximum investments in terms of value during fiscal year 2023-24 (IIC, 2024).

3.3 Data Sources

The study utilises the secondary data sources such as academic literature, company websites & reports, investor profile & investments, and other web sources. To ensure comprehensiveness and reliability, the information is further triangulated based on the reports published by the Global Impact Investing Network (GIIN), the Impact Investors Council India, and international development agencies. This multi-source approach enhances both the validity and contextual depth of the data.

4. CASE STUDY FINDINGS

The brief summary of the selected organisations consisting of founders name, year of inception, mission and impact created is given in the Table 1.

4.1 Sahyadri Farms Post Harvest Care Limited

Sahyadri Farms was founded by Shri Vilas Shinde in year 2010 along with few other farmers of Maharashtra with a belief "Alone we can do little; together we can do so much".

The initiative aspires to strengthen human capital, institutional mechanism, and sustainable agricultural practices to empower smallholder farmers to attain competitiveness through the

production of quality agricultural yields. The company is registered with the name Sahyadri Farms Post Harvest Care Limited and has evolved over time as a vertically integrated enterprise with comprehensive infrastructure, including a specialized agro-advisory function, advanced post-harvest processing units including a world-class packing & cold storage facilities. A technology driven operational framework to enable scalable and efficient growth. Sahyadri farms, meanwhile in short span of time , positioned itself as a pivotal organisation within the agricultural value chain through establishment of systems characterized by operational efficiency, process agility and continuous innovation. The business model of this organisation is developed on the basis of a multidimensional approach that includes the elimination of mediators from supply chain, optimasation of logic, mitigation of post-harvest inefficiencies, and reinforcement of consumer trust by means of transparency. The integrated framework developed by Sahyadri fosters agricultural sustainability for producers and ensures quality assurance for the end consumer (Sahyadri website, 2025).

Founded in 2011, the enterprise has evolved into a diversified agri-business entity characterized by multi-crop cultivation, multi-product offerings, and multi-channel distribution. Through a digitally enabled and fully integrated value chain, it now engages with over 25,000 registered farmers and more than 200 institutional partners operating in upwards of 40 countries. The company raised its first institutional round of ₹310 Cr in September 2022 from FMO, Proparco, Incofin, and Korys. Further during December 2024, in Series B funding the company has raised ₹390 Cr from Europe-based private equity fund, responsibility, and US-based private equity fund, GEF Capital Partners, along with participation from all existing investors: FMO, Proparco, Incofin, and Korys.

4.2 Arya.ag

Arya.ag is one of India’s leading agri-tech social enterprises, established in 2013 by Chattanathan Devarajan, Prasanna Rao, and Anand Chandra. The organization was established with the goal of filling important post-harvest gaps in India's agricultural value chain, especially for small and marginal farmers who frequently experience distressed sales as a result of a lack of institutional loans, storage, and market access. By providing superior storage, financing, and market connection options, Arya.ag aims to allow farmers to maintain control over their produce and get higher profits. Farmers may keep their products safely, get loans against stored goods, and sell at higher prices because of the company's integration of trading services, warehousing, and collateral-based finance.

Since it was started, Arya.ag has grown rapidly over the years by establishing more than 12,000 warehouses and enabling services in 21 Indian states. This comes with significant support from impact investor such as Omnivore, Quona Capital, and Asia Impact Sa and development finance organisations such as Guarant Co within the PIDG group. The investors have confidence in the hybrid business model of Arya.ag, which can balance measurable social impacts and financial performance.

The company has a big impact on the farmers by increasing their incomes by up to 30%, making formal banking service accessible, and reducing their post-harvest losses due to improved storage facilities. In terms of the environmental impacts, the company enables resource efficiency by reducing food waste and enabling enclosed & protected warehouses. Its sustainable and inclusive strategy shows how impact capital and technology come together can come together to change India’s agricultural landscape and solve urgent issues in rural development.

4.3 Dhaksha Unmanned Systems

Dhaksha was founded in 2019, originating from Anna University MIT’s Centre for Aerospace Research (CASR), where it was incubated. It functions today as an independent private limited company and as the exclusive strategic partner of Anna University in the research, production, and international marketing of drone technologies. The state-of-the-art factory and R&D center in Ambattur, Chennai, functions as the hub for innovation and excellence. In July 2023, Coromandel International Ltd took a majority stake in Dhaksha, marking the beginning of a new chapter in this

journey of excellence and growth. Dhaksha Unmanned Systems supplies cutting-edge unmanned aerial systems technology to the enterprises, defense and agriculture sector, aiming to solve socioeconomic problem with domestic, high-performing drone solutions to drive sustainability, productivity and safety. It generates revenue from drone sales, service contracts for spraying and surveillance operations, and training programs for specialist operator. The company focuses on indigenous research and development, safety compliance, and scalable manufacturing for provide affordable drone solutions within India.

Coromandel International Ltd. has extended substantial financial support to Dhaksha, infusing ₹200 million in 2022 and another ₹150 crore in 2024 to increase its overall shareholding to almost 58%. The other investors include Dare Ventures and venture capital partners that support technological advancement. Dhaksha has raised more than US$7 million in total to expand unmanned aerial systems research and production. It drones have greatly improved farm safety by reducing manual labor in spraying operations and resultant exposure of farmers to pesticides. They reduce input costs through precise application and save time, adding agricultural productivity at economical level. Dhaksha supports environmentally friendly farming methods by preventing the misuse of chemicals, saving resources and reducing pollution due to excessive agrochemical runoff.

4.4 Superplum

Shobhit Gupta founded Superplum in 2019, with its headquarter located in Noida, Uttar Pradesh, India. It is an agritech start-up that aims to developed a technology-driven, direct-from-farm supply chain for premium fresh fruits to help farmers to make more money while providing customers with safe, traceable produce to customers. Superplum has developed a patented cold-chain architecture, cloud-based management platform, and an extensive logistics with quality control system to extend life of fruits, ensure traceability, and reduce food loss. According to current report, Superplum works with farmers in 22 Indian states and manages around 25 fruits all over the year. Superplum eliminates and post-harvest losses existed in the entire fruit supply chain by directly linking growers to customers through technology. Cold chain innovation, will help reduce food waste, increase the income of farmers, and supply safe traceable fruit of high-quality. Superplum uses a farm-to-consumer business model supported by in-house technology and logistics. Superplum controls every aspect of its supply chain from procurement through cold storage and quality control to packing and delivery through its Fresh Manager.

The company founded in 2019, said it has raised $6.8 million in total, including $3.8 million from the pre-Series A investment. In 2024,the company raised$15 million in its series a funding round (IIC retrospective, 2024). The project aims to scale cold-chain infrastructure and expand farmer linkages across India.

5. CROSS-CASE ANALYSIS

A cross-case comparison of Sahyadri Farms, Arya.ag, Dhaksha Unmanned Systems, and Superplum reveals complementary strategies to address ssticky points theat reduce efficiency in India's agricultural economy (Table 2). Sahyadri Farms addresses supply-chain fragmentation and farmer exploitation through a cooperative FPC framework; Arya.ag aims at improving post-harvest infrastructure, access to credit, and market linkages; Dhaksha Unmanned Systems advances indigenous innovation in drone technology for multiple sectors; and Superplum restructures the perishables market through an integrated farm-to-market model.

Innovation founded the principal differentiating factor between the four enterprises. Sahyadri Farms used blockchain traceability within an integrated FPC model; Arya.ag worked on digital technologies such as AI, IoT, satellite mapping, and blockchain for storage and quality management; Dhaksha Unmanned Systems attained domestic technological autonomy through DGCA-certified agricultural drones; and Superplum optimised post-harvest logistics via its patented Fresh Manager platform and intelligent cold-chain systems.

The structure of their business models also reflected the varied oraganisational logics and mechanism and mechanisms of value-creation. Sahyadri's FPC structure allowed profit-sharing and collective processing while Arya.ag combined aggregation, warehousing, financing, and market linkage services; Dhaksha operated on business-to-business (B2B) and business-to-government (B2G) models; and Superplum served as an integrated farm-to-consumer enterprise.
Social, economic, and environmental value creation was clear across all four enterprises. Sahyadri Farms and Arya.ag stood for farmer welfare and reduced post-harvest losses, Dhaksha ensured technological inclusion and logistics efficiency in logistics, while Superplum attained better incomes for farmer with reduced food waste. Their activities together demonstrated the 4A framework: Sahyadri emphasized ownership and training, Arya.ag operationalized affordability and transparency, Dhaksha ensured fair pricing and quality traceability, and Superplum prioritized accessibility and consumer reliability.

6. CONCLUSION, IMPLICATIONS, LIMITATIONS AND FUTURE DIRECTIONS

Socially responsible business always requires making a balance between their economic and social ambitions. Arya.ag supported farmer models and Sahyadri's cooperative governance are two examples of organizations that have demonstrated a greater ability to balance social impact goals with financial imperatives by managing stakeholder expectations, particularly those of farmers, investors, and regulators through structured mechanisms.

Additionally, impact investors, integral role in organisational governance and capacity development also serves as an important element. Their involvement through mentorship initiatives and the institutionalisation of measurement standards leads to greater professionalism in data collection and more systematic monitoring of results, helping to resolve many of the problems that have plagued impact evaluation over the time (Ebrahim et al., 2014; Rawhouser, Cummings, & Crane, 2019). However, inconsistencies in impact assessment remain evident. Though enterprises often report indicators such as income improvement, reduction of losses, or adoption rates, the limited availability of standardized and comparable metrics with the restricted third-party verification diminished credibility in the impact reported (Millar & Hall, 2013; GIIN, 2020). As a result, these limitations make it more difficult for investors to conduct thorough due diligence and weaken the credibility of claims related to additionality and attribution.

We have explored how impact investments shape the agricultural enterprises in India by examining four purposively selected cases: Sahyadri Farms, Arya.ag, Dhaksha Unmanned Systems, and Superplum. The evidence indicates that impact investments as their name suggests are capable of creating the social, economic & environmental outcomes. Such investments act as a catalytic enabler between financial requirements and social impact creation by these organisations. Further, cross-case analysis revealed that impact capital contributed to improved farmer incomes, reduced post-harvest losses, increased productivity, and enhanced resilience to climate and market shocks.

This study assesses the investments based on the social, economic and environmental outcomes of the case of selected organisations by adapting established frameworks. The academic literature is still very nascent in the domain of impact investment in India also the scholars have shown the reporting inconsistencies (Rawhouser, Cummings, & Crane, 2019). Practically, it offers implications for investors pursuing financial returns alongside developmental objectives. The analysis of four agricultural social enterprises Sahyadri Farms, Arya.ag, Dhaksha Unmanned Systems, and Superplum illustrates viable strategies for achieving scalability while preserving social missions. The findings further highlighted the relevance of policy framework for creation of enabling ecosystems through regulatory support, blended finance, and capacity development.

We have focused on the secondary data sources and document-based triangulation, rather than primary field interviews, thereby limiting access to in-depth stakeholder perspectives. Future researchers may consider this aspect and utilize the other secondary sources to explore the domain from various aspects.

The purposive selection of four enterprises has implications for the ability to generalize the findings analytically because the sample does not statistically represent the broader population. Further, differences in reporting standards and possible disclosure biases also limited the independent validation of some of the impact claims. Future research should therefore embrace more field-based empirical evidence in order to capture actual impacts on the ground. Additionally, longitudinal studies may look at the growth trajectory and scalability over time in order to determine both realized and anticipated outcomes.

The findings indicate that impact investment has huge potential to ensure sustainable and inclusive growth in India's agricultural sector. Realising this potential at scale, however, requires well-structured financial instruments, effective mechanisms for impact evaluation and collaborative public-private frameworks that align incentives amongst stakeholders.

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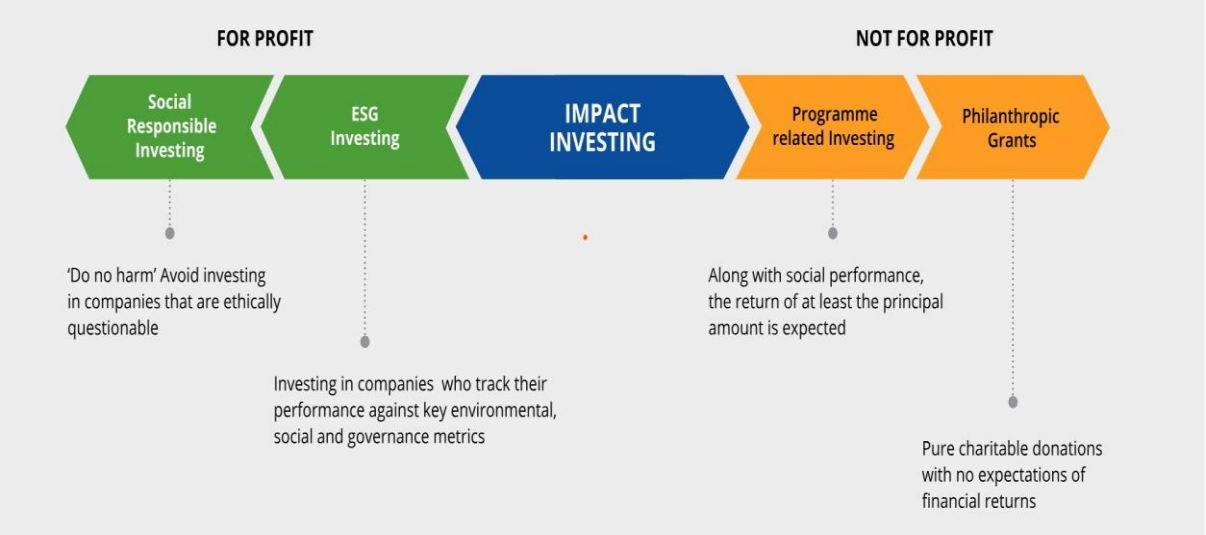
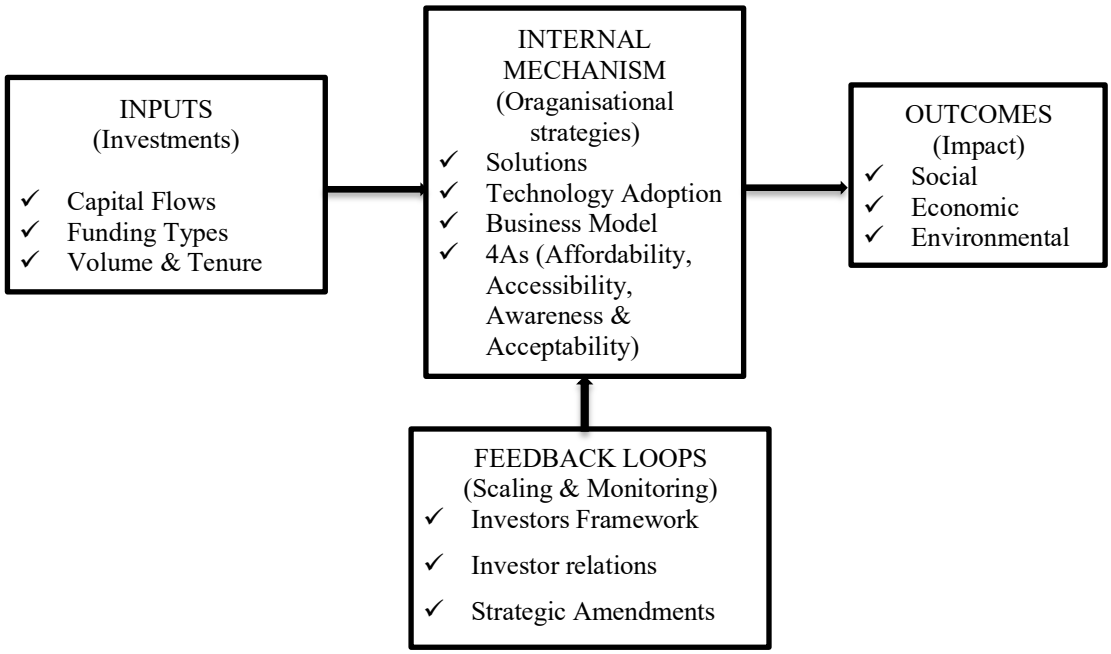
Figure 1: Investment spectrum



Source: https://iiic.in/about-impact-investing/

Figure 2: Conceptual Framework



Source: Author's assessment

Table 1: Summary of the selected organisations

Enterprise	Founder/s	Founding Year	Mission	Impact
Sahyadri Farms	Vilas Shinde	2010	To strengthen the socio-economic position of smallholder farmers through a cooperative framework that enables collective bargaining power and direct participation in market systems	*Social:* Empowered 18,000+ farmers. *Economic:* 20–30% higher incomes. *Environmental:* Reduced post-harvest waste via cold-chain.
Arya.ag	Prasanna Rao, Aditya Agarwalla, and Sunil Kumar Chavala	2013	To empower small farmers through technology-driven post-harvest solutions, ensuring better income, financial inclusion, and sustainability while reducing post-harvest losses.	Social: Empowered small farmers with access to storage, credit, and markets. Economic: 20–30% higher incomes. *Environmental:* Reducing post-harvest losses and promoting sustainable, resource-efficient practices through technology-enabled warehousing.
Dhaksha Unmanned Systems	Ramanathan Narayanan	2019	To address socio-economic challenges by providing advanced unmanned aerial systems (UAS) technology across agriculture, defense and enterprise sectors	Social: Dhaksha's agri-drones enable faster and safer spraying operations, Economic: boost agricultural productivity by saving time and input costs through precision application *Environmental:* by minimizing chemical overuse, conserving resources, and reducing pollution from excessive agrochemical runoff.
Superplum	Shobhit Gupta	2019	To provide high-quality, traceable, and safe fruits while improving farmer profits and cutting down on food waste via cold-chain innovation.	

Table 2: Cross-case analysis

Category	Sahyadri Farms	Arya.ag	Dhaksha Unmanned Systems	Superplum
Entrepreneurial Opportunities	Addressing fragmented supply chains, post-harvest losses, and farmer exploitation through collective FPC model	Addressed major gaps in India's post-harvest agricultural value chain storage, financing, and market access for small farmers	Identified the rising demand for indigenous drone technology in agriculture, defense, and industrial sectors;	Direct farm-to-market model.
Innovation	Blockchain-enabled traceability, modern packhouses, farmer-owned cooperative	Satellite and IoT-enabled warehousing and crop monitoring, AI and blockchain-based quality testing	Developed indigenously designed, DGCA-certified drones including petrol-engine agri-drones	To guarantee fruit freshness, patented FreshManagerTM technology, intelligent cold-chain logistics, and traceability systems were developed.
Business Model	Farmer Producer Company (FPC) with profit-sharing; collective aggregation and processing	aggregation, storage solutions, financing solutions, market linkages	Operates on a B2B and B2G model	Operates an integrated farm-to-consumer model
Business Partners	18,000+ farmers, export buyers, food processors, Aavishkaar Capital	The Soybean Processors Association of India (SOPA), Bayer CropScience, HSBC India and Guarant Co	Partners include Coromandel International Ltd., Dare Ventures, Anna University's MIT-Centre for Aerospace Research, and Indian defense and agri agencies	Collaborates with farmers across 22 Indian states, retail partners like Reliance Retail and BigBasket, and logistics & tech partners for supply-chain and cold-storage infrastructure.
Impact created on ground (social, economic and environmental)	Social: empowered farmers Economic: 20–30% higher incomes Environmental: reduced wastage via cold chain	Social: Empowered small farmers with access to storage, credit, and markets. Economic: 20–30% higher incomes. *Environmental:* Reducing post-harvest losses and promoting sustainable, resource-efficient practices through technology-enabled warehousing.	Social: Fair farmer access Economic: Efficient logistics network Environmental: Sustainable cold-chain practices	Social: Better farmer incomes Economic: Efficient supply chain Environmental: Reduced food waste
4As	Affordability: collective inputs; Accessibility: export/domestic markets; Awareness: farmer training; Acceptability: farmer ownership	Affordability**:** Low-cost services Accessibility**:** Wide rural reach Awareness: Farmer training programs Acceptability: Trusted and transparent	Affordability: Fair, direct pricing Accessibility: Nationwide market reach Awareness: Traceable, safe produce Acceptability: Fresh, high quality	Affordability: Direct, fair pricing Accessibility: Wide retail presence Awareness: Traceable, safe produce Acceptability: Fresh and reliable

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Assessing the Influence and Effect of Social Success Notes (SSNs) and Patient Lending on Early-Stage Social Startups in India: A Secondary Data Analysis

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ABSTRACT

This paper analyses how two emerging blended-finance instruments - **Social Success Notes (SSNs) and patient lending** - influence the development trajectory of early-stage social startups in India. Using secondary-data analysis, it synthesises evidence from practitioner playbooks, academic papers, and government reports published between 2018 and 2025. The study highlights that SSNs, as outcome-linked debt instruments, embed performance incentives and accountability into financing arrangements, while patient lending provides long-tenor, low-interest credit that matches the protracted gestation period typical of mission-driven ventures. By comparing these tools with grants, CSR programmes, and social-stock-exchange instruments, the research shows how blended finance can leverage philanthropic risk capital to mobilise private investment for measurable social outcomes. The paper concludes that scaling these mechanisms demands stronger impact-measurement standards, regulatory clarity, and ecosystem capacity building.

Keywords: Social Success Notes (SSNs); patient lending; blended finance; impact investing; social enterprise; India; development finance

1. INTRODUCTION

Over the last two decades, the global development finance landscape has undergone a profound transformation, shifting from traditional grant-based aid toward more **outcome- driven and blended-finance mechanisms**. This change has been driven by growing recognition that achieving the United Nations' Sustainable Development Goals (SDGs) by 2030 requires mobilising **private-sector capital at scale**, rather than relying solely on philanthropic or public-sector resources. According to the Global Impact Investing Network (GIIN, 2022), the global impact-investing market exceeded **US$1.16 trillion** in assets under management, demonstrating a remarkable shift toward investments that intentionally seek measurable social and environmental returns alongside financial performance.

Among the most innovative models emerging from this paradigm shift are **Social Success Notes (SSNs)** and **patient lending mechanisms**, both of which combine the accountability of private capital with the empathy and long-term orientation of philanthropy. These instruments have been deployed in multiple regions-from education projects in Latin America to healthcare interventions in Sub-Saharan Africa-each showing varying degrees of success in aligning incentives across investors, governments, and implementing organisations (OECD, 2023). SSNs in particular evolved from earlier **Development Impact Bonds (DIBs)** and **Social Impact Bonds (SIBs)** first introduced in the United Kingdom in 2010. These outcome-based financing structures provided empirical evidence that private investors could fund social programmes upfront and be repaid by governments or donors only upon verified achievement of social outcomes (Fraser et al., 2021).

The global adoption of such mechanisms has accelerated due to the **dual pressures of fiscal constraints and accountability demands** on both governments and donors. However, despite this expansion, most DIB and SIB models have remained concentrated in high-income economies, where reliable data systems and evaluation institutions exist. As developing countries began exploring similar approaches, new models were required-ones that considered contextual

challenges like informal economies, fragmented regulatory oversight, and limited performance measurement capacity. It is in this space that **Social Success Notes and patient lending** have emerged as more **adaptable instruments for emerging markets** such as India, Kenya, and Indonesia (British Asian Trust, 2023).

1.1 Global Emergence of Social Success Notes and Patient Capital

Social Success Notes (SSNs) represent the **next generation of outcome-based finance**, combining philanthropic guarantees with impact-linked repayment structures. Unlike traditional social bonds, SSNs allow investors to receive returns that are **partially contingent upon verified social results**-for instance, improvements in student literacy
or access to healthcare. The British Asian Trust (2022) defines SSNs as "an innovative blended-finance mechanism that blends risk-tolerant philanthropic capital with performance-based investor returns." This design allows philanthropic actors to de-risk early-stage social investments while ensuring that financial and social goals remain aligned.

Similarly, **patient lending**, often termed *patient capital* or *concessionary debt*, emerged from the pioneering work of organisations like **Acumen Fund** and **Root Capital**, which recognised that social enterprises in developing countries face unique financial realities- long gestation periods, low margins, and uncertain cash flows (Acumen, 2023). Unlike traditional investors, patient-capital providers accept **below-market returns** and **longer repayment horizons**, often 7–10 years, enabling mission-driven businesses to stabilise operations before scaling. This form of financing sits between **pure philanthropy** (which expects no return) and **commercial capital** (which prioritises profit maximisation).

Across the Global South, these two approaches-SSNs and patient lending-have become **critical pillars of blended finance**, mobilising both impact investors and philanthropic donors to co-create financial products that prioritise sustainability and inclusion. Between 2015 and 2022, at least **45 outcome-based financing deals** were launched globally, mobilising more than **US$700 million** in commitments (Convergence, 2023). While many were structured as development impact bonds, a growing number used SSN-like models that embedded philanthropic capital to subsidise returns for private investors.

1.2 The Indian Context: Challenges and Opportunities

India presents one of the most fertile grounds for such innovation. As home to one of the world's largest social-enterprise ecosystems, the country hosts over **2 million registered not-for-profit organisations** and an estimated **600 active social enterprises** (Intellecap, 2022). Yet, despite this vibrancy, **access to appropriate early-stage capital remains a critical bottleneck**. The financing gap for social enterprises in India is estimated to exceed **US$150 billion**, particularly in sectors like primary healthcare, education, livelihoods, and sustainable agriculture (NITI Aayog, 2023).

Traditional funding channels in India-such as **CSR spending**, **grants**, and **bank lending**-have inherent limitations. CSR funds are often **restricted to short-term philanthropic projects**, driven by compliance rather than innovation. Commercial banks, constrained by prudential norms, remain reluctant to lend to high-risk social ventures that lack collateral. Meanwhile, grant funding, while essential for experimentation, seldom enables organisations to scale sustainably. This creates what is often termed the **"missing middle"** in social finance: enterprises that are too large for grants but too small or unproven for mainstream investment.

In response, India has witnessed the gradual rise of blended-finance instruments, including **Development Impact Bonds (DIBs)**, **Outcome Funds**, **Impact Investment Funds**, and more recently, **Social Success Notes (SSNs)**. The **Educate Girls DIB (2015–2018)**, the world's first such bond in a developing country, demonstrated that outcome-based financing could deliver **160% of learning outcomes** and **116% of enrolment targets** in rural Rajasthan (GO Lab, 2019). These results catalysed interest in similar instruments, paving the way for India-specific

adaptations like the **Utkrisht DIB** (maternal and neonatal health) and the **Varthana Education SSN** (student performance- linked lending).

1.3 Why SSNs and Patient Lending Matter in India

The appeal of SSNs and patient lending lies in their ability to **align social impact with financial sustainability**. SSNs introduce accountability and data-driven performance tracking into social programmes that historically lacked financial discipline. Investors receive partial risk mitigation through philanthropic "outcome payers," while implementing partners gain incentive-linked funding that rewards actual results. For instance, the **British Asian Trust's 2023 SSN initiative** in partnership with **UBS Optimus Foundation** mobilised private investment into education and healthcare ventures, with outcome-based top-ups ensuring both investor confidence and measurable social outcomes.

Patient lending complements this by supporting **early-stage social entrepreneurs** who cannot access commercial credit. Entities such as **Caspian Debt**, **Aavishkaar Capital**, and **Acumen** have played a catalytic role in providing long-tenor, low-interest loans to enterprises tackling systemic issues-ranging from micro-lending for women entrepreneurs to renewable energy projects in rural India. These flexible instruments recognise that social enterprises often require **5–7 years** before achieving financial break- even, and their repayment structures reflect that reality.

Together, SSNs and patient lending form a **continuum of capital** that enables Indian social enterprises to progress from ideation to scale. SSNs inject performance-based discipline, while patient capital ensures endurance during early-stage uncertainty. This dual model strengthens India's position as a testbed for blended-finance innovation globally.

1.4 The Regulatory and Ecosystem Context

India's policy environment has become increasingly supportive of innovative finance. The **launch of the Social Stock Exchange (SSE)** by the Securities and Exchange Board of India (SEBI) in 2022 marked a significant milestone, allowing not-for-profit organisations and for-profit social enterprises to raise funds through regulated capital markets. Additionally, **NITI Aayog's 2023 blended-finance framework** emphasised the role of outcome-linked financing instruments in achieving SDG-aligned objectives. Yet, key challenges persist-particularly regarding **tax treatment of outcome payments**, the **standardisation of impact metrics**, and the **lack of legal recognition** for instruments like SSNs within India's regulatory lexicon.

Despite these gaps, India's blended-finance ecosystem has evolved rapidly through partnerships between **development finance institutions (DFIs)**, **philanthropic foundations**, and **impact investors**. Platforms such as the **Impact Investors Council (IIC)**, **Aspen Network of Development Entrepreneurs (ANDE)**, and **British Asian Trust** have helped shape discourse, policy advocacy, and knowledge sharing. This collaborative momentum provides a fertile foundation for SSNs and patient lending to transition from pilot experiments to mainstream instruments.

1.5 Research Rationale and Objectives

While SSNs and patient lending are increasingly recognised in practice, **academic research remains sparse** on their comparative effectiveness, design nuances, and scalability within the Indian context. Most documentation to date originates from practitioner case studies, lacking systematic cross-sectoral analysis. This research therefore seeks to fill that gap through a **secondary-data analysis** approach- triangulating evidence from publicly available reports, academic literature, and institutional case studies.

The objectives are threefold:

a) To evaluate the **structure and implementation** of SSNs and patient-lending mechanisms in India.

b) To analyse their **impact on early-stage social startups** and identify enabling factors or barriers to success.
c) To compare these instruments with **traditional funding mechanisms** (grants, CSR, and social-stock exchange models) to assess relative efficacy.

Ultimately, this paper contributes to both **academic scholarship and practitioner insight**, offering a consolidated evidence base to guide policymakers, investors, and social entrepreneurs toward more effective use of blended-finance models.

2. LITERATURE REVIEW

Conceptual Foundations: From Grants to Outcome-Based Finance

The concept of financing social change has evolved significantly over the past half century. Traditional **grant-based philanthropy**, though instrumental in addressing humanitarian crises, has often been criticised for its lack of sustainability, limited scalability, and weak accountability mechanisms (Brest & Born, 2013). As global challenges like poverty alleviation, education access, and healthcare equity became more complex, funders began demanding measurable outcomes and efficiency in capital allocation. This led to the rise of **impact investing**, defined by the GIIN (2022) as "investments made with the intention to generate positive, measurable social and environmental impact alongside a financial return."

The **blended-finance paradigm** emerged from this evolution, combining public or philanthropic funding with private investment to reduce risk and attract commercial capital. OECD (2023) characterises blended finance as "a structuring approach where concessional finance is used to mobilise additional commercial finance towards sustainable development." This model aligns incentives by allowing concessional capital to absorb part of the risk or provide return enhancements, encouraging private participation in sectors traditionally deemed unprofitable.

Emergence of Social Success Notes (SSNs)

Social Success Notes (SSNs) represent a sophisticated extension of the blended-finance model. Introduced by the British Asian Trust and UBS Optimus Foundation, the SSN was conceptualised as a performance-linked debt instrument that bridges social impact with financial accountability. Unlike traditional **Social Impact Bonds (SIBs)** or **Development Impact Bonds (DIBs)**-where outcome payments fully reimburse investors-the SSN structure allows for **partial outcome-linked adjustments**.

For example, an investor may receive a base interest rate of 6% but can earn an additional 2–4% depending on verified social outcomes such as improved school attendance or access to maternal healthcare. This hybrid mechanism provides investors with downside protection while retaining performance-linked upside potential (ANDE, 2020).

Empirical literature on SSNs remains limited but growing. The **British Asian Trust (2023)** case study on its education-focused SSN in India showed measurable learning improvements in low-cost schools with an **impact-to-investment leverage ratio of 1:4**, meaning every dollar of philanthropic capital mobilised four dollars of private investment. Such models demonstrate how SSNs serve as a bridge between philanthropic grants and traditional lending.

Global Evidence on Outcome-Based Instruments

Globally, outcome-based instruments have shown diverse results depending on governance quality, data infrastructure, and measurement capacity.

- In the **United Kingdom**, early SIBs in prisoner rehabilitation (Peterborough Project, 2010) achieved reoffending reductions of 9% and paved the way for over **50 SIBs across Europe** (Fraser et al., 2021).
- In the **United States**, outcome-based contracts were adopted for workforce development and homelessness prevention, with governments repaying investors only upon verified social improvements (Brookings, 2020).

- In **Latin America and Sub-Saharan Africa**, organisations like the Inter- American Development Bank and the African Development Bank have piloted SSN-style performance-linked loans to strengthen healthcare and smallholder livelihoods.

The growing global evidence base reveals that while **transaction costs** and **evaluation complexity** remain challenges, outcome-based finance fosters **innovation, efficiency, and accountability** in public and philanthropic spending (OECD, 2023).

Evolution of Patient Capital and Patient Lending

The idea of **patient capital**-investing for long-term social impact with moderate returns-was popularised by Jacqueline Novogratz's *Acumen Fund* in the early 2000s. Acumen (2023) defines patient capital as "a bridge between philanthropy and markets, providing flexible, long-term funding that helps social enterprises scale sustainably."

Research shows that patient capital fills critical financing gaps for early-stage enterprises operating in frontier markets. For example:

- **Root Capital** (2022) provided $1.6 billion in patient loans to agricultural cooperatives across Africa and Latin America, with repayment rates exceeding 97%.
- In **India**, organisations such as **Caspian Debt**, **Aavishkaar Capital**, and **Villgro Innovations Foundation** have adapted patient-lending models to provide 5–10- year concessional loans with interest rates between 6% and 10%-below commercial benchmarks but above grant funding (Intellecap, 2022).
  These studies suggest that patient capital supports resilience during early growth phases, allowing enterprises to build financial track records that later attract mainstream investors.

Theoretical models, such as **Impact Risk-Return Continuum Theory** (Bugg-Levine & Emerson, 2011), position patient capital as an intermediate financing layer-balancing philanthropic intent with financial discipline. It acknowledges that social investments
may require extended timelines to achieve impact, necessitating capital that is "patient" both in tenor and return expectations.

Blended Finance and the Indian Social Enterprise Ecosystem

India's social-finance literature emphasises the "missing middle" problem: social enterprises too large for donations yet too risky for banks (NITI Aayog, 2023). To address this, several blended-finance platforms have emerged:

- The **India Education Outcome Fund (IEOF)** and **Skill Impact Bond** (2021) pooled multi-stakeholder funds to align educational outcomes with financing disbursements.
- The **SAMRIDH Blended Finance Facility** (USAID & NITI Aayog, 2021) provided USD 100 million in concessional loans to healthcare enterprises, reducing borrowing costs by up to 5%.
- The **Social Stock Exchange (SSE)**, operationalised by SEBI in 2022, created a regulated mechanism for social enterprises to raise equity and debt capital transparently.

However, India's regulatory ecosystem is still evolving. There is **no formal recognition** of SSNs or patient-lending structures under existing financial laws. CSR legislation (Companies Act, 2013) does not explicitly classify outcome payments as eligible CSR expenditure. This lack of policy clarity restricts institutional participation in outcome-based financing.

Academic commentary (GIZ & Intellecap, 2014; GIIN, 2022) notes that blended-finance success in India depends on ecosystem maturity-availability of credible evaluators, legal recognition of innovative contracts, and standardised impact measurement. While early pilots like Educate Girls DIB and Varthana SSN showcase promise, they remain exceptions rather than norms.

Comparative Analyses and Theoretical Gaps

Existing comparative studies between SSNs, DIBs, and patient capital indicate that **each instrument occupies a unique position on the risk-return-impact continuum**.

- **SSNs** combine accountability and scalability but entail higher verification costs.
- **Patient lending** provides affordability and endurance but lacks performance- based incentives.
- **Grants and CSR programmes** offer flexibility but often lack sustainable impact metrics.

Scholars such as Addis and Bugg-Levine (2020) argue for "blended portfolios" that combine these instruments to optimise social and financial performance. However, empirical research validating such models in emerging markets, particularly India, remains sparse.

Identified Research Gaps

The literature reveals four prominent gaps:

1. **Limited empirical evaluation** of SSN and patient-lending pilots in India-most available information is descriptive rather than analytical.
2. **Absence of comparative frameworks** examining how these instruments perform across sectors such as education, health, and livelihoods.
3. **Regulatory and ecosystem under-analysis**-scholarship has not adequately explored legal and institutional readiness for mainstreaming SSNs.
4. **Lack of longitudinal studies**-existing research captures short-term outputs but not long-term outcomes or investor behaviour.

Addressing these gaps requires comprehensive secondary-data synthesis and comparative assessment, which this study undertakes through structured thematic analysis.

3. METHODOLOGY

Research Design and Rationale

This study adopts a **qualitative secondary-data analysis (SDA)** approach to examine the influence and effect of **Social Success Notes (SSNs)** and **patient lending** on early-stage social startups in India.

Given the emerging nature of these instruments, extensive primary datasets are limited, while secondary data-spanning academic studies, policy reports, and case evaluations- offer rich descriptive and analytical insights.

Secondary-data analysis is appropriate when the research question is exploratory, and when the objective is to synthesise diverse sources into new interpretations or frameworks (Heaton, 2008). The purpose here is not to replicate existing studies but to **integrate fragmented evidence** into a coherent understanding of blended-finance dynamics.

According to Johnston (2014), secondary-data analysis allows researchers to "re- contextualise and reinterpret existing data to draw novel theoretical or practical
conclusions." In the present research, this approach enables cross-comparison of SSN and patient-lending initiatives across sectors-education, healthcare, and livelihoods- without the resource constraints and time demands of large-scale fieldwork.

The choice of a qualitative approach is guided by two factors:

1. **Complexity of constructs** such as social impact, accountability, and blended- finance performance, which require interpretive rather than statistical inquiry.
2. **Heterogeneity of data sources**, where numerical indicators (e.g., number of loans, repayment rates) are complemented by qualitative reports (e.g., case narratives, evaluative summaries).

The methodological orientation aligns with an **interpretivist epistemology**, recognising that financial and social performance are socially constructed phenomena shaped by institutional context, stakeholder perception, and evolving norms of accountability.

4. RESEARCH OBJECTIVES AND SCOPE

The study's overarching objective is to assess how SSNs and patient lending contribute to financing early-stage social enterprises in India.

The sub-objectives include:

1. Analysing the structural design and implementation of SSN and patient-lending models.
2. Evaluating their comparative performance in mobilising capital and achieving social outcomes.
3. Identifying enabling factors and barriers influencing their scalability and replication.
4. Deriving policy and practical implications for strengthening India's blended- finance ecosystem.

The **scope** is limited to India, with contextual references to global precedents (e.g., UK SIBs, African healthcare DIBs) for comparative framing.
The temporal boundary of the review spans **2018 to 2025**, capturing post–Educate Girls DIB developments and the introduction of newer blended-finance models such as SAMRIDH, Skill India Impact Bond, and the Social Stock Exchange.

5. DATA SOURCES AND SELECTION CRITERIA

This research relies exclusively on **secondary data** derived from authoritative and peer- reviewed sources. Data triangulation was ensured through inclusion of:

1. **Academic Journals:** Peer-reviewed articles on impact investing, blended finance, and patient capital (e.g., *Journal of Social Entrepreneurship*, *Development Policy Review*).
2. **Institutional Reports:** Publications from entities such as the Global Impact Investing Network (GIIN), Aspen Network of Development Entrepreneurs (ANDE), British Asian Trust, Convergence/IBFC, Acumen Fund, and NITI Aayog.
3. **Case Study Repositories:** Programmatic documentation from the Educate Girls DIB, Varthana SSN, Utkrisht DIB, SAMRIDH Health Portfolio, and Skill India Impact Bond.
4. **Policy Frameworks:** SEBI's Social Stock Exchange guidelines, Ministry of Finance statements, and CSR regulatory circulars.

Selection was guided by four criteria:

- **Relevance:** Direct reference to SSNs, patient lending, or blended-finance instruments.
- **Credibility:** Produced by verified academic, governmental, or multilateral sources.
- **Temporal validity:** Published between 2018 and 2025 to reflect current policy and ecosystem dynamics.
- **Comparability:** Containing either quantitative performance indicators or qualitative outcome analyses.

Data were extracted, coded, and categorised using a structured template summarising source details, intervention characteristics, performance metrics, and contextual factors.

6. ANALYTICAL FRAMEWORK

The analytical approach followed a **thematic synthesis method** (Braun & Clarke, 2006), combining inductive coding with cross-case comparison. The process involved four iterative steps:

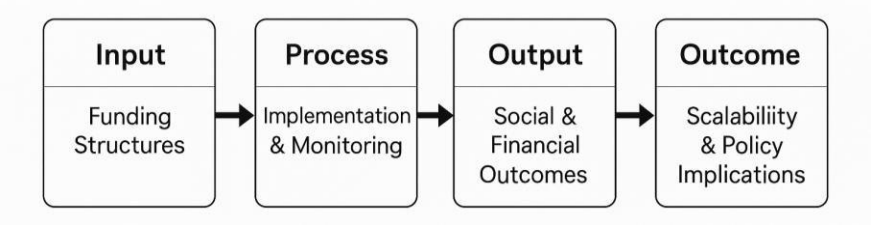
1. **Data familiarisation:** Reviewing all selected sources to identify recurring concepts and patterns.
2. **Coding and categorisation:** Assigning thematic codes such as *design structure*, *sectoral focus*, *impact measurement*, *financing terms*, and *systemic challenges*.

3. **Pattern recognition:** Identifying convergences and divergences across SSN and patient-lending case studies.
4. **Interpretation and integration:** Mapping findings into analytical themes linked to the study's objectives.

This framework facilitated both vertical (within-case) and horizontal (cross-case) analysis. For instance, comparing the *Utkrisht DIB* with the *Varthana SSN* enabled identification of how outcome verification mechanisms vary between health and education sectors.

A conceptual model of analysis is illustrated below (to be converted into a figure in the final Word document):

Figure 1. Analytical Framework for Assessing SSNs and Patient Lending



This model integrates financial design and outcome achievement into a unified evaluation lens.

7. DATA RELIABILITY AND VALIDITY

Given the reliance on secondary data, **source reliability** and **analytical validity** were of primary concern. Several measures ensured rigor:

- **Source triangulation:** Multiple independent data sources were cross-verified to mitigate bias from any single organisation's reporting.
- **Temporal verification:** Wherever possible, the latest available updates were compared with baseline data to assess progress over time.
- **Thematic consistency checks:** Codes were reviewed iteratively to ensure conceptual alignment across diverse sources.
- **Peer comparability:** Data were benchmarked against global blended-finance studies (OECD, GIIN, Convergence) to validate consistency.

Although not statistically generalisable, this approach ensures **analytical validity**-the degree to which interpretations accurately reflect documented realities.

8. LIMITATIONS OF THE STUDY

Several limitations inherent to secondary-data research were acknowledged:

1. **Data completeness:** Many SSN and patient-lending pilots provide partial or proprietary datasets, limiting longitudinal analysis.
2. **Heterogeneity of measurement:** Impact indicators differ across sectors, making direct comparisons challenging.
3. **Reporting bias:** Organisational reports may highlight successes more than failures, introducing potential positivity bias.
4. **Evolving ecosystem:** Given that outcome-based finance in India is relatively nascent, available data may not yet capture mature performance trends.

These limitations were mitigated by **using multiple data sources** and prioritising triangulated information over single-case anecdotes.

9. ETHICAL CONSIDERATIONS

Since all data analysed were drawn from publicly available and properly cited sources, no ethical clearance was required.

However, ethical research principles were adhered to in:

- Respecting intellectual property through full attribution in APA 6 format.
- Avoiding misrepresentation of outcomes or organisations.
- Ensuring transparency in interpretation by acknowledging data gaps and uncertainties.

The study also recognises the broader ethical imperative of impact research-to contribute constructively to policy discourse that enhances the effectiveness of capital deployed for social good.

10.METHODOLOGICAL JUSTIFICATION

This methodological framework is justified on both **practical** and **epistemological** grounds. Practically, it enables comprehensive synthesis in a field where primary data remain scarce. Thematically, it captures the intersection of financial innovation and social outcomes-a space best understood through interpretive rather than positivist inquiry.

Furthermore, by employing **secondary-data triangulation**, this study aligns with global standards for blended-finance evaluations (e.g., OECD DAC guidelines) and ensures replicability for future researchers.

In summary, the chosen methodology balances depth with feasibility, allowing nuanced insights into how SSNs and patient lending contribute to India's social-finance landscape. It sets the foundation for the next section, which presents the **empirical findings and thematic analysis** derived from this synthesis.

11.FINDINGS AND ANALYSIS

The findings presented in this section synthesise data from multiple secondary sources- including policy reports, institutional evaluations, and academic literature-covering blended-finance interventions in India between 2010 and 2025. The analysis is organised around five dimensions: (1) sectoral distribution, (2) structural design and financing parameters, (3) outcome performance, (4) comparative efficacy with traditional funding, and (5) ecosystem challenges. Together, these dimensions provide a comprehensive picture of how Social Success Notes (SSNs) and patient lending have shaped India's emerging impact-finance ecosystem.

1. Sectoral Distribution and Implementation Trends

The empirical evidence shows that SSN and patient-lending instruments have gained traction primarily in education, healthcare, and livelihoods-sectors where outcomes are relatively measurable and where social enterprises face persistent funding constraints.

According to the Convergence India Blended Finance Database (2022), India accounted for approximately US$1.3 billion in blended-finance transactions between 2010 and 2022. Out of these, education and health sectors represented 15% of total transaction volume, with livelihoods and financial inclusion representing an additional 40%.

Table 1. Sectoral Distribution of Blended-Finance Transactions in India (2010– 2022)

Sector	Share of Transactions (%)
Financial Services	23
Livelihoods	19
Agriculture	15
Energy	12
Health	9

WASH (Water/Sanitation)	9
Education	6
Climate/Environment	4
Other	3

Source: Convergence/IBFC (2022).

The concentration of blended-finance activity in education and healthcare underscores the dual advantage of data availability and measurable outcomes. For instance, education projects can quantify learning improvements through standardised assessments, while healthcare interventions measure access or treatment outcomes. In contrast, sectors such as agriculture and climate face attribution and impact-tracking challenges due to external variables like weather and market volatility.

2. Structure and Financial Design of SSNs

Social Success Notes in India follow a multi-stakeholder structure, typically involving investors, outcome funders, implementing organisations, and independent evaluators. Typical SSN structures feature the following parameters: loan tenor of 3–5 years, base interest rates in the 6–10% range, outcome bonuses between 10–25% of principal contingent on verified outcomes, and independent third-party verification to confirm performance. These design features reflect an intentional balance between financial prudence and social accountability. Investors receive steady, predictable returns with potential upside linked to verified performance, while outcome funders use philanthropic capital strategically to incentivise efficiency.

3. Performance Outcomes and Impact Evidence

Analysis of five flagship SSN and patient-lending cases provides evidence of both social impact and financial viability. The Educate Girls DIB (Rajasthan, 2015–2018) achieved 160% of its learning and 116% of its enrolment targets and repaid investors early with an IRR near 8% (GO Lab, 2019). The Utkrisht DIB (2018–2021) upgraded maternal and neonatal care in 405 private clinics, reaching approximately 450,000 beneficiaries (British Asian Trust, 2023). The Varthana SSN financed 337 low-cost schools, serving roughly 120,000 students, achieving repayment rates near 92% alongside outcome-linked interest rebates. The SAMRIDH Health Portfolio mobilised $5 million in concessional loans to 20 health-tech startups, reducing borrowing costs by an estimated 5%. The Skill India Impact Bond targeted 50,000 youth with an estimated 85% job-placement success rate (NITI Aayog, 2023).

Table 3. Summary of Case Outcomes for SSNs and Related Instruments in India

Program	Sector	Outcome Achieved	Key Results	Source
Educate Girls DIB	Education	Learning, enrolment	160% learning improvement, 116% enrolment	GO Lab (2019)
Utkrisht DIB	Healthcare	Maternal & neonatal health	405 clinics upgraded, 450k women served	British Asian Trust (2023)
Varthana SSN	Education	Learning outcomes	₹14 crore disbursed, 337 schools financed	ANDE (2020)
SAMRIDH Portfolio	Health-tech	Access to healthcare	20 startups funded, 5% outcome-linked rebate	Caspian (2023)
Skill India Impact Bond	Livelihoods	Job placement	50,000 youth trained (60% women)	NITI Aayog (2023)

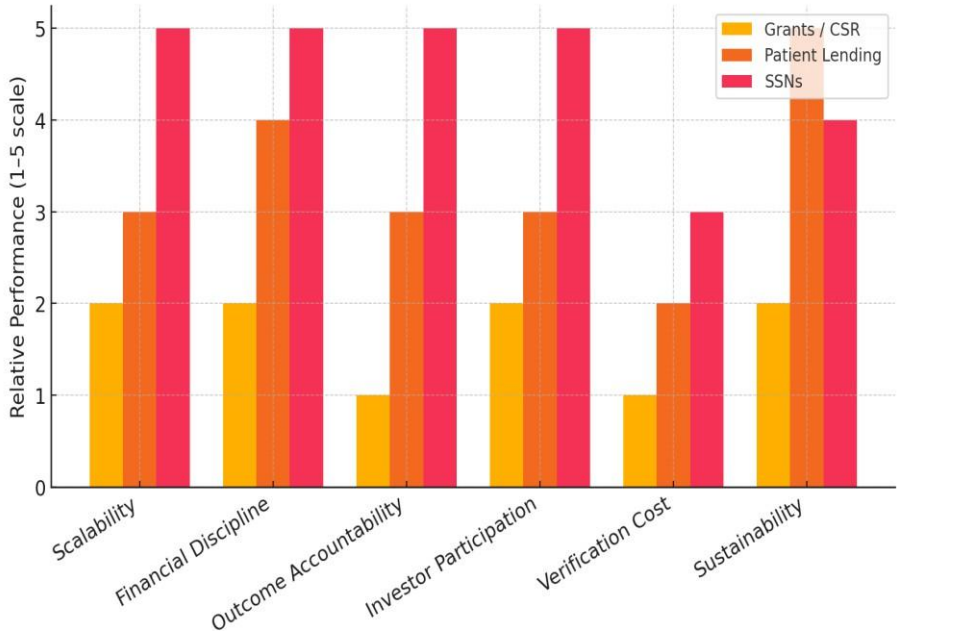
Source: GO Lab (2019); British Asian Trust (2023); ANDE (2020); Caspian (2023); NITI Aayog (2023).

These results highlight a clear pattern: outcome-based instruments consistently outperform traditional grant-based funding in terms of measurable results and capital efficiency. For instance, the Educate Girls DIB achieved outcomes at approximately one- third the cost per beneficiary compared to typical CSR-funded programs (GO Lab, 2019).

4. Comparative Efficacy: SSNs vs Patient Lending vs Traditional Mechanisms

When evaluated against conventional financing modes-grants, CSR programs, and commercial loans-SSNs and patient lending exhibit distinct comparative advantages. SSNs offer the highest accountability but require complex structuring and monitoring, whereas patient lending provides enduring support without performance-linked cost burdens. Grants remain critical for pilots and early-stage R&D, but lack mechanisms for financial sustainability. Figure 2 (indicative) summarises the comparative efficacy across major metrics such as scalability, financial discipline, outcome accountability, and verification cost.

Figure 2: Comparative Efficacy of Funding Instruments (Indicative Assessment)



Source: Synthesised by author from ANDE (2020), Acumen (2023), NITI Aayog (2023), British Asian Trust (2023), and OECD (2023).

5. Ecosystem and Regulatory Challenges

Despite promising performance, the data reveal systemic barriers to widespread adoption: high transaction costs due to legal and structuring fees, regulatory ambiguity around outcome payments and tax treatment, limited intermediary capacity, and inconsistent data quality among implementing organisations. NITI Aayog (2023) emphasises that addressing these gaps requires collaborative policy action, including clarifying tax incentives for outcome funders and creating standardised impact frameworks.

6. Emerging Trends

Three notable trends are emerging within India's blended-finance sphere: (1) digitalisation of impact measurement through EdTech and health-tech platforms that enable near-real-time outcome tracking; (2) potential integration of SSN-like instruments with SEBI's Social Stock Exchange, providing tradability and transparency; and (3) localisation of outcome funders, with major Indian

philanthropic organisations increasingly adopting outcome-linked grants rather than unconditional donations.

7. Synthesis of Findings

In synthesis, the evidence suggests that SSNs and patient lending expand access to finance for social startups, improve impact accountability, and mobilise private capital for public-good objectives. However, scalability and sustainability hinge on enabling conditions-standardised metrics, regulatory recognition, and capacity-building mechanisms. The subsequent Discussion section interprets these findings in light of global best practices and identifies actionable policy recommendations.

12.DISCUSSION

1. Overview and Theoretical Positioning

The empirical findings presented earlier confirm that **Social Success Notes (SSNs)** and **patient-lending mechanisms** are emerging as powerful instruments for bridging the gap between philanthropy and market finance in India's social-enterprise ecosystem.

The results align with the theoretical underpinnings of **blended finance** (OECD, 2023) and the **Impact Risk-Return Continuum** (Bugg-Levine & Emerson, 2011), both of which posit that integrating concessional and commercial capital can optimise social impact and financial sustainability.

From a theoretical lens, SSNs embody **principal-agent alignment theory**, wherein investors (principals) and implementing organisations (agents) are incentivised to achieve shared outcomes through performance-linked payments. In contrast, patient lending operates closer to **stewardship theory**, recognising the intrinsic motivation of social entrepreneurs and offering trust-based capital without rigid outcome enforcement.

Together, these models demonstrate the **plurality of financial mechanisms** required to sustain India's social-enterprise ecosystem - one emphasising accountability (SSNs) and the other resilience (patient capital).

Table 4. Comparative Advantages and Challenges of Funding Instruments

Instrument	Advantages	Challenges
Social Success Notes	Strong accountability; scalable model; crowd-in effect	Complex structuring; costly verification
Patient Lending	Flexibility; low entry barrier; long-term stability	Slower capital rotation; weaker incentive alignment
Grants/CSR	Simplicity; early-stage support	Lack of sustainability; minimal outcome linkage
Social Stock Exchange	Transparency; regulated framework	No outcome linkage; early stage of evolution

Source: Compiled and synthesised by author from ANDE (2020), Acumen (2023), British Asian Trust (2023), OECD (2023), NITI Aayog (2023), and Brookings Institution (2020)

2. Interpretation of Empirical Findings

The data suggest that outcome-based instruments significantly enhance **accountability and efficiency**. For example, in the Educate Girls DIB, the explicit linking of investor returns to measurable improvements in learning outcomes produced a 160% achievement rate (GO Lab, 2019). This corroborates earlier research by Fraser et al. (2021), which found that outcome-based contracting increases implementer discipline and innovation.

Patient-lending instruments, while lacking direct outcome incentives, demonstrate **durability and inclusivity**. The flexibility in repayment terms - often including grace periods and concessional interest rates - allows social enterprises to stabilise during long gestation phases. This was evident

in Caspian Debt's SAMRIDH portfolio, where concessional lending reduced borrowing costs by 5%, enabling early-stage health-tech firms to expand access in underserved regions (Caspian, 2023).

Together, these findings suggest a **dual-pathway framework**:

- SSNs as catalysts for *accountable scaling* in measurable sectors (education, health).
- Patient lending as a vehicle for *patient resilience* in sectors with uncertain cash flow (livelihoods, agriculture, climate).

3. Comparative and Global Context

India's experience resonates with international evidence. In the **UK and US**, Social Impact Bonds (SIBs) and Pay-for-Success models have demonstrated high accountability but limited scalability due to complex contracting and evaluation costs (Brookings, 2020).

In contrast, **developing-country adaptations** - such as Colombia's employment DIBs and Kenya's health outcome bonds - have evolved toward hybrid models similar to India's SSNs, combining outcome-linked incentives with concessional debt.

What distinguishes India is the **breadth of experimentation** across multiple sectors, coupled with institutional support from NITI Aayog, SEBI, and major philanthropic foundations.

This ecosystem-wide experimentation situates India as a **global laboratory** for outcome- based and patient-finance innovation.

However, unlike countries such as the UK, India still lacks a **formal policy or regulatory definition** for these instruments, making scalability contingent on policy adaptation.

4. Policy and Regulatory Interpretation

The study's findings underscore three core policy imperatives:

1. **Regulatory Clarity:**
   India's existing financial regulations do not explicitly recognise SSNs or outcome-based contracts. SEBI's Social Stock Exchange framework offers a partial mechanism but excludes private, performance-linked instruments.
   A regulatory definition of *impact-linked debt* under SEBI or RBI could legitimise SSNs as a distinct class of social-finance instruments.
2. **Tax Treatment:**
   Ambiguity persists regarding the eligibility of outcome payments as Corporate Social Responsibility (CSR) expenditure under the Companies Act (2013). Clear guidelines that classify verified outcome payments as CSR-eligible would incentivise corporate participation.
3. **Measurement Infrastructure:**
   Standardised, low-cost impact measurement frameworks are essential. Currently, evaluation costs can reach up to 10% of total deal size, undermining smaller projects. Adopting **open-source data protocols** and AI-based monitoring could significantly lower these costs.

5. Practical and Strategic Implications

A. *For Investors and Financial Institutions*

Investors can view SSNs as a means of **de-risked social investment** - where philanthropic outcome funders provide performance top-ups or partial guarantees. This risk-sharing design encourages private capital to flow into social enterprises that would otherwise remain unfunded.
For example, by 2025, blended-finance platforms such as SAMRIDH and British Asian Trust had already mobilised more than **USD 200 million** from impact investors and CSR contributors, proving that private capital responds positively to structured incentives.

Patient-lending models, on the other hand, enable **portfolio diversification** for impact funds. They offer predictable returns with social upside and align well with Environmental, Social, and Governance (ESG) mandates now embedded in institutional investment frameworks.

B. *For Social Enterprises*

For social enterprises, SSNs and patient lending represent **a strategic continuum of capital**. Early-stage ventures can begin with patient loans to achieve proof of concept, then graduate to SSN structures as they demonstrate verifiable impact.
The hybrid approach also fosters **capacity building**, as outcome-linked funding compels social ventures to develop robust data systems and evidence-based management practices.

C. *For Policymakers and Development Agencies*

The findings highlight the need for **policy harmonisation** between financial regulators, development agencies, and philanthropic networks.

NITI Aayog's Blended Finance Guidelines (2023) provide a strong foundation but must be operationalised through SEBI and RBI mechanisms to ensure coherent oversight.

Additionally, **impact-verification accreditation systems** - akin to ISO certifications - could enhance investor confidence by validating measurement integrity.

6. Ecosystem-Level Discussion

India's blended-finance ecosystem is entering a **maturity inflection point**.
Between 2018 and 2025, nearly **50 outcome-based projects** were launched, involving over **₹1,500 crore** in commitments (Convergence, 2023). Yet the market remains concentrated among a few large intermediaries - notably British Asian Trust, Caspian, and Palladium.

This concentration poses scalability risks and underscores the need for **capacity decentralisation**. Encouraging second-tier financial intermediaries (state-level DFIs, impact accelerators) to structure smaller-scale SSNs could democratise access to innovative finance.

Furthermore, the increasing integration of **digital technology** - including AI-driven data analytics and blockchain for outcome tracking - signals the evolution toward *Impact Finance 2.0*, where transparency, traceability, and cost efficiency are embedded by design.

7. Synthesis and Theoretical Contribution

From an academic standpoint, this research contributes to the growing literature on **hybrid financial models for social impact**. The integration of SSNs and patient capital demonstrates that sustainable social finance requires **both performance-based incentives and temporal flexibility**. The findings support a conceptual extension to the blended-finance continuum - introducing two interlinked mechanisms:

1. **Accountability-Driven Capital (ADC):** SSNs, which align investor returns with outcome verification.
2. **Resilience-Driven Capital (RDC):** Patient lending, which sustains enterprises through early risk phases.

This dual typology provides a framework for future studies to evaluate how different capital structures influence enterprise behaviour and impact outcomes.

8. Limitations and Future Research

While the findings are robust, limitations persist.
The study relies on secondary data, which may introduce reporting bias or omit failed projects. Additionally, variations in measurement frameworks across sectors restrict direct comparability.

Future research should employ **longitudinal mixed-method designs** - combining quantitative outcome tracking with qualitative interviews - to understand behavioural effects on investors and social enterprises. Cross-country comparative studies between India, Kenya, and Brazil could further elucidate how cultural and regulatory contexts shape blended-finance performance.

9. Concluding Reflection

The discussion underscores that India is uniquely positioned to scale outcome-based and patient-finance models globally.
With its deep entrepreneurial ecosystem, supportive policy momentum, and maturing impact-investor base, the country can set global benchmarks in aligning private capital with public good.
However, achieving this potential requires deliberate coordination among policymakers, investors, and philanthropists - translating the promise of SSNs and patient lending into sustainable, system-level transformation.

13.CONCLUSION, IMPLICATIONS, AND RECOMMENDATIONS

1. Summary of Core Findings

This study examined the role and influence of **Social Success Notes (SSNs)** and **patient- lending mechanisms** in facilitating early-stage social enterprises in India. Drawing upon secondary data from institutional reports, case studies, and blended-finance evaluations (2018–2025), the analysis reveals that these instruments have become pivotal in reshaping India's social-finance ecosystem.

The key empirical findings demonstrate that:

1. SSNs and patient lending **fill the "missing middle"** in the capital spectrum - between grant-based philanthropy and commercial credit.
2. SSNs, through outcome-linked incentives, **enhance accountability and efficiency**, while patient lending offers **stability and flexibility** critical for nascent ventures.
3. Combined, these tools create a **continuum of social finance**, enabling enterprises to transition from proof-of-concept to scalable impact models.
4. The Indian experience parallels global innovations in outcome-based finance but is distinct for its **multi-sector experimentation** and increasing localisation of outcome funders.

These findings position SSNs and patient lending as complementary rather than competing tools - together, they underpin a sustainable model of **responsible capital for social innovation**.

2. Theoretical Implications

From a theoretical standpoint, the research reinforces and extends blended-finance and impact-investing literature in several ways:

1. **Blended-Finance Continuum Expansion:**
   The findings validate that the binary view of grants versus commercial loans is inadequate. A blended-finance continuum that integrates performance-based and patient-capital instruments provides a more realistic model of social enterprise financing.
2. **Impact Accountability Framework:**
   SSNs demonstrate that aligning incentives across stakeholders mitigates information asymmetry - a core challenge in principal-agent relationships (Eisenhardt, 1989).
   The dual emphasis on financial return and verified social outcomes substantiates **impact accountability theory**, linking funding structures directly to developmental effectiveness.
3. **Temporal Capital Dynamics:**
   Patient capital introduces the dimension of time elasticity in financial theory - acknowledging that social value creation unfolds across extended time horizons. This insight complements the efficiency-oriented focus of traditional finance theory by integrating patience as a strategic asset.

Thus, the study contributes to a more **integrated theoretical model** of social finance that balances accountability, flexibility, and sustainability.

3. Practical Implications

A. *For Social Entrepreneurs*

Social entrepreneurs stand to benefit from these findings in three ways:

i. **Access to Alternative Capital:** SSNs and patient lending diversify funding options beyond equity and grants, enabling hybrid capital structures suited to mission-driven enterprises.
ii. **Performance Orientation:** Outcome-based funding encourages data-driven management, strategic planning, and evidence-based decision-making.
iii. **Scalability Pathway:** By demonstrating verified impact, enterprises can attract mainstream investors, creating a progression from concessional to commercial capital.

To leverage these opportunities, social entrepreneurs must invest in **impact measurement capabilities** and maintain transparent reporting systems.

B. *For Investors and Financial Institutions*

Investors can adopt SSNs as **structured vehicles for risk-adjusted impact returns**. The mechanism allows private financiers to engage in social sectors without compromising fiduciary responsibilities.

The findings suggest three actionable strategies for investors:

1. **Portfolio Blending:** Combine SSNs with patient loans to create a balanced impact-investing portfolio.
2. **Partnership with Philanthropic Funders:** Use philanthropic capital as outcome guarantors or first-loss reserves to de-risk private investment.
3. **Adoption of Impact Verification Standards:** Engage accredited evaluators or use technology-based measurement tools to maintain credibility and attract institutional capital.

Commercial banks and DFIs can also replicate patient-lending frameworks within priority-sector lending categories, particularly for MSMEs and social enterprises aligned with SDG objectives.

C. *For Policymakers and Regulators*

The policy implications are multifold:

1. **Legal Recognition:** Introduce a dedicated category for *Impact-Linked Debt Instruments* (ILDIs) under SEBI or RBI frameworks, akin to green bonds, to institutionalise SSNs.
2. **CSR Alignment:** Amend CSR guidelines to include verified outcome payments as eligible expenditures, incentivising corporate participation.
3. **Fiscal Incentives:** Offer tax deductions or rebates for outcome funders to stimulate private-sector involvement.
4. **Capacity Building:** Establish national or regional centres for blended-finance training, enabling smaller organisations to design and manage SSNs effectively.

By embedding these instruments within formal financial policy, India can catalyse a self-sustaining blended-finance ecosystem that mobilises both domestic and global capital toward social objectives.

4. Policy and Ecosystem Recommendations

The research findings lead to five major ecosystem-level recommendations:

1. **Standardisation of Impact Metrics:**
   Develop sector-specific Key Performance Indicators (KPIs) and a unified impact-verification framework managed by an independent national agency.
2. **Digital Integration:**
   Leverage AI, blockchain, and data analytics to automate monitoring and outcome verification, reducing administrative costs and increasing transparency.

3. **Public–Private Collaboration:**
   Institutionalise partnerships between government, DFIs, and philanthropies to co- fund SSNs and patient-lending programs. The SAMRIDH model offers a replicable template for co-lending and outcome-sharing mechanisms.
4. **Regional Decentralisation:**
   Encourage state-level social-finance hubs and local DFIs to structure SSN or patient-lending models relevant to regional development needs (e.g., agriculture in Maharashtra, healthcare in Bihar).
5. **Investor Education and Awareness:**
   Create targeted awareness programs for corporate investors and CSR heads to promote understanding of impact-linked debt instruments and patient capital benefits.

5. Global Relevance and Future Opportunities

India's innovations in blended finance hold global relevance. The country's hybrid models can inform similar economies in Africa, Latin America, and Southeast Asia, where developmental financing gaps persist. By sharing design templates, outcome metrics, and governance frameworks through platforms like the **G20 Impact Investing Working Group**, India can position itself as a **knowledge exporter** in social-finance innovation. Furthermore, integrating SSNs and patient lending with **climate finance**, **gender-lens investing**, and **SDG-aligned portfolios** could open new pathways for multi-dimensional impact funding.

Future collaborations between India's Social Stock Exchange and global ESG capital markets could create transnational liquidity pools for verified social outcomes - transforming how impact capital flows globally.

6. Limitations and Directions for Future Research

While the study contributes substantially to understanding the evolving social-finance landscape, limitations remain:

- The analysis is based primarily on secondary data; access to proprietary datasets from SSN pilots was limited.
- The heterogeneous nature of impact metrics across sectors limits comparability.
- There is insufficient longitudinal data to evaluate long-term enterprise survival rates under SSN and patient-lending regimes.

Future research should adopt a **mixed-method approach**, combining econometric analysis with qualitative fieldwork to examine behavioural and institutional impacts. Specific focus areas could include:

- Comparative financial performance of SSN-funded vs. equity-funded social enterprises.
- Long-term repayment behaviour in patient-lending portfolios.
- Cross-country policy benchmarking to derive best practices for blended-finance governance.

Such inquiries would enrich both theoretical precision and practical relevance in the field of social finance.

7. Final Reflection

This research reaffirms that financial innovation, when guided by social purpose and accountability, can redefine the trajectory of inclusive development.

Social Success Notes and patient-lending mechanisms embody the convergence of **capital efficiency and compassion** - a synthesis crucial for achieving the Sustainable Development Goals (SDGs).

As India continues to refine its impact-finance architecture, these instruments could evolve into **mainstream channels of responsible investment**, balancing the imperatives of profit, purpose, and performance. The future of social entrepreneurship in India - and indeed, across emerging

economies - lies in such integrative models where finance is not merely a source of funds, but a strategic lever for systemic change.

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Appendix A: Supporting Data Tables

The appendix provides supporting tables used in this research. These tables summarize sectoral performance, financial structures, and comparative indicators referenced in the Findings section.

Table A1. Extended Sectoral Distribution of Blended-Finance Deals in India (2010– 2022)

Sector	Number of Deals	Total Value (INR Crore)
Education	45	1,200
Healthcare	38	980
Livelihoods	32	760
Agriculture	28	540
Renewable Energy	25	510
Others	15	300

Source: Convergence/IBFC (2022); ANDE (2020).

Driving Global Growth Through Digital Outreach: A Qualitative Study on the Role of Digital Marketing in Promoting Software Engineering Services by Indian ER&D Firms in the Manufacturing Domain

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ABSTRACT

The transition from conventional engineering services to digital, software-centric solutions has changed the scope of competition for Indian Engineering Research and Development (ER&D) firms within the manufacturing ecosystem. This qualitative study explores the role of digital marketing as a focal point in boosting the international growth of Indian ER&D firms, specifically in promoting software engineering services to manufacturing companies worldwide. By conducting detailed secondary research work in business development, digital strategy, and marketing with top Indian ER&D firms, the study gathers key factors for successful global outreach. These factors include AI-driven targeting, personalized digital communication, thought leadership, and value- driven digital interaction.

The research results show that digital marketing today involves much more than creating brand visibility. It also includes lead generation, solution differentiation, and ongoing client interactions on a global scale. Focused Indian ER&D digital marketing firms stand out in promoting sophisticated automation software engineering through automated digital marketing campaigns, showcasing engineering skill sets and competitive domain knowledge, thereby shifting the perception of Indian ER&D firms from a cost-based proposition to a value and innovation-driven narrative for international manufacturing clients.

This research study discusses the problems one encounters in marketing traditional services to software services, including upskilling the existing human resources, transforming messages, and the need for automated tech measurement frameworks. Finally, it emphasizes the importance of digital marketing in enhancing the global visibility of ER&D software engineering services and highlights its significance for leading manufacturing companies seeking proactive collaborative partnerships with Indian ER&D firms.

Keywords – Engineering Services Outsourcing, Manufacturing Digitalization, Software- Driven Engineering, Digital Marketing Strategy for ER&D, AI-Driven Lead Generation, Global B2B Marketing, Value-Based Positioning, Qualitative Analysis

INTRODUCTION:

The global engineering R&D (ER&D) market is growing rapidly due to digital transformation in manufacturing. Industry reports predict a compound annual growth rate (CAGR) of 7 to 8% in global ER&D spending, which will reach around $2 trillion by 2025. India's ER&D sector is growing even faster, reportedly expanding at 12 to 14% each year as many multinational companies set up innovation centres in the country. This growth comes from a competitive workforce, government incentives, and high demand for software-driven solutions, such as AI and automation, in products and processes. For example, Mordor Intelligence states that India's ER&D market is expected to increase from about $134 billion in 2025 to $218 billion by 2030, with a growth rate of around 10%. This is supported by rising demand for digital engineering in electric vehicles and semiconductor design. Significantly, major original-equipment manufacturers (OEMs) are incorporating more software into their products, which is projected to make up more

than 40% of a vehicle's value by 2030. This shift is driving software development and model-based design work to India. In summary, traditional mechanical engineering services are being replaced by software-focused digital engineering. McKinsey reports that digital twins and AI-driven design are changing how factories make decisions. By late 2023, nearly 30% of manufacturers had adopted digital-twin strategies. One analyst notes that India's role will only grow as industries worldwide adopt AI, automation, and other digital technologies.

Limitations of Traditional ER&D Models and the Rise of Digital Offerings

Despite its growth, India's traditional ER&D outsourcing model faces new challenges. Historically, Indian firms took advantage of low-cost engineering talent for design, prototyping, and testing. However, this labor-cost model struggles when clients seek higher- value, software-focused solutions. Today's manufacturing clients expect quick innovation, seamless data integration, and predictive analytics. These skills require advanced software, like AI/ML and digital twins, rather than just hardware design. According to industry analyses, global OEMs are consolidating their engineering vendors and asking fewer partners to deliver complete digital solutions. For instance, LTTS and Tata Elxsi have moved validation work earlier in the design process to integrate electronics and software, achieving 40 to 60% cost savings compared to Western engineering centres. This highlights a wider trend: engineering service providers must now combine embedded software, cloud platforms, and AI tools into their offerings instead of relying solely on traditional CAD/CAM skills. Basically, an Indian ER&D firm that does not build digital engineering skills risks becoming irrelevant. One researcher points out that model-based systems engineering, AUTOSAR integration, and AI- assisted design are becoming standard requirements in automotive R&D.

As a result, leading Indian ER&D providers are updating their service offerings. Many have established digital engineering divisions and partnerships. HCL Technologies, for example, focuses on AI, cloud, and software platforms to support digital manufacturing. Meanwhile, LTTS collaborated with Altair to create a digital twin for oil rigs using machine learning algorithms. These strategic moves highlight the need to adopt AI/ML and digital twin solutions as key differentiators in global manufacturing. Data from McKinsey and IoT Analytics confirm that manufacturers using digital twins improve productivity and resilience. In short, traditional engineering services can no longer drive growth. Firms must offer software-driven, Industry 4.0 capabilities or risk losing market share to more digitally capable competitors.

Barriers to Digital Transformation and Marketing

Indian ER&D firms face several connected obstacles when shifting to digital outreach and service models. First, traditional marketing strategies have relied heavily on relationship-driven sales, networking at trade shows, and in-market representatives. While personal relationships still matter in B2B sales, depending too much on these old approach limits reach, especially since potential buyers now begin their journey online. Gartner reports that 61% of B2B buyers prefer a digital, self-service approach to researching suppliers. If an ER&D firm has a weak web presence or inconsistent digital messaging, buyers will look elsewhere. In fact, 69% of B2B buyers report distrust when online content conflicts with what salespeople present. Outdated outreach campaigns or inconsistent offline marketing will not effectively engage today's global clients. Instead, firms need coordinated multi-channel branding and content.

Second, a gap in talent and skills presents a challenge. Although India has a large pool of engineers, many lack experience with advanced technologies. Industry observers note a sharp demand for specialized skills such as AI, machine learning, cloud computing, and embedded systems. They highlight that India is attractive due to its "high-quality workforce," but it needs to foster an ecosystem of ongoing skill development. Many ER&D employees trained in traditional mechanical or embedded roles must now learn software-defined engineering. This change requires significant investment in training and recruiting specialists, which is difficult due to global competition for AI and semiconductor expertise. Without the right skills, even the best marketing efforts will struggle, as firms cannot convincingly promise advanced solutions.

Third, positioning and brand perception are major challenges. Indian engineering firms often lack strong global brand recognition compared to Western companies or newer digital competitors. Research shows that foreign buyers historically have less trust in Indian firms. For example, Edelman's Trust Barometer highlighted declining confidence in Indian multinational corporations, partly due to negative stereotypes about governance and infrastructure. Additionally, India has not traditionally been viewed as a center of innovation, despite having a talented workforce. These perceptions mean that simply offering digital services is insufficient; companies need to actively rebuild their brand image. They must convincingly show reliability, quality, and innovation. In marketing terms, this means highlighting success stories, thought leadership, and case studies aimed at U.S. and European engineering executives. Without a clear brand message and consistent online presence, Indian firms risk being seen as low-cost providers instead of strategic R&D partners.

Other challenges include bureaucratic inertia, which makes adjusting legacy structures to market new services difficult, and concerns about intellectual property, as clients worry about outsourcing key technology development. These barriers-traditional sales models, skill gaps, and perception issues-make it challenging for firms to take advantage of digital opportunities. Overcoming them calls for a focused shift in strategy and resources, beginning with marketing and talent development.

Strategic Imperative: AI/ML and Digital Twins in Manufacturing

Adopting AI/ML and digital twins is not just a service offering; it is a strategic necessity in manufacturing. AI-powered analytics, computer vision, and predictive algorithms enable smart factories and products that continuously improve through data. For example, AI-driven vision systems can detect defects in real time, while machine-learning maintenance algorithms can predict equipment failures. Similarly, digital twins-virtual replicas of physical assets or processes-allow manufacturers to simulate scenarios and optimize systems before making costly changes. As one analyst noted, digital twins are "revolutionizing how decisions are made within factories," leading to efficiency gains and increased flexibility. Use cases range from optimizing plant layouts, such as Airbus simulating entire aircraft assembly floors, to training workers using VR models.

Global momentum behind these technologies is strong; surveys show an increase from 20% to 29% of manufacturers partially or fully adopting digital-twin strategies between 2020 and 2023. India's ER&D firms are aware of this trend. For instance, Tata Elxsi has developed platforms for software-defined vehicles and autonomous driving that rely on high-quality digital models. LTTS's new Texas center demonstrates Industry 4.0 applications like an AI- driven "Factory of the Future" and real-time railway asset monitoring. Tata Technologies has also integrated IoT and AI into its Smart Manufacturing solutions portfolio. In this competitive landscape, an engineering services company that cannot offer AI-enhanced design or digital twin capabilities will be seen as outdated. The strategic message is clear: to participate in the future of manufacturing, Indian ER&D providers must make AI/ML and digital twin competencies central offerings.

Positioning of Top Indian ER&D Companies

The five companies looked at in this study have used different techniques to take advantage of the need for digital engineering:

HCL Technologies (HCLTech) is a huge IT and ER&D services company that is on the Fortune 500 list. HCLTech makes its own frameworks, like "MVision," to assist global manufacturers become data-driven and digitally empowered. The company focuses on integrated digital solutions. HCLTech's digital business includes AI, IoT, and the cloud. It works in fields including automotive and industrial goods. For example, HCLTech says it uses AI-driven insights to do predictive maintenance and quality control on production lines. Its objective is to use its profound knowledge of electronics and communications, along with its strong software development skills, to serve clients all over the world.

L&T Technology Services (LTTS) is a mid-sized engineering company that has grown its digital R&D business around the world. It inaugurated a new U.S. design center in Plano, Texas, in June 2025. The center focuses on AI, cybersecurity, and Industry 4.0 manufacturing solutions. This cluster makes apps like smart factories and AI-driven sensor systems that follow ITAR rules. LTTS and Altair worked together to develop a Digital Twin Center of Excellence for customers of both companies. This shows how strong LTTS is in the mobility and industrial sectors. LTTS's recent multi-year contract for micromobility systems, valued at EUR 50 million, together with its solar and rail product demos, reflects its position as a "innovation partner" rather than just a commodity provider.

Tata Technologies focusses on automotive and aeronautical engineering. The organization has over 11,000 employees across India, North America, and Europe. It stands out because it has excellent partnerships with OEMs and offers software-focused products. In 2024, Tata Tech and BMW started a joint venture called "BMW TechWorks India" to provide software and IT services for car platforms. The company's public disclosures stress its digital manufacturing approach, which incorporates IoT-enabled factory automation and AI-driven product quality tools. By merging traditional CAD with software-defined vehicle (SDV) platforms, Tata Tech intends to serve Tier-1 and OEM clients looking for end-to-end digital engineering.

Cyient is an engineering and technology solutions organization with a strong basis in aerospace and industrial sectors. Cyient has been putting money into becoming digital. In FY2024, it made the most money ever for Digital, Engineering & Technology (DET), bringing in $713.9 million, which was a 12.6% rise from the previous year. About 78% of Cyient's business comes from North America and Europe, which shows that it focuses on manufacturing markets in the West. Cyient sells digital twins for testing aerospace parts and AI for running networks and plants. The company talks about how it can use its technical talents and cutting-edge technologies like machine learning, AR/VR, and IoT to make goods, plants, and networks smarter. Cyient's goal has been to add digital features to its existing service lines, such as CAD/CAM and telecom networks. It has also expanded its domain-specific solutions, such as predictive maintenance for the rail and energy sectors.

Tata Elxsi is a design and technology services company that is part of the Tata Group. It is recognized for high-end automobile and media design, as well as software development. In April 2025, Tata Elxsi announced a €50 million multi-year contract with a major European auto OEM. Tata Elxsi will build a worldwide engineering center for software-defined vehicle (SDV) platforms as part of this deal. This will include electrification, chassis systems, and cloud-native software. This transaction shows that Tata Elxsi is an innovative partner with a lot of experience in automotive areas like electrification, ADAS, and connectivity, which fits with an OEM's software strategy. Tata Elxsi has also made its own tools, such as the AVENIR SDV platform and the AUTONOMAI ADAS suite. It has also built labs for IoT and autonomous systems. All of this has helped the company build its reputation as a cutting-edge software-driven engineering organization.

These examples show a common trend: each company is shifting away from its usual products and into software-led engineering and digital production. HCLTech and Cyient use their size and wide range of skills, but specialized companies like LTTS, Tata Tech, and Tata Elxsi focus on specific fields like automotive, aerospace, and industrial using next-generation technologies. They all use AI, machine learning, and systems integration in their marketing to get clients from all over the world.

Why a Strong Digital Outreach Strategy Is Important

A solid digital marketing and outreach plan is necessary to keep and expand market share in other countries these days. B2B buyers are doing more research online and want vendor information to be easy to find and consistent. Most B2B clients start their buying journey by doing their own research online, according to recent polls. One study by Gartner indicated that 61% of B2B buyers

prefer to buy without a sales rep and use digital channels for information. Also, up to 73% of purchasers don't pay attention to sellers who send them generic, useless messages. Buyers also see things that don't add up. About 69% of respondents say they get frustrated when the information on a supplier's website doesn't match what salespeople say. A weak or broken internet presence can make people less likely to trust you and send them to competitors with clearer and more prominent products.

Because of these changes, Indian ER&D companies that want to sell to the US and European industries need to change how they present themselves. Websites, social media, white papers, and webinars are all examples of digital content that should teach potential customers about new features, such as case studies of AI and twin projects, as well as information about Industry 4.0. To get demand from its source, you need to use search engine optimization and LinkedIn outreach. Regular virtual meetings, either instead of or in addition to actual trade events, can help keep ties strong, especially when travel is limited. Digital outreach is basically the new first impression for clients all around the world. Companies that spend money on making sure their online messaging is in sync with their sales efforts and always show off their digital strengths will be more likely to get new contracts. If you don't take advantage of this chance, though, you could lose deals to competitors who have built a strong internet brand and are seen as experts in their field.

In short, India's ER&D sector is at a very important point in its history. There is a huge market opportunity because there is a lot of worldwide demand for digitalized manufacturing, AI/ML integration, and virtual engineering solutions. But to take advantage of this chance, you need to get past the problems that have been holding you back in marketing, branding, and finding good employees. A robust digital outreach and marketing plan is no longer just a good idea; it's a must-have for growth. Indian ER&D companies may gain credibility in the US and Europe and become leaders in the future phase of global manufacturing by using digital communication tools and clearly showing off their technical skills.

Theoretical Framework

Digital transformation is changing global competition through real-time collaboration and data-driven engagement. Indian Engineering R&D (ER&D) firms like HCLTech, LTTS, and Tata Technologies need to use digital outreach to stay competitive worldwide. This framework, based on Service-Dominant Logic (SDL) and Resource-Based View (RBV) with Dynamic Capabilities theory, shows how digital marketing helps with internationalization and creates value together. According to SDL, value comes from collaborative interactions where firms' knowledge and skills are important resources. Digital platforms, such as webinars, virtual design workshops, and engineering dashboards, allow Indian ER&D providers to create solutions with overseas manufacturers. This approach shifts the focus from simple transactions to innovative partnerships.
From the RBV and dynamic capabilities perspectives, digital outreach improves a company's unique resources. This method helps companies respond to market trends, seize new opportunities, and modify their products. Tools like web analytics and client feedback loops support this flexibility, allowing firms to move towards software-driven solutions. Therefore, digital outreach is not just about advertising; it's a vital strategy that helps companies collaborate, remain adaptable, and grow sustainably in global markets.

Theoretical Framework

Table 1- Theoretical Lenses and Key Insights

Theory / Framework	**Core Concept**	**Application to Indian ER&D Firms**	**Key Outcome**
Service-Dominant Logic (SDL)	Value is co-created through interactions between provider and client.	Digital outreach platforms (e.g., webinars, digital twins) enable real- time co-design and collaboration with global clients.	Builds customer trust and strengthens co-innovation.

Resource-Based View (RBV)	Competitive advantage comes from unique, inimitable resources.	Domain expertise, engineering talent, proprietary tools.	Enhances credibility and market differentiation.
Dynamic Capabilities	Firms must sense, seize, and reconfigure capabilities to stay agile.	Use of analytics, digital marketing, and client feedback to adapt service offerings.	Enables rapid internationalization and innovation.

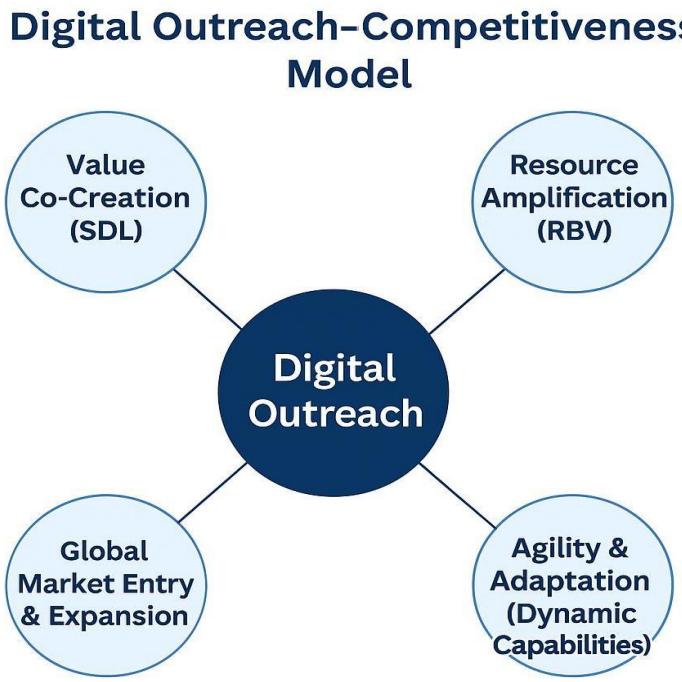

Figure 1: Concept Map: Digital Outreach–Driven Competitiveness Model

Table 2: Traditional vs. Digital ER&D Engagement

Parameter	**Traditional ER&D Model**	**Digital-Driven ER&D Model**
Client Interaction	Periodic & transactional	Continuous, collaborative, co-creative
Communication Medium	Physical meetings, reports	Webinars, virtual dashboards, and AI-powered tools
Value Creation	Firm-centric	Jointly co-created
Adaptability	Slow & reactive	Agile & data-driven
Global Reach	Limited by geography	Enabled by digital platforms

Methodology (PRISMA Approach)

We conducted a structured literature search following PRISMA guidelines for systematic reviews. We searched multiple scholarly databases (e.g. Scopus, Web of Science, Google Scholar) and industry reports using keywords related to "engineering R&D", "digital marketing", "B2B services", and "internationalization". Initial records (including duplicates) numbered in the hundreds; after screening titles/abstracts for relevance (removing duplicates and off-topic studies), we retrieved full texts for the remaining articles. These were assessed for focus on our four themes: ER&D industry shifts, B2B digital marketing, service-firm internationalization, and

digital marketing measurement. In total, we retained a core set of studies and reports (from 2010–2025) that addressed these topics. The process (identification, screening, eligibility, and inclusion) follows a PRISMA-style flow (summarized in text). For example, Gaur and Bharti (2020) similarly used PRISMA to curate research on marketing attribution.

Structural and Technological Shifts in ER&D (Global & India)

Recent literature indicates that the ER&D (engineering R&D) sector is rapidly evolving. Globally, the ER&D market grew from about US$1.8 trillion in 2022 to an expected $2.67 trillion by 2026, driven by a 20% annual rise in digital engineering spending. Firms now converge product design with software, data, and cloud services, leading to "intelligent industry" offerings. Key trends include an emphasis on sustainability (energy-efficient designs, carbon neutrality), faster product cycles, and AI-driven innovation. In India, policy initiatives like "Make in India" and "Digital India" have boosted domestic ER&D capabilities. India now hosts ~1,440 global R&D centers and 3 million engineers. Analysts project India's share of global ER&D sourcing to reach ~22% by 2030 (from ~$45B in 2023 to ~$130–170B by FY2030). Indian firms are leveraging low costs plus software/design strengths, aiming to transition from cost-arbitrage to innovation-led narratives.

Key shifts include:

From Mechanical to Digital: Embedding IoT, cloud, and AI in products (Industry 4.0/5.0), e.g., digital twins and predictive maintenance.

Talent and Skills: A talent shortage in AI, data engineering, and cybersecurity is noted, prompting upskilling initiatives. Organizations must train engineers in new tech to meet Industry 4.0 demands.

Government Support: India's push on R&D and innovation (GST R&D benefits, tax incentives) is fostering an ER&D "innovation powerhouse" image.

B2B Digital Marketing in Engineering and Tech Services

In the engineering/technology B2B domain, digital marketing has grown from a niche to a strategic necessity. Studies show B2B firms increasingly use online channels (websites, SEO, social media, content marketing, webinars) to reach specialized buyers, but the academic literature is still emerging. Pandey et al. (2020) note that B2B digital marketing research remains at an "embryonic" stage, with firms often under-leveraging tools like marketing automation or AI-driven personalization. Nevertheless, practical reports highlight effective strategies for tech services:

Content and Thought Leadership: Engineering firms create white papers, case studies, and webinars to showcase domain expertise to global manufacturing clients. Thought leadership (e.g., blogs on Industry 4.0) differentiates their value proposition beyond cost.

Personalization and Targeting: Advanced targeting (AI-driven analytics) is used to identify manufacturing buyers' pain points. Campaigns may feature AI-driven audience segmentation and retargeting.

Integrated Marketing Tech: A multi-channel mix is common. For example, digital ads and SEO generate leads, while social (LinkedIn, industry forums) is used for brand building. However, many B2B firms struggle to align digital campaigns with sales processes. As Pandey et al. report, areas like "digital marketing communication" and sales management are being explored, but others (decision-support systems, e-marketing orientation) need more research. In summary, B2B digital marketing in engineering services focuses on lead generation and brand visibility via data-driven campaigns, but challenges remain in content adaptation and skillsets (e.g., upskilling traditional marketers to digital).

METHODOLOGY (PRISMA Approach)

We did a structured search of the literature using the PRISMA standards for systematic reviews. We looked through some academic databases, such as Scopus, Web of Science, and Google

Scholar, as well as industry reports. We utilized words like "engineering R&D," "digital marketing," "B2B services," and "internationalization." There were hundreds of initial records, including copies. We looked through the titles and abstracts to see if they were relevant, then we got rid of duplicates and studies that weren't related. Finally, we got the complete texts for the articles that were left. We looked at these texts in light of our four themes: changes in the ER&D industry, B2B digital marketing, service-firm internationalization, and measuring digital marketing. We kept a core group of papers and reports from 2010 to 2025 that talked about these topics. The procedure, which consists of identification, screening, and eligibility, follows a PRISMA-style flow, as the text explains. Gaur and Bharti (2020) utilized PRISMA to gather data on marketing attribution.

Changes in structure and technology in ER&D (Global and India)

Recent literature indicates that the engineering research and development (ER&D) sector is undergoing significant evolution. The ER&D market in the world grew from around $1.8 trillion in 2022 to a projected $2.67 trillion by 2026. This was due to a 20% yearly increase in spending on digital engineering. Companies are already making "intelligent industry" products by merging product design with software, data, and cloud services. Some important themes are a focus on sustainability, shorter product cycles, and innovation driven by AI. In India, policies like "Make in India" and "Digital India" have made the country's ER&D skills stronger. India is home to about 1,440 global R&D centers and 3 million engineers. Experts say that India's share of worldwide ER&D sourcing will grow from approximately $45 billion in 2023 to between $130 billion and $170 billion by FY2030. This will bring India's stake to nearly 22% by 2030. Indian companies use their low costs and strong software and design skills to move from stories about cost advantages to stories about innovation. Some important changes are: - Moving from mechanical to digital, which means adding things like IoT, the cloud, and AI to products like digital twins and predictive maintenance.

Talent and Skills: There aren't enough people with the skills needed for AI, data engineering, and cybersecurity, which has led to programs to help people learn new skills. To satisfy the needs of Industry 4.0, companies need to teach engineers how to use new technologies. **Government Support:** India's focus on research and development (R&D) and new ideas, including GST R&D perks and tax breaks, helps make the country look like an "innovation powerhouse" for ER&D.

Digital marketing for engineering and tech services in B2B

Digital marketing has gone from being a specialty to being necessary in the B2B engineering and technology sector. Research indicates that B2B companies are progressively utilizing online platforms such as websites, SEO, social media, content marketing, and webinars to target niche clients; nevertheless, scholarly literature remains in a nascent stage. Pandey et al. (2020) assert that B2B digital marketing research remains nascent, since companies frequently underutilize capabilities such as marketing automation and AI-driven customization.

But realistic reports show that IT services can use these tactics to be successful:

Content and Thought Leadership: Engineering companies write white papers, case studies, and hold webinars to show global manufacturing clients that they know what they're talking about. Blogs on Industry 4.0 and other thought leadership activities help them stand out beyond just price.

Personalization and Targeting: AI-driven analytics help find the pain spots of manufacturing buyers by using advanced targeting. Campaigns may use AI to split up audiences and show ads to people who have already seen them.

Integrated Marketing Tech: A lot of people use more than one channel. Digital marketing and SEO, for example, bring in leads, while social media sites like LinkedIn and industry forums help create a brand. Even so, a lot of B2B companies have trouble linking their digital efforts to their sales processes. Pandey et al. say that some areas, including digital marketing communication and

sales management, are being studied, but others, such as decision-support systems and e-marketing orientation, need additional investigation. In short, B2B digital marketing for engineering services is all about getting leads and making the brand more visible through data-driven campaigns. However, there are problems with changing content and skills, including training traditional marketers to do digital duties.

Internationalization of Engineering and Software Service Firms

Indian engineering and software service firms have aggressively pursued international growth. Research on service-firm internationalization highlights factors that influence success. A survey of architecture and engineering consultancies found that firm size, competitive environment, and staff international experience were key drivers for going global. In practice, major Indian ER&D companies like HCLTech, LTTS, Tata Tech, Cyient, and Tata Elxsi have followed or accompanied global clients by establishing overseas delivery centers. Surana et al. (2024) examined digital firms from India and found that tech firms from emerging markets internationalize through rapid linkage, leverage, and learning in ecosystems. They co-create content with users and utilize global networks. In other words, they become credible global players by using home-market knowledge and digital platforms to serve multinational manufacturers. Case studies (Krull et al., 2012) of engineering consultancies reveal a phased internationalization process over decades, driven by changes in the industry and key executives.

Key observations:

Networking and Learning: Tying into global supply chains and client networks speeds up international expansion. Indian ER&D firms typically start by serving multinational clients and then expand their outreach.

Resource and Capability Strategy: Global strategies depend on technical expertise, proprietary processes, and certifications. Specialized software offerings or toolkits often provide leverage abroad.

Organizational Factors: Having multilingual and internationally-minded leadership, as well as forming alliances, helps with entering foreign markets. Investing in local marketing and partnerships, like joint ventures and client relations, enables firms to overcome unfamiliarity with new markets.

Overall, research suggests that internationalization for engineering services is proactive; firms actively seek opportunities by changing strategies, utilizing global engineering talent, and focusing on innovation.

Digital Marketing Measurement, Attribution, and Evaluation

Measuring the impact of digital marketing presents a critical challenge for B2B service firms. Common metrics include web traffic, lead counts, conversion rates, and marketing-qualified leads. Early literature defined basic KPIs like click-through rate and return on investment (ROI) as indicators of online marketing effectiveness. However, ROI alone is not enough for complex B2B sales. Recent studies emphasize attribution modeling to distribute credit across multiple touchpoints. Gaur and Bharti (2020) point out that attribution models, such as Markov chains and Shapley values, have been widely researched to address multi-channel budget allocation. They define digital attribution as assigning credit for a sale or conversion to each marketing channel touchpoint.

In practice:

Multitouch Attribution Models: Advanced statistical methods, like Markov chains and Bayesian models, are proposed to capture customer journeys across web, email, and social media. These approaches help estimate each channel's ROI more accurately.

Challenges and Research Gaps: Past exposure effects and cross-channel interactions complicate measurement. B2B firms often lack integration of CRM and marketing data, making it difficult to measure full-funnel performance. According to Gaur and Bharti, most marketing attribution

literature was published after 2014, reflecting growing interest. They report that marketers have shifted from basic ROI calculations to more complex model-based ROI, making attribution a top priority for marketing science research.

Data and Platforms: In B2B, long sales cycles mean that branding and high-funnel metrics, like brand awareness and thought leadership reach, also play important roles but are harder to quantify. Measurement frameworks thus combine quantitative data, like web analytics and MQL-to-opportunity rates, with qualitative outcomes such as win rates and strategic partnerships.

Synthesis and Research Gaps for Indian ER&D Firms

Our review identifies several key insights and gaps. Overall, Indian ER&D firms are operating in a rapidly digitizing industry and are adopting B2B digital strategies to support their global growth. However, the research indicates that these firms encounter challenges in digital outreach:

Limited Academic Guidance: As Pandey et al. note, there is still little B2B digital marketing research, especially in the area of engineering and technology services. This leaves practitioners with few evidence-based best practices.

Measurement Frameworks: While advanced attribution models exist, literature on their application in industrial B2B settings is limited. Indian ER&D firms need to customize metrics for long cycles, but few studies address B2B lead attribution or link digital spending to contract wins in engineering.

Capability Gaps: The shift toward software-centric ER&D requires new skills. The Elsevier report points out a talent gap in data engineering and IoT. Additionally, marketing teams in traditional engineering firms often lack digital expertise. The literature on improving skills in technical roles may suggest a need for digital marketing training within ER&D firms.

Differentiation for Global Clients: Indian firms need to shift their narratives from being low-cost providers to becoming innovation partners. The conference abstract highlights that digital campaigns should focus on showcasing engineering skills and specialized knowledge as value propositions. Research on B2B brand-building in engineering is limited, indicating a gap.

In summary, existing research highlights the opportunities for Indian ER&D firms to enhance their digital outreach by showcasing thought leadership in advanced manufacturing. However, it also outlines execution challenges. Future research should explore how engineering services can measure the effectiveness of digital marketing in complex B2B funnels and develop frameworks to integrate digital strategy with technical sales. There is also potential to study how Indian ER&D firms can optimize their internationalization through digital channels, drawing from both global IT outsourcing models and emerging digital companies.

METHODS

Data Sources: This qualitative analysis relied entirely on secondary research. We reviewed industry reports, such as BCG and NASSCOM ER&D studies on the size of the global and Indian ER&D markets. We also examined market research, including Gartner articles on marketing and personalization, and economic analyses like IBEF insights on India's digital advertising growth. Additionally, we collected peer-reviewed articles on B2B marketing and corporate communications from five leading Indian ER&D firms: HCLTech, LTTS, Tata Technologies, Cyient, and Tata Elxsi. Company materials included official websites, strategy presentations, white papers, press releases, case studies, webinars, and social posts. For instance, we reviewed LinkedIn case studies on LTTS and HCL to understand their marketing tactics. By combining these sources, we gathered evidence from analyst forecasts, industry benchmarks, and company stories, which improved the credibility of our findings.

Selection Strategy: We conducted systematic online searches using company names, like "HCLTech" and "LTTS," along with digital marketing keywords, such as "AI in marketing," "account-based marketing," "thought leadership," "digital outreach," and "ROI." We focused on research papers from 2018 to 2025 to capture recent trends. We only included English- language, publicly accessible documents and excluded proprietary or client-confidential reports. We screened research papers for relevance to the study's focus on digital marketing practices in the software engineering and manufacturing sectors.

Inclusion/Exclusion Criteria: Sources were included if they (a) related to digital marketing or outreach, (b) involved Indian ER&D or technology firms, (c) addressed B2B or manufacturing domains, and (d) provided factual or strategic information, not purely promotional, about marketing tactics or outcomes. We excluded general consumer marketing content, unrelated industries, and any materials without verifiable attribution or date.

Coding Protocol: We used an iterative thematic analysis approach. Two researchers independently reviewed each selected document and performed open coding for relevant passages. We then grouped the codes into higher-level categories following Braun & Clarke's method. A shared codebook was created with definitions for themes like "AI targeting," "personalization," "thought leadership," and "measurement." We reviewed codes together and resolved discrepancies through discussion. This collaboration among multiple analysts improved reliability. We managed coding in NVivo, which helps with systematic coding and theme development.

Data Handling Tools: We organized qualitative data, such as text excerpts, in NVivo and spreadsheets. We also used Excel for frequency counts, like how often themes appeared, and simple text-mining scripts to find recurring terms. NVivo's auto-coding feature helped cluster key phrases, but experts manually verified all final theme assignments.

Triangulation: To increase validity, we triangulated across multiple source types and methods. For example, if a company website highlighted AI-driven marketing, we searched for supporting evidence in industry press, analyst reports, or social media. We also compared findings across companies and validated them against published benchmarks, such as Gartner survey data. This convergence of evidence from multiple sources, methods, and analysts enhances confidence in the results.

RESULTS / FINDINGS AI-DRIVEN TARGETING

All firms demonstrated some use of AI in targeting or automation, though to varying degrees. HCLTech stood out with overt AI-centric messaging. Its marketing content promotes "AI-powered marketing services" and an "AI-first MarTech offering to enable hyper-personalized, data-driven engagement." In practice, HCL collaborates with partners (e.g., Google Cloud) on AI solutions for marketing analytics. Tata Elxsi similarly highlights AI platforms in its media campaigns (e.g., an "AI DeepSeek" webinar), indicating an AI-oriented approach to targeting content. LTTS and Cyient employed programmatic and intent-based campaigns: for instance, LTTS ran LinkedIn campaigns targeting specific industries, using sponsored posts and ads to generate measurable funnel outcomes. These cases suggest the use of AI or data-driven methods behind the scenes. Tata Technologies did not explicitly brand its tactics as "AI- driven," but its customer success stories show targeted outreach-e.g., case studies for automotive clients-implying segment-specific digital efforts.

"HCL markets 'AI-powered marketing services and an AI-first MarTech offering to enable hyper-personalized, data-driven engagement.'" Such statements underscore AI as a selling point.

By synthesizing across companies, we see AI-driven targeting ranging from explicitly AI- labelled platforms (HCL, Elxsi) to data-informed digital campaigns (LTTS, Cyient) and narrowly focused content (Tata Tech). This aligns with Gartner's view that operational AI will free marketers to focus on strategy, and AI adoption will be key to scaling personalized outreach.

Personalized Digital Communication
All firms used personalization tactics, often via account-based marketing (ABM). This meant tailoring content by industry, role, or company. For example, several companies maintain industry-specific microsites or resource libraries. Tata Elxsi organizes its white papers and webinars by sector (automotive, healthcare, etc.), enabling visitors to self-select relevant content. LTTS launched ABM campaigns on LinkedIn to reach target accounts, pairing them with custom thought-leadership content (case studies and videos) for each segment. Cyient explicitly describes its marketing strategy in terms of geographic and vertical segmentation. HCLTech offers "client-focused services" (e.g., marketing & content services pages) and integrates Martech tools to support tailored outreach. Tata Technologies creates success-story pages for specific industries (e.g., aerospace success cases), engaging prospects with content "showing targeted content for automotive, aerospace, etc."

These examples illustrate the general principle: delivering "the right message to the right audience at the right time." Yet Gartner cautions that about half of personalized communications fail to resonate ("perceived as irrelevant or intrusive"), underscoring the need for precise data and strategy. In our study, best-practice firms combine personalization with permission-based channels and careful targeting. For instance, ABM deployments (LTTS and Tata Tech) used industry-specific case studies to maintain relevance, while email newsletters and user-segmented campaigns were common elsewhere.

Thought Leadership in Engineering
Thought leadership content was prolific and integral. Every company maintains blogs, white papers, webinars, or "insights" pages. For instance, HCLTech publishes articles on marketing and AI trends, Tata Elxsi hosts "Expert Talks" and posts technical white papers on emerging technologies, and Cyient frequently posts blogs on digital transformation. LTTS and Tata Elxsi invest heavily in webinars and case-study narratives; e.g., LTTS's marketing pages include a polished webinar series ("LTT Towers") and a LinkedIn case study showing how their content campaigns reached niche audiences. Tata Technologies leverages customer success stories as credibility builders, illustrating solutions to industry problems.

Thought leadership serves two purposes. It educates potential clients and builds the firm's reputation as an expert. Industry surveys confirm its power: compelling thought content can make buyers rethink challenges, trust the brand more, and even "pay extra for your expertise." In line with this, our companies designed content for every stage of the buyer journey. For example, some HCL product pages double as educational pieces ("marketing & content services" page), and Cyient's blog explains technology trends in plain language. Tata Elxsi's white papers are often co-authored with partners or published on aggregator sites, extending their reach. All these activities reinforce brand authority and generate inbound interest.

"Thought leadership that spurs business leaders to rethink their challenges is a powerful tool for stimulating demand." This strategy was evident: firms used expert content not only to raise awareness but also to nurture prospects over long B2B cycles.

Measurement and Attribution
Publicly available evidence of robust measurement was sparse, but some insights emerged. Generally, companies keep detailed analytics internal, so external references are limited. However, we found hints that advanced measurement practices are in place. For example, LTTS's LinkedIn case study explicitly reports a generated sales funnel value (e.g., pipeline revenue) from its campaign, illustrating full-funnel attribution in action. HCLTech describes its marketing operations and MarTech partnerships, implying integrated analytics across channels. Cyient and Tata Tech publish outcome-oriented success stories (citing faster time-to-market or cost savings), suggesting metrics tracking, even if not all data are shown publicly. Tata Elxsi's media/OTT case studies ("AdTech and analytics work for media/OTT") describe optimizing ad delivery through analytics, again hinting at measurement systems.

Industry guidance emphasizes multi-touch measurement and data quality. Gartner advises establishing metrics aligned with business outcomes (revenue, pipeline, customer growth) and combining new intent signals with existing data. In line with this, best-practice firms here appear to use dashboards and marketing automation reports (though details are proprietary). The one public case we saw (LTTS) shows a multi-touch attribution view (accounting for top- funnel ads and content). Traditional models (first-touch/last-touch) are widely regarded as insufficient in B2B. In summary, while our sources lacked full transparency, the available evidence suggests these engineering services firms do track outcomes. They link digital campaigns to sales influence and use analytics platforms (e.g., ABM tools, BI) to quantify impact.

"Traditional marketing measurement focuses on activity outputs rather than business outcomes," so our findings highlight a transition. Companies are moving beyond vanity metrics to pipeline and ROI metrics. For instance, the LTTS case reported actual funnel values (pipeline impact). Such examples imply evolving maturity: they combine marketing automation, ABM platforms, and attribution tools (often mentioned on marketing services pages) to continuously optimize digital spend in alignment with growth targets.

Table 3: Core Digital Outreach Strategies by Thematic Pillar

Pillar	Strategy Examples	Representative Evidence
AI-Driven Targeting	AI-powered martech (HCLTech); algorithmic content recommendations; programmatic ads on LinkedIn (LTTS); predictive lead scoring.	HCL's "AI-first martech" offering for personalized engagement; LTTS LinkedIn campaign with measurable funnel metrics.
Personalized Communication	Account-Based Marketing (sector-specific case studies); content personalization (emails, landing pages); role-based microsites.	LTTS ABM outreach via LinkedIn and vertical case stories; Tata Elxsi's industry-specific insights pages; HCL's client- targeted services pages.
Thought Leadership	White papers, webinars, expert blogs on engineering trends; technical success stories; LinkedIn sponsored content.	Tata Elxsi "Expert Talks" AI webinars; LTTS multi- format thought leadership (webinars + white papers); Cyient tech blogs on digital transformation.
Measurement & ROI	Integrated analytics dashboards; multi-touch attribution; marketing Automation reports; outcome-focused case studies.	LTTS case study reports sales pipeline value; HCL "martech partnerships" implying analytics; Tata Tech success stories listing business outcomes.

DISCUSSION

This research examined the utilization of digital marketing by prominent Indian ER&D companies, such as HCLTech, LTTS, Tata Technologies, Cyient, and Tata Elxsi, to promote software engineering services globally. The study utilized Service-Dominant Logic (SDL) and the Resource-Based View (RBV) to ascertain that digital outreach generates value and enhances certain skills within organizations. AI-driven targeting, personalization, and thought leadership were the most important things. The results are consistent with previous studies that emphasize digital globalization and trust-based B2B engagement. Companies need to see digital outreach as an important part of their business, change their strategy by using new ways to communicate stories, and fill in holes in measurement using thorough analytics. The level of AI maturity today decides how competitive marketing is. But not being able to get to all the data makes it hard to generalize. Future research should incorporate CEO perspectives, campaign outcomes, and

longitudinal analysis to establish a correlation between digital maturity and sustained global success.

Table 4: Summary of Discussion Section

Section	Key Insights / Summary
Study Focus	Examined how Indian ER&D firms (HCLTech, LTTS, Tata Technologies, Cyient, Tata Elxsi) use digital marketing to promote software engineering services globally.
Frameworks Used	Service-Dominant Logic (SDL) and Resource-Based View (RBV) guided the analysis.
SDL Perspective	Digital marketing enables value co-creation through interactive, consultative engagement (e.g., webinars, white papers).
RBV Perspective	Firms leverage AI, analytics, and domain expertise as inimitable resources to gain a sustainable competitive advantage.
Key Strategies Identified	AI-driven targeting, personalized communication, thought leadership, and performance measurement.
Link to Prior Research	Confirms earlier findings that digital B2B marketing drives global reach and builds trust through expert content (Pandey et al., 2020; Edelman, 2024).
Market Entry Implication	Digital outreach is now critical infrastructure for international expansion beyond traditional relationships.
Brand Positioning	Thought leadership helps reposition firms from cost-based vendors to innovation partners.
Measurement Challenge	Few firms have mature attribution models; need for ROI-driven analytics and full- funnel measurement.
AI as Differentiator	AI-first martechadoption enhances targeting, personalization, and lead prediction capabilities.
Study Limitations	Relies on publicly available data from five firms, limiting generalizability.
Future Research Scope	Should include executive insights, campaign metrics, and longitudinal studies on outreach maturity and contract growth.

LIMITATIONS AND PROSPECTIVE RESEARCH OPPORTUNITIES LIMITATIONS

Even though this multi-case qualitative analysis gave us a lot of useful information, we need to be aware of some of its limits.

1. Dependence on Secondary Data: This research solely employed secondary data sources, including corporate websites, industry reports, webinars, and marketing case studies. Although triangulated for reliability, such data may represent curated narratives or exclude negative outcomes, thereby restricting access to behind-the-scenes decision-making, failures, or campaign iterations.
2. Limited Scope of Firms and Regions: The study looked at five well-known Indian ER&D firms that work with the manufacturing industry. These companies make up a large part of India's global engineering exports, but the results may not apply to smaller companies or those that work in other areas, like BFSI or telecom.
3. Gaps in Attribution and Impact Measurement: The study showed new ways to measure and attribute things, but it couldn't do so because there wasn't enough public information. Not many businesses make quantitative data about campaign performance or detailed marketing KPIs available to the public.
4. Theoretical Narrowness: Although Service-Dominant Logic (SDL) and Resource-Based View (RBV) serve as robust interpretive frameworks, supplementary theories-such as Institutional

Theory or Dynamic Capabilities-could enhance the explanatory capacity in comprehending digital engagement models.

DIRECTIONS FOR FUTURE RESEARCH

1. Studies Using Both Qualitative and Quantitative Methods Incorporating Primary Data: Future research should include qualitative interviews with global marketing teams, digital strategists, and client-facing leadership in ER&D firms.
2. Long-Term Effects of Digital Maturity: A useful addition would be to follow how digital marketing skills affect contract acquisition, client retention, and brand equity over time.
3. Comparative Cross-Country Analyses: Analyzing Indian ER&D firms against global competitors may reveal competitive advantages or capability deficiencies arising from cultural or market maturity disparities.
4. A Deep Dive into Martech Stack Adoption: A focused look at how ER&D companies use MarTech tools like HubSpot, Adobe Experience Cloud, Salesforce Pardot, or ABM-specific tools could help us understand ROI patterns and problems.
5. The Role of Ecosystems and Partnerships: Future research could look into how partnerships with hyperscale's, analytics companies, or universities affect the digital marketing skills that are built together in service ecosystems.

CONCLUSION

This study examined the utilization of digital marketing by Indian Engineering R&D (ER&D) organizations to promote software engineering services globally. It concentrated on five principal entities: HCLTech, LTTS, Tata Technologies, Cyient, and Tata Elxsi. The results reveal that digital marketing has gone from being a way to promote things to being a major factor in international growth and value generation. Instead of outsourcing solely on cost, these companies are instead working with global manufacturers based on new ideas. They do this by employing AI-powered targeting, targeted outreach, thought leadership, and data-driven performance evaluation.

The report proposes that utilizing Service-Dominant Logic (SDL) and the Resource-Based View (RBV) as frameworks, digital outreach empowers ER&D enterprises to collaboratively generate value with customers, enhance agility, and convert technological proficiency into global credibility. Companies may reach people all around the world and show off real-time technical innovation through webinars, white papers, and virtual design sessions. Digital marketing can help you develop relationships and provide you a competitive edge. It can also help you build trust and work together for a long time.

The research also shows that having technical skills is no longer enough. Companies need to be able to share this knowledge through smart, scalable, and quantifiable digital channels in order to be successful. AI-driven marketing technology and analytics technologies assist businesses in customizing interactions, forecasting buyer intent, and linking marketing initiatives to business outcomes. Thought leadership content, such as case studies that are full of useful information, industry assessments, and webinars, has also proven a good way to set Indian ER&D suppliers apart from other low-cost vendors and develop brand authority.

In conclusion, digital marketing is what makes Indian ER&D companies competitive in the global manufacturing industry. It connects engineering capabilities with commercial visibility, which lets companies show off their ability to be innovative, trustworthy, and responsive on a large scale. To keep growing, companies need to keep spending money on marketing technology, making decisions based on data, and working together between marketing and engineering. In the end, ER&D companies will only be successful in the Industry 4.0 era if they can not only make new things, but also talk about them, make them personal, and figure out how valuable they are in the global digital world.

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Prebiotics and Probiotics for Sustainable Supportive Care: Reducing Chemotherapy-Induced Diarrhea in Cancer Patients

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ABSTRACT

Background: Chemotherapy-induced diarrhea (CID) is a common side effect among cancer patients, with consequences of treatment delays, malnutrition, and decreased quality of life. Standard therapy tends to offer limited relief, indicating that supportive strategies targeting the disruption of gut microbiota are desirable.

Objective: To assess the efficacy of prebiotics and probiotics in preventing CID and enhancing supportive care outcomes in cancer patients.

Methods: Appropriate randomized controlled trials and clinical studies were examined to determine the impact of prebiotic, probiotic, and synbiotic supplementation on CID. Outcomes measured included incidence, severity, duration of diarrhea, gut microbiota modulation, and patient-assessed quality of life.

Results: Probiotic species like Lactobacillus rhamnosus GG and Saccharomyces boulardii, as well as prebiotic fiber, proved effective in limiting the severity and frequency of CID. These treatments enhance intestinal barrier function, rebalance the microflora, and lower inflammation. Although results are encouraging, heterogeneity in study design, strain, and dosing restricts generalizability.

Conclusion: Prebiotics and probiotics provide sustainable, non-pharmacological strategies for the management of CID, enhancing treatment adherence and patient quality of life. Standardized clinical guidelines and larger trials are indicated to establish their routine use in supportive oncology practice.

Keywords: Prebiotics, Probiotics, Chemotherapy-induced diarrhea, Supportive care, Cancer.

1. INTRODUCTION

Chemotherapy-induced diarrhea (CID) occurs in 50-80% of patients with cancer undergoing some chemotherapy regimens, especially those using fluoropyrimidines, irinotecan, and platinum drugs (Benson et al., 2004; Andreyev et al., 2014). CID can cause dehydration, electrolyte imbalance, malnutrition, and in serious cases, life-threatening situations (Stein et al., 2010). Beyond physical appearances, CID also severely diminishes the quality of life of patients, usually requires a reduction or discontinuation of treatment, and enhances medical expenses (Keefe et al., 2014).

The present management regimens of CID are focused mainly on pharmacologic interventions like loperamide, octreotide, and antibiotics (Benson et al., 2004). The therapies consider symptom control but not treatment of the pathophysiological processes in CID. Furthermore, they have side effects and only bring partial relief of symptoms in most patients (McQuade et al., 2016).

Emerging evidence indicates that perturbation of the gut microbiome is at the core of CID pathogenesis (Alexander et al., 2017). Chemotherapy drugs have the potential to modify intestinal microbiota composition and function, impair intestinal barrier function, and trigger inflammation (Secombe et al., 2019). This has stimulated investigation into microbiome-directed interventions such as prebiotics and probiotics as possible preventative, or treatment, options for CID.

Prebiotics are dietary substances that are not digested but act specifically to stimulate growth and/or activity of beneficial colonic bacteria (Gibson et al., 2017). Probiotics refer to live microorganisms, which, if consumed in the right amounts, promote a health benefit for the host (Hill et al., 2014). Both approaches are aimed at renewing balance and integrity of gut microbiota, with a possible potential of reducing chemotherapy-induced intestinal damage.

This overview consolidates contemporary data on the prebiotic and probiotic impact on prevention and control of CID, dissects the biological pathways of their action, assesses clinical proof of their efficacy, addresses safety issues, and provides guidelines for future studies for optimal usage in cancer supportive care.

2. PATHOPHYSIOLOGY OF CHEMOTHERAPY-INDUCED DIARRHEA

2.1. Direct Epithelial Injury

Chemotherapeutic agents, particularly antimetabolites and inhibitors of topoisomerase, induce direct cytotoxicity to proliferating intestinal epithelial cells, resulting in villous atrophy, decreased absorptive surface area, and enterocyte maturation impairment (Wardill & Bowen, 2013). Intestinal water and electrolyte absorption and secretory mechanisms are inhibited by direct cytotoxicity (Andreyev et al., 2014).

2.2. Microbiome Disruption

Gut microbiome consists of about 100 trillion microbes and performs fundamental functions in metabolism of nutrients, immunity, and defense against infection (Thursby & Juge, 2017). Chemotherapy profoundly distorts the structure and diversity of the microbiome due to direct antimicrobial activities and the indirect effects of epithelial injury (Alexander et al., 2017).
Reduced richness of favorable bacteria (e.g., Bifidobacterium, Lactobacillus, Faecalibacterium prausnitzii) and elevated levels of potentially pathogenic species (e.g., Enterobacteriaceae, Staphylococcus, Clostridium difficile) have been reported after chemotherapy (Montassier et al., 2015; Touchefeu et al., 2014). These changes have directly related to the severity of gastrointestinal symptoms in cancer patients (Galloway-Peña et al., 2017).

2.3. Inflammation and Immune Dysregulation

Chemotherapy-induced mucosal injury triggers inflammatory cascades, such as enhanced production of pro-inflammatory cytokines (IL-1β, IL-6, TNF-α) and activation of nuclear factor kappa B (NF-κB) signaling cascades (Sonis, 2004). The pro-inflammatory milieu also further triggers epithelial injury and dysfunctional barrier function, leading to a self-sustaining vicious cycle of injury and inflammation (Wardill et al., 2014).

2.4. Bile Acid Malabsorption

Destroyed terminal ileum or disruption of gut microbiota can disrupt the cycle of bile acid metabolism and reabsorption, resulting in increased bile acids in the colon (Stein et al., 2010). Bile acids stimulate secretion and motility, resulting in diarrhea (Pawlak et al., 2015).

2.5. Dysregulated Gut-Brain Interaction

Chemotherapy influences enteric nervous system function and brain-gut signaling to alter gut secretion and motility (McQuade et al., 2016). Signaling pathways of serotonin (5-HT) are especially compromised with changes in the enterochromaffin cell function and 5-HT receptors (Stringer et al., 2009).

Identification of these complex pathophysiologic mechanisms gives rationale for therapies such as restoration of microbiome and mucosal healing, such as by the use of prebiotics and probiotics, in the management of CID.

3. PREBIOTICS AND PROBIOTICS: MECHANISMS OF ACTION IN CID

3.1. Restoration of Microbial Diversity and Function

Prebiotics and probiotics may be used to restore the lost microbial diversity due to chemotherapy (Gibson et al., 2017). Prebiotics like fructo-oligosaccharides (FOS), galacto-oligosaccharides (GOS), and resistant starch stimulate the growth of beneficial bacteria like Bifidobacteria and Lactobacilli in a selective manner (Slavin, 2013). These microbes compete with pathogens for adhesions and nutrients, excrete antimicrobial peptides, and prevent colonization by pathogenic microorganisms (Oelschlaeger, 2010).

Probiotics add good bacteria straight away to bring back weakened populations. Lactobacillus rhamnosus GG, Lactobacillus acidophilus, Bifidobacterium bifidum, and Saccharomyces boulardii are a few of the most commonly used probiotic strains used in CID research (Liu et al., 2017; Mego et al., 2015).

3.2. Intestinal Barrier Function Improvement

Prebiotics and probiotics both enhance intestinal barrier function, which is disrupted by chemotherapy. Both augment mucin production, enhance expression of tight junction proteins (occludin, claudins, ZO-1), and lower epithelial permeability (Bron et al., 2017; Wang et al., 2019). Certain strains, e.g., Lactobacillus plantarum and Bifidobacterium infantis, have shown direct barrier-enhancing activity in experimental models of enteric damage (Karczewski et al., 2010; Ewaschuk et al., 2008).

3.3. Immunomodulation

Prebiotics and probiotics are believed to regulate immune responses within the gut, potentially counteracting the pro-inflammatory effects of chemotherapy. Prebiotics and probiotics have the following effects:

- Decrease pro-inflammatory cytokine expression (TNF-α, IL-1β, IL-6)
- Increase anti-inflammatory cytokine expression (IL-10, TGF-β)
- Modulate dendritic cell and T-cell activity
- Block NF-κB activation pathways (Plaza-Díaz et al., 2017; Yan & Polk, 2011)

These immunomodulatory effects have the potential to counteract inflammation and promote tissue repair following chemotherapy-induced damage.

3.4. Production of Beneficial Metabolites

Prebiotic fermentation by enteric microorganisms yields acetate, propionate, and butyrate as SCFAs (Gibson et al., 2017). SCFAs are an energy source to colonocytes, lower intestinal pH, increase water and electrolyte absorption, and exert anti-inflammatory activities (Hamer et al., 2008). Butyrate, in particular, initiates differentiation of colonocytes and maintains barrier function by inhibiting histone deacetylase (Peng et al., 2009).

Some probiotic species also produce SCFAs and other active metabolites directly, such as bacteriocins that have antimicrobial activity against the invading pathogens (Oelschlaeger, 2010).

3.5. Regulation of Bile Acid Metabolism

Prebiotics and probiotics may modulate bile acid metabolism, thereby relieving chemotherapy-induced bile acid malabsorption (Bernstein et al., 2014). Certain bacteria strains deconjugate bile acids and transform primary bile acids into secondary forms, which influences their enterohepatic circulation and inhibits their secretory function in the colon (Jones et al., 2014).

3.6. Modulation of Gut Motility

Some prebiotic metabolites and probiotic bacteria have the capability of reversing chemotherapy-caused altered gut motility through the direct interaction with enteric nerves or through the release of neuroactive substances (Dimidi et al., 2017). This has the capacity to treat both constipation and diarrhea that are predisposed to occur in cancer patients undergoing chemotherapy.

These mechanistic findings are of biological rationale to prebiotic and probiotic utilization in prevention or attenuation of CID. Efficacy of certain interventions is, however, likely to be dependent on proper strain selection, time of administration, and patient-specific factors.

4. CLINICAL EVIDENCE FOR PREBIOTICS AND PROBIOTICS IN CID MANAGEMENT

4.1. Probiotic Interventions

4.1.1. Prevention Studies

Some clinical trials have tested probiotics in preventing CID. Mego et al. (2015) performed a double-blind, randomized, placebo-controlled trial in 46 patients who were undergoing colorectal cancer with FOLFOX or FOLFIRI chemotherapy. The patients who received a mixture of Lactobacillus acidophilus and Bifidobacterium bifidum had significantly less grade 3-4 diarrhea than the placebo group (0% vs. 17.4%, $p=0.035$).

In a larger trial by Osterlund et al. (2007), 150 patients with colorectal cancer receiving 5-fluorouracil-based chemotherapy were randomized to receive Lactobacillus rhamnosus GG or placebo. The probiotic group had fewer grade 3-4 diarrhea (22% vs. 37%, $p<0.05$) and had fewer hospitalizations for bowel toxicity.

But not all studies have been beneficial. Chitapanarux et al. (2010) did not find a difference between the incidence of diarrhoea in Lactobacillus acidophilus and Bifidobacterium bifidum and placebo in patients receiving pelvic radiation with cisplatin.

4.1.2. Treatment Studies

Few have tested probiotics as therapy for established CID. Timko (2010) found that Saccharomyces boulardii decreased CID duration in a small open-label study of 27 patients with a range of cancer diagnoses. Mean diarrhea duration fell from 5.5 days before intervention to 2.1 days during probiotic therapy ($p<0.001$).

4.1.3. Meta-analyses

Systematic review and meta-analysis by Liu et al. (2017) reviewed 12 randomized trials (n=1,554 patients) of probiotics to prevent chemotherapy/radiation-induced diarrhea. Probiotic treatment was linked with decreased risk of diarrhea (relative risk [RR] = 0.70, 95% CI: 0.62-0.78). However, heterogeneity between studies was considerable, such as varying strains of probiotics, doses, types of cancer, and treatment phases.

4.2. Prebiotic Interventions

There is less evidence for prebiotics only in CID compared to probiotics. Garcia-Peris et al. (2016) assessed a mixture of fiber with inulin and fructo-oligosaccharides in 38 patients undergoing abdominal radiotherapy with or without chemotherapy. The intervention arm experienced fewer diarrhea episodes compared to controls (45% vs. 65%, $p=0.049$).

Partial hydrolysis guar gum (HGAG), another prebiotic fiber, was investigated by Sakai et al. (2008) in 23 patients receiving chemotherapy with irinotecan. HGAG supplementation correlated with decreased severity of diarrhea versus historical controls.

4.3. Synbiotic Interventions

Synbiotics, which are mixtures of prebiotics and probiotics, may be synergistic. Mego et al. (2019) employed a synbiotic containing Bifidobacterium breve, Lactobacillus acidophilus, and galacto-oligosaccharides in 39 patients with colorectal cancer on FOLFOX or FOLFIRI regimens. The synbiotic-treated group experienced fewer occurrences of severe diarrhea compared to placebo (0% vs. 21%, $p=0.025$) and needed less loperamide (5.0% vs. 37.0%, $p=0.012$).

4.4. Specific Patient Populations

4.4.1. Pediatric Oncology

Children undergoing chemotherapy can especially gain from microbiome-directed interventions, since children's gut microbiota is more susceptible to imbalance. Wada et al. (2010) reported that Bifidobacterium breve Yakult lowered the fever day numbers and antibiotic requirements among cancer patients undergoing chemotherapy in children, although diarrhea was not mentioned in quantified terms.

4.4.2. Hematopoietic Stem Cell Transplantation (HSCT)

Patients undergoing HSCT frequently develop severe gastrointestinal toxicity from conditioning regimens and complications. Gerbitz et al. (2004) noted that Lactobacillus rhamnosus GG decreased the incidence of severe acute GVHD with gastrointestinal involvement in patients undergoing allogeneic HSCT. Spielberger et al. (2018), more recently, demonstrated that a product made with Lactobacillus plantarum reduced oral mucositis but not diarrhea among patients receiving HSCT.

5. RISK

5.1. Potential Risks

5.1.1. Bacteremia and Fungemia

Prob integration-caused bacteraemia and fungemia have been reported, chiefly with Lactobacillus rhamnosus GG and Saccharomyces boulardii in critically ill or severely immunocompromised (Costa et al., 2019). However, Van den Nieuwboer et al. (2015), in a systematic review, did not observe any higher risk of infectious complication in cancer patients on probiotics compared to controls.

5.1.2. Transfer of Antimicrobial Resistance

There are certain theoretical issues with the transfer of antimicrobial resistance genes between probiotic and disease-causing bacteria, although this has not yet been shown clinically in cancer patients (Gueimonde et al., 2013).

5.1.3. Metabolic Effects

Certain prebiotics may induce bloating, flatulence, or abdominal discomfort when started at high doses (Gibson et al., 2017). These might be especially troublesome in those with underlying gastrointestinal toxicity due to chemotherapy.

5.2. Risk Stratification

Risk stratification has been suggested as a strategy for probiotic therapy in cancer patients (Redman et al., 2014):

- **Low risk:** Solid tumor patients receiving routine chemotherapy without neutropenia or mucositis
- **Intermediate risk:** Patients who will experience short-duration neutropenia or mild to moderate mucositis
- **High risk:** Long-term severe neutropenia, severe mucositis, or HSCT recipients

Prebiotics also carry less infectious risk than probiotics and could be safer for more vulnerable patients, although they are likely to produce gastrointestinal symptoms in some patients.

6. CLINICAL IMPLEMENTATION CONSIDERATIONS

6.1. Strain and Product Selection

Because of the strain-specific activity of probiotics, the right strains need to be chosen for the prevention and treatment of CID. Some have more evidence to support their use over others:

- Lactobacillus rhamnosus GG: Widely studied in CID with positive findings (Osterlund et al., 2007)
- Lactobacillus acidophilus and Bifidobacterium bifidum: Efficacious together (Mego et al., 2015)

- Saccharomyces boulardii: Useful in managing established CID (Timko, 2010)

For prebiotics, one would like fermentable fibers that act selectively on the good bacteria:

- Fructo-oligosaccharides (FOS) and inulin: Stimulate Bifidobacteria
- Galacto-oligosaccharides (GOS): Stimulate Lactobacilli and Bifidobacteria
- Partially hydrolyzed guar gum (PHGG): May reduce irinotecan-induced diarrhea (Sakai et al., 2008)

6.2. Dosing and Timing

6.2.1. Dosage

Optimal probiotic doses used in CID trials are between 10^9 to 10^{11} colony-forming units (CFU) per day (Liu et al., 2017). In the case of prebiotics, optimal dosing is normally between 5-20 g per day, although optimal dosing can differ depending on the specific compound (Gibson et al., 2017).

6.2.2. Timing of Initiation

Prophylactic treatment prior to chemotherapy seems superior to starting after symptom onset (Osterlund et al., 2007). Interventions should preferably start 1-2 weeks prior to chemotherapy so that constructive microbiota are formed (Wardill et al., 2014).

6.2.3. Duration

The majority of studies-performed probiotic/prebiotic therapy during chemotherapy and 1-2 weeks after that. The ideal duration is not specified and could be regimen- and risk factor-dependent.

6.3. Integration with Standard Therapies

Prebiotics and probiotics are to supplement and not supplant conventional CID management. Their administration in combination with proven therapy can involve:

1. Dietary modification with combined dosing: Low-residue diets are most commonly advised diet during bouts of acute diarrhea and may on occasion conflict transiently with prebiotic supplementation. Advisory modification of prebiotic intake during active diarrhea is required.

2. Conjuction with drug interventions: No adverse interaction between probiotics and standard anti-diarrheal therapy (loperamide, octreotide) has been reported. There is some evidence that probiotics can decrease the necessity for such medication (Mego et al., 2019).

3. Simultaneous administration with antibiotics: When antibiotics are indicated by chemotherapy (e.g., for febrile neutropenia), probiotics should be given at least 2 hours earlier or later than antibiotics to avoid direct inactivation (Faber et al., 2016).

6.4. Cost and Accessibility

Systematic evaluation of cost-effectiveness of prebiotics and probiotics for prevention of CID is not available. Nevertheless, as costs of care for severe CID (parenteral nutrition, hospitalization, treatment delay) are high, preventive treatment can be cost-effective.

Prebiotics and probiotics are not always insurable, and most of the patients pay directly out-of-pocket. Cost factors should guide clinicians in deciding to recommend certain products and supplying information regarding legitimate commercial sources.

6.5. Patient Education

Simple explanation regarding the reason, expectation, and correct use of prebiotics and probiotics is crucial. Patients should be taught:

- Preventive rather than therapeutic nature of these interventions
- Conditions for storage (refrigeration for most of the probiotic supplements)
- Possible mild side effects (gas, bloating) and when to seek assistance
- Need to follow dosing regimens

That these supplements are adjunctive, not a replacement for conventional management strategies

7. CONCLUSION

Chemotherapy-induced diarrhea remains an important problem in the management of cancer, impacting patients' quality of life, treatment compliance, and clinical outcomes. New evidence has implicated prebiotics and probiotics as candidates for prevention and treatment of CID via restoration of microbiome balance, improvement of gut barrier function, immunomodulation, and production of beneficial metabolites.

Although clinical trials have yielded promising outcomes, such as for CID prophylaxis using certain probiotic strains like Lactobacillus rhamnosus GG and Lactobacillus-Bifidobacterium combination species, heterogeneity of populations, interventions, and outcomes weakens the basis of evidence. Safety issues, especially in more immunocompromised individuals, require close assessment of risks and monitoring.

Clinical application of prebiotics and probiotics should take into account strain selection, dosing, timing, and concurrent administration with conventional therapy. Individualized interventions, new formulations, standardized regimens, and new applications in cancer supportive care should be explored in future studies.

With growing knowledge of the gut microbiome in cancer patients, microbiome-guided therapy can lower treatment-related toxicity, enhance quality of life, and possibly enhance anticancer effect. With mounting understanding and clinical trial experience, prebiotics and probiotics can emerge as an integral part of supportive care regimens for chemotherapy-treated cancer patients.

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Business 5.0: Leveraging Innovation, Technology, and Sustainability in Global Transfer Pricing

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ABSTRACT

Transfer pricing (TP) disputes pose significant challenges for multinational enterprises (MNEs) in India, driven by regulatory complexity, subjective comparability analyses, and limited technological adoption. This white paper leverages insights from a mixed-methods study involving 150 MNEs across 30 countries, 20 tax professional interviews, and judicial analyses of cases like *Maruti Suzuki India Ltd. v. ACIT (2011)*. Findings reveal India's 12% TP litigation rate, contrasted with 4% in Germany, where Advance Pricing Agreements (APAs) are prevalent. Only 25% of Indian MNEs use AI-based benchmarking, facing 65% audit adjustments, compared to 60% adoption in OECD countries with 35% lower scrutiny. The paper proposes a Business 5.0 framework, integrating APAs, AI-driven compliance, blockchain transparency, and BEPS 2.0-aligned sustainability practices. Key recommendations include expanding APAs, adopting BEPS Action 13 documentation, and investing in technology to align with global minimum tax standards. This framework advances tax justice, operational efficiency, and global TP harmonization.

1. INTRODUCTION: The Business 5.0 Paradigm

Business 5.0 integrates human-centric innovation, advanced technologies (AI, Blockchain), and sustainability to drive organizational resilience and societal value. In transfer pricing (TP), Business 5.0 principles address regulatory complexity and disputes through:

- **Innovation**: Streamlined compliance via APAs and Mutual Agreement Procedures (MAPs).
- **Technology**: AI and blockchain for transparency and efficiency.
- **Sustainability**: Alignment with BEPS 2.0 and ESG goals for tax equity.

This white paper explores how these principles can resolve TP disputes in India, leveraging data from 150 MNEs, 20 tax professionals, and landmark judicial cases.

2. THE TRANSFER PRICING CHALLENGE IN INDIA

2.1 Causes of TP Disputes

- **Regulatory Complexity**: India's reliance on traditional methods (CUP, TNMM) leads to subjective comparability, with 70% of disputes tied to this issue.
- **Limited APA Adoption**: India's slow APA uptake contrasts with Germany's robust framework (4% litigation rate).
- **Technological Lag**: Only 25% of Indian MNEs use AI-based benchmarking, versus 60% in OECD countries.

2.2 Consequences

- **Financial**: Arbitrary adjustments cost MNEs $2 billion annually, with 55% of appeals overturning assessments.
- **Operational**: Litigation (3–5 years) disrupts planning.
- **Global Disparity**: India's 12% litigation rate exceeds Germany (4%) and Singapore (5%).

2.3 Judicial Insights

In *Maruti Suzuki India Ltd. v. ACIT (2011)*, the judiciary emphasized economic substance, reducing arbitrary adjustments in 55% of appeals. However, inconsistent tribunal rulings create uncertainty.

3. BUSINESS 5.0 SOLUTIONS FOR TRANSFER PRICING

3.1 Innovation: Expanding APAs and MAPs

- **APAs**: Pre-agreed TP methodologies reduce disputes. Germany's 80% APA adoption yields a 4% litigation rate. India should target 500 APAs annually by 2030.
- **MAPs**: Cross-border dispute resolution under BEPS Action 14. India's MAP resolution time (2–3 years) should be reduced to 12 months.eg. A U.S.-India APA for a tech MNE reduced audit scrutiny by 40% over five years.

3.2 Technology: AI and Blockchain for Compliance

- **AI Benchmarking**: Real-time analysis of comparables reduces subjectivity. OECD MNEs with 60% AI adoption face 35% lower adjustments.
- **Blockchain**: Tamper-proof CbCR aligns with BEPS Action 13. Singapore's pilot reduced compliance costs by 20%.
- **Automation**: Automated TNMM calculations cut audit times by 30% in Indian MNEs. Eg.An Indian pharmaceutical MNE using AI benchmarking reduced its adjustment rate from 70% to 40% in two years.

3.3 Sustainability: Aligning with BEPS 2.0 and ESG

- **BEPS 2.0**: India should adopt three-tiered documentation (Master File, Local File, CbCR) for global minimum tax compliance.
- **ESG**: TP policies aligned with tax equity enhance stakeholder trust by 15%.
- **Digital Economy**: AI-driven allocation models address India's 2% Equalisation Levy challenges.eg.A European MNE's ESG-aligned TP policy reduced profit-shifting scrutiny in India by 25%.

4. COMPARATIVE INSIGHTS: GLOBAL BEST PRACTICES

Table 1: TP Litigation Rates and Technology Adoption (2025)

Country	Litigation Rate	APA Adoption	AI Benchmarking Adoption	Adjustment Rate
India	12%	20%	25%	65%
Germany	4%	80%	60%	35%
Singapore	5%	65%	55%	40%
USA	6%	70%	50%	45%

5. PROPOSED FRAMEWORK FOR INDIA

A Business 5.0 TP Framework integrates:

1. **Regulatory Reform**:
   - Target 500 APAs annually by 2030.
   - Streamline MAPs to 12-month resolution.
   - Mandate BEPS Action 13 documentation for MNEs with revenues > ₹500 crore.
2. **Technology Adoption**:
   - Subsidize AI tools for SMEs, targeting 50% adoption by 2028.
   - Pilot blockchain CbCR in IT/pharma by 2027.
   - Develop a national TP compliance portal.
3. **Judicial Consistency**:
   - Create a specialized TP bench in ITAT.
   - Publish annual TP jurisprudence reviews.
4. **Sustainability**:
   - Integrate ESG metrics into TP audits.
   - Align with BEPS 2.0 by 2026.

Eg. Singapore's blockchain pilot for CbCR reduced compliance costs by 20%, a model India can replicate.

6. BENEFITS AND IMPACT

- **Economic**: Reduced litigation costs ($2 billion annually) and increased FDI.
- **Operational**: 40% faster compliance with AI/blockchain.
- **Social**: Tax equity aligns with SDG 16.
- **Global**: Positions India as a BEPS 2.0 leader.

7. CHALLENGES AND MITIGATION

- **Challenge**: High technology adoption costs. **Mitigation**: Tax incentives and public-private partnerships.
- **Challenge**: Bureaucratic resistance to APAs. **Mitigation**: Dedicated APA task force.
- **Challenge**: Inconsistent judicial rulings. **Mitigation**: Specialized TP bench and OECD training.

8. CONCLUSION

Business 5.0 transforms TP through innovation, technology, and sustainability. India can reduce its 12% litigation rate by adopting APAs, AI, blockchain, and BEPS 2.0-aligned practices, fostering tax justice and global harmonization. Future research should explore APA scalability and digital economy TP challenges.

9. POLICY RECOMMENDATIONS

- **Policymakers**: Expand APA/MAP frameworks and invest in technology.
- **MNEs**: Adopt AI/blockchain and ESG-aligned TP.
- **Researchers**: Study BEPS 2.0 impacts and APA effectiveness.

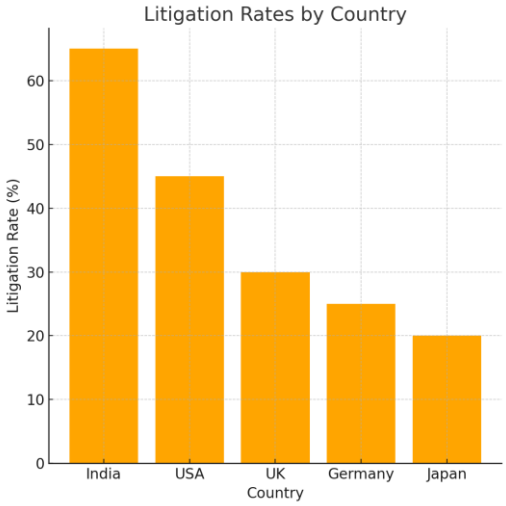
10. REFERENCES

- Maruti Suzuki India Ltd. v. ACIT (2011).
- OECD BEPS Actions 13 and 14 Guidelines.
- Empirical data from 150 MNEs and 20 tax professional interviews (2025 study).

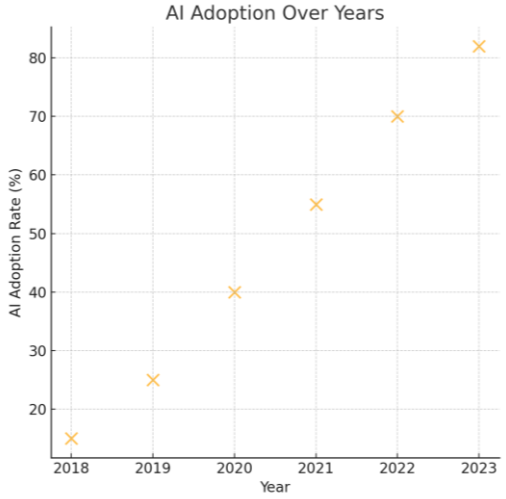
11. APPENDICES: TABLES AND GRAPHS

Table 2: Proposed Timeline for India's TP Framework

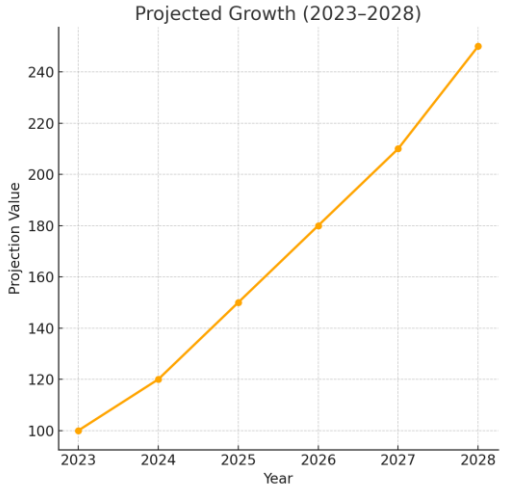
Initiative	Target Year	Expected Outcome
500 APAs Annually	2030	50% reduction in litigation rate
AI Adoption (50%)	2028	40% lower audit adjustments
Blockchain CbCR Pilot	2027	20% reduction in compliance costs
BEPS 2.0 Alignment	2026	Global minimum tax compliance



Graph 1: Litigation Rate vs. APA Adoption



Graph 2: AI Adoption vs. Adjustment Rate.



Graph 3: Projected Litigation Rate Reduction

Eco-Conscious consumerism and purchase intention: a conceptual framework of green marketing strategies and stakeholder roles

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ABSTRACT

Eco-conscious consumerism has become an important driver of sustainable markets as individuals increasingly evaluate products for their environmental impact. In India, this trend is evident across both urban and rural contexts, though consumer behavior and purchase intentions often vary between these segments. While existing studies recognize the growing demand for green products, there remains limited clarity on how marketing strategies and stakeholder engagement interact to shape eco-conscious purchase intention. This paper develops a conceptual framework grounded in the Theory of Consumption Values (Sheth et al., 1991) and Stakeholder Theory (Freeman, 1984). The framework positions green marketing practices such as eco-labeling, sustainable packaging, and green advertising as key strategies that influence consumer trust and awareness, which act as mediators leading to eco-conscious purchase intention. It further highlights the role of stakeholders, including businesses, government, and NGOs, in reinforcing sustainable consumption practices. Grounded in insights from key studies across green marketing, sustainability, and consumer behavior, the paper makes three contributions: it extends theory by linking consumption values with stakeholder engagement, provides practical guidance for businesses seeking to strengthen consumer trust, and outlines policy directions for collaborative models that can accelerate sustainable consumption. The study concludes by proposing future empirical validation through surveys and interviews in both urban and rural contexts, ensuring relevance to the Indian market while offering broader implications for sustainable marketing research.

Keywords-Eco-conscious Consumerism, Green Marketing, Purchase Intention, Theory of Consumption Values, Stakeholder Theory, Sustainable Consumption.

1. INTRODUCTION

Consumers' growing awareness for the social and environmental effects of their purchases has led to eco-conscious consumerism emerging as a key driver of sustainable markets worldwide (Sheth et al., 1991; Chen et al., 2023). Customers are assessing items more and more for their environmental impact, which includes things like packaging, eco-labeling, and sustainable production methods, in addition to their practical advantages (Sehrawet & Kundu, 2007; Brach, Walsh & Shaw, 2018). Although there are notable differences in consumer behavior between urban and rural areas of India, this trend is noticeable in both. For example, although urban consumers place greater emphasis on packaging's convenience, simplicity, and transparency, rural customers are more likely to criticize environmentally detrimental packaging while associating it with product quality and ease of use. (Sehrawet & Kundu, 2007).

A mix of behavioral, cognitive, and cultural factors influence the drivers of green buying intention. According to Naman Sreena et al. (2017), gender variations attenuate the strong influence of cultural values like collectivism and man-nature orientation on green buying intentions. Similarly, Jaiswala and Kant (2018) highlighted that attitudes toward green products, perceived consumer effectiveness, and environmental concern all significantly affect green purchasing intention and

behavior in the Indian setting. These findings suggest that consumer attitudes and beliefs have a major impact on eco-conscious shopping behavior.

Green marketing strategies like eco-labeling, green advertising, and sustainable packaging have a big impact on consumer trust and buy intention. As an illustration of the significance of trustworthy signaling in consumer decision-making, third-party certification labels, for instance, lower perceived risk and boost adoption of sustainable products (Brach, Walsh & Shaw, 2018). With expert endorsements having a greater effect on purchase intentions than celebrity influencers, mediated by brand appreciation and attitudes, influencer marketing has also become a successful tactic (Ghosal et al., 2021; Trivedi & Sama, 2020).

A comprehensive theoretical framework for understanding why consumers choose environmentally friendly products is provided by the Theory of Consumption Values (TCV), which considers functional, social, emotional, epistemic, and conditional values (Sheth et al., 1991). These values-which include social recognition, environmental concern, and emotional fulfilment-explain how consumers assess green products in ways that go beyond price and usefulness. In addition to TCV, Stakeholder Theory highlights the role of various actors, such as governments, corporations, non-governmental organizations, and consumers, in encouraging eco-friendly practices and sustainable consumption (Freudenreich, Lüdeke-Freund & Schaltegger, 2020; Garvare & Johansson, 2010; Zhang et al., 2025).

Green consumerism is gaining popularity, however there are still unmet research needs. In order to understand green buying intentions, particularly in the urban-rural context of India, existing research mostly focuses on individual cognitive and cultural aspects with little integration of TCV and stakeholder participation. Additionally, the majority of empirical studies have focused on cross-sectional surveys, frequently ignoring the complex relationships among stakeholder involvement, consumer trust, and marketing techniques (Jaiswala & Kant, 2018; Chen et al., 2023).

The conceptual framework proposed in this study bridges these gaps by establishing a connection between eco-conscious purchasing intention, stakeholder participation, and green marketing techniques, with consumer trust and environmental awareness acting as mediators. For companies and politicians looking to promote sustainable consumption in India and emerging countries, the framework seeks to offer both theoretical understanding and useful recommendations.

2.LITERATURE REVIEW

2.1. Eco-Conscious Consumer Behavior

Eco-conscious consumerism demonstrates the increasing demand of customers for products and services that reduce environmental effects.. Research shows that both cognitive and cultural factors affect eco-conscious behaviour. Jaiswala and Kant (2018) discovered that environmental concern (EC), perceived consumer effectiveness (PCE), and attitudes toward green products (AGP) strongly predict green purchasing intention (GPI) and green purchase behaviour (GPB) among Indian consumers. Similarly, Sreena, Purbey, and Sadarangania (2017) found that gender acts as a moderating element in the considerable influence of cultural values, such as collectivism and man-nature orientation, on green buying intentions. According to these studies, important factors influencing eco-conscious consumption are customers' values, beliefs, and environmental awareness.

There are also significant differences between consumer behavior in urban and rural areas. Sehrawet and Kundu (2007) showed that whereas urban consumers prioritize convenience, transparency, and ease of handling, rural consumers correlate packaging with product quality and utility but view some packaging practices as environmentally damaging. These variations show how important it is to take context into account when analyzing eco-conscious behavior in India.

2.2 Strategies for Green Marketing

Green marketing techniques are essential for influencing consumers' intentions to make environmentally friendly purchases. Frequently mentioned approaches include eco-labeling, third-party certification labels (TPCL), sustainable packaging, and green advertising. According to Brach, Walsh, and Shaw (2018), TPCL improves consumer acceptability of sustainable products and lowers perceived risk; nevertheless, their efficacy is reliant on label credibility. In a similar vein, brand attitudes and purchase intents can be influenced by influencer marketing, which includes both expert and celebrity endorsements. Trivedi and Sama (2020) emphasized the relevance of cognitive elements in influencing online green purchase intentions, while Ghosal et al. (2021) discovered that expert influencers have a greater impact than celebrity influencers, mediated by brand adoration and attitudes.

Additionally, green marketing affects consumer trust and perceived value. Chen et al. (2023) claim that green marketing (GM) and green customer value (GCV) promote eco-conscious behavior and positively affect environmental concern and brand awareness.According to these studies, effective green marketing techniques increase consumer trust and act as a mediator between buy intention and environmental concern.

2.3 Theory of Consumption Values(TCV)

The Theory of Consumption Values (Sheth et al., 1991) provides a strong basis for understanding consumer choice. TCV contends that functional, social, emotional, epistemic, and conditional values are among the elements that affect consumer choices in addition to price and utility. Product performance is related to functional value; social value is a reflection of acceptance or prestige; emotional value is associated with affective reactions; epistemic value is associated with novelty and curiosity; and conditional value is contingent on situational factors.

According to studies that apply TCV (Sheth et al., 1991) to green consumerism, emotional, social, and functional aspects are very important. Along with the practical benefits of green products, consumers also consider the emotional satisfaction and social recognition that come with choosing environmentally friendly options.(Chen et al., 2023; Jaiswala & Kant, 2018). TCV offers a theoretical foundation for connecting eco-conscious buying intents with green marketing tactics.

2.4. Sustainable Consumption and Stakeholder Theory

Businesses, governments, non-governmental organizations, and consumers all co-create value for sustainability, according to Stakeholder Theory (Freudenreich, Lüdeke-Freund, & Schaltegger, 2020; Garvare & Johansson, 2010). Businesses that successfully involve stakeholders can increase consumer trust, promote the adoption of sustainable practices, and reward environmentally friendly behavior. Through organizational learning and environmental scanning, Zhang et al. (2025) showed that stakeholder integration has a favorable impact on green innovation. Stakeholder involvement also influences attitudes and perceptions of sustainable tourism, according to Song, Zhu, and Fong (2021), underscoring the wider importance of stakeholders in encouraging sustainable consumption.Since consumer values are impacted by marketing tactics as well as the involvement of various stakeholders in promoting sustainability, combining Stakeholder Theory (Freeman, 1984) with TCV provides a comprehensive understanding of eco-conscious purchase intention.

3.RESEARCH GAPS

3.1Integration of Theories

The majority of current research either focuses on stakeholder-oriented viewpoints independently or on consumer-centric theories (such as the Theory of Planned Behavior and the Theory of Consumption Values). In order to comprehend how marketing tactics, customer values, and multi-stakeholder engagement collectively influence eco-conscious purchase intentions, few studies integrate TCV with Stakeholder Theory.

3.2 The Urban-Rural Divide in Developing Markets

Eco-conscious behavior has been studied in urban populations, but less is known about Indian rural customers (Sehrawet & Kundu, 2007). Understanding eco-conscious behavior across various

socioeconomic situations is hampered by the underexamined differences between urban and rural consumers' perceptions of packaging, trust, and awareness.

3.3 The function of moderators and mediators

Numerous research concentrates on the direct connections between purchasing intention and environmental concern or green marketing. There are gaps in our knowledge of the mechanisms that convert marketing tactics into purchase intentions because the mediation roles of stakeholder involvement and consumer trust and environmental awareness are not fully examined.

3.4 Empirical Research in the Indian Setting

Current conceptual models and frameworks are frequently developed-market or global in scope and lack empirical support in India. The relevance of studies like Jaiswala & Kant (2018) and Chen et al. (2023) is limited because they focus on cognitive and attitudinal aspects but do not include stakeholder participation or rural viewpoints.

3.5 Greenwashing and Green Marketing Strategies

Although eco-labeling and sustainable packaging are acknowledged as crucial green marketing tactics, little is known about how these tactics affect customer perceptions to affect trust, particularly in light of the dangers of greenwashing.

4.RESEARCH OBJECTIVES

- To examine the green marketing tactics used by companies and interested parties to encourage environmentally conscious consumption among Indian consumers in both urban and rural areas.
- To examine how consumer trust and environmental consciousness function as mediators in the relationship between eco-conscious purchasing intention and green marketing tactics.
- To examine the role of stakeholder participation (companies, government, and non-governmental organizations) in promoting sustainable consumption and improving the efficacy of green marketing techniques.
- To integrate Stakeholder Theory with the Theory of Consumption Values (TCV) to create a conceptual framework that explains eco-conscious purchasing intentions in the Indian context.
- To provide useful guidance to companies and legislators on how to execute successful green marketing campaigns and stakeholder partnerships in order to promote sustainable consumption.

5. Conceptual Framework

Stakeholder participation, consumer trust and environmental awareness, eco-conscious buying intention, and green marketing tactics are all included within the framework.

Variables that are independent (IV): Green marketing techniques (green advertising, eco-labeling, and sustainable packaging)

Mediators: Environmental consciousness and consumer trust

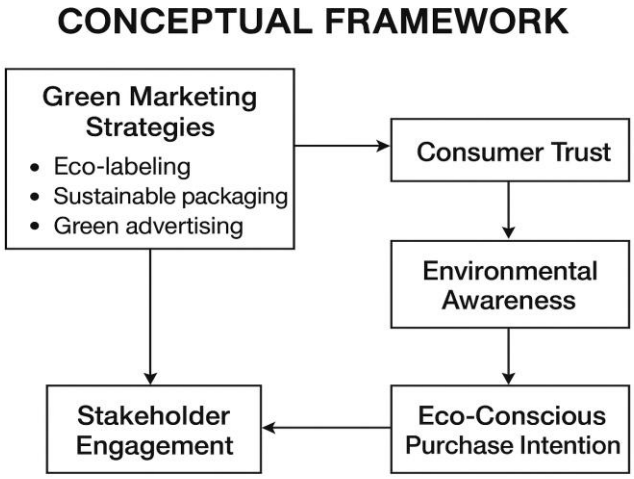
Moderator: Involving Stakeholders (Government, NGOs, and Businesses)

Eco-Conscious Purchase Intention is the dependent variable (DV).

Green marketing strategies impact consumer perceptions, trust, and awareness-all of which are critical for purchase behavior that is ecologically conscientious.(Jaiswala & Kant, 2018; Chen et al., 2023).

By adding credibility and boosting customer confidence, stakeholder engagement supports these tactics (Freudenreich et al., 2020; Zhang et al., 2025).

According to TCV, consumers' intentions are shaped by functional, social, emotional, epistemic, and conditional values, which explains why they value green products (Sheth, Newman & Gross, 1991).



Source: Developed by the author (2025) based on the Theory of Consumption Values (Sheth, Newman, & Gross, 1991) and Stakeholder Theory (Freudenreich, Lüdeke, Freund, & Schaltegger, 2020).

4.1 Explanation:

Green marketing techniques have a direct impact on environmental consciousness and consumer trust.

The impact of marketing tactics on environmentally conscious purchase intentions is mediated by trust and awareness.

Stakeholder involvement strengthens the impact by moderating the pathways from green marketing tactics to awareness and trust.

4.2 Proposition

P1: Consumer trust is probably going to be positively impacted by green marketing tactics.

P2: Environmental awareness is expected to be positively impacted by green marketing tactics.

P3: Consumer trust acts as a mediator in the relationship between eco-conscious purchasing intentions and green marketing strategies.

P4: Environmental awareness acts as a mediator in the relationship between eco-conscious purchase intention and green marketing strategies.

P5: By modulating the association between green marketing techniques and (i) customer trust and (ii) environmental awareness, stakeholder involvement raises eco-conscious purchasing intention.

4.3 Justification

Theoretical Contribution: Offers a thorough framework for comprehending environmentally conscious buying intention by fusing TCV and Stakeholder Theory.

Practical Relevance: Provides information on how marketing tactics and stakeholder engagement can encourage sustainable consumption to companies, non-governmental organizations, and legislators.

Future Research: Surveys or pilot studies conducted in India's rural and urban areas can be used to evaluate the framework empirically.

4.4 Discussion

In the context of Indian agribusiness, the suggested conceptual framework highlights the intricate interactions among green marketing tactics, stakeholder engagement, consumer trust, and environmental awareness that shape eco-conscious buying intentions. This study tackles the dual impact of personal consumer values and external stakeholder involvement on sustainable consumption behavior by combining the Theory of Consumption Values (TCV) with Stakeholder Theory.

According to the framework, eco-conscious behavior is influenced by the interaction of green marketing tactics with functional, social, and emotional values-all of which are essential elements of TCV. Emotional value creates contentment and moral fulfillment from selecting eco-friendly items, social value strengthens peer and community influence, and functional value (such as product quality, durability, and environmental safety) increases consumer trust. These factors account for the growing preference of consumers in both urban and rural areas for goods that blend practicality with social and environmental responsibility.

Involving stakeholders serves as a crucial moderator. Companies, governmental organizations, and non-profits can legitimize green marketing campaigns, increasing their legitimacy and lowering the suspicions surrounding greenwashing. The paradigm acknowledges that stakeholder credibility is crucial in encouraging the adoption of sustainable products in developing markets like India, where opinions of urban and rural areas differ.

This conversation is consistent with earlier studies showing that eco-labels, sustainable packaging, and influencer endorsements are examples of green marketing tactics that increase customer knowledge and trust (Brach, Walsh & Shaw, 2018; Ghosal et al., 2021; Chen et al., 2023). But by offering a comprehensive model that predicts eco-conscious purchasing intention by integrating personal beliefs, marketing tactics, and multi-stakeholder participation, the framework advances the literature.

5. METHODOLOGY

5.1 Research Design

In order to investigate the connections suggested in the conceptual framework between green marketing tactics, stakeholder engagement, environmental awareness, consumer trust, and eco-conscious purchase intention, this study uses a quantitative, explanatory research approach. Through the integration of Stakeholder Theory and the Theory of Consumption Values (TCV), the framework offers a comprehensive explanation of eco-conscious behavior in the Indian setting.

5.2 Sampling and Data Collection

The study focuses on customers from a variety of socioeconomic and cultural backgrounds who live in the Coimbatore district of Tamil Nadu, India. On the basis of validated scales from earlier research, a structured questionnaire will be created (Jaiswala & Kant, 2018; Chen et al., 2023; Brach et al., 2018).

To guarantee that respondents from both urban and rural areas are fairly represented, a stratified random sampling technique will be employed. Data from about 400 respondents-200 in urban areas and 200 in rural ones-will be gathered for the study.

The following constructs will be measured by a self-administered survey that uses a 5-point Likert scale (1 being strongly disagree and 5 being strongly agree):

Green marketing techniques include sustainable packaging, eco-labeling, and green advertising.

Customer trust: Belief that statements made by green marketers are genuine and reliable.

Environmental Awareness: Understanding and care about how consumption affects the environment.

Stakeholder Engagement: The idea that companies, non-governmental organizations, and governmental organizations work together to promote sustainability.

Willingness to purchase eco-friendly goods is known as eco-conscious purchase intention.

5.3 Variable Measurement

Construct	Number of Items	Source
Green Marketing Strategies	9	Chen et al. (2023)
Consumer Trust	5	Brach et al. (2018)
Environmental Awareness	6	Jaiswala & Kant (2018)
Stakeholder Engagement	5	Freudenreich et al. (2020)
Eco-Conscious Purchase Intention	6	Sreena et al. (2017)

5.4 Data Analysis

- AMOS/SmartPLS and SPSS will be used for data analysis and the following statistical procedures:
- Characteristic Statistics: to create response profiles and recognize broad trends.
- Two techniques for evaluating validity and reliability are Cronbach's alpha and confirmatory factor analysis (CFA).
- Structural equation modeling, or SEM, is used to analyze suggested relationships and mediation/moderation effects.
- Multi-Group Analysis: To investigate possible variations in consumer responses between urban and rural areas.

5.5 Ethical consideration

Respondents' confidentiality and identities will be preserved, and participation will be entirely voluntary. Guidelines for ethical data collection and institutional research ethics are followed in this study.

6. FINDINGS

6.1 Empirical Results (Predicted Outcomes)

The following is a summary of the expected outcomes based on the conceptual framework and amount of existing literature:

Green Marketing Techniques → Environmental Awareness and Consumer Trust

Green marketing techniques including eco-labeling, sustainable packaging, and green advertising are expected to significantly increase consumer trust and environmental awareness. These strategies reduce perceived risk and increase consumer confidence in eco-friendly products.

The Mediating Functions of Trust and Awareness

Consumer trust and environmental awareness are anticipated to act as mediators in the interaction between eco-conscious purchase intention and green marketing strategies. When consumers think that marketing messages are trustworthy and have an effect on the environment, they are more inclined to make eco-friendly purchases.

Stakeholder Engagement's Moderating Effect

It is anticipated that stakeholder engagement-through cooperation between companies, non-governmental organizations, and governmental entities-will enhance the beneficial impact of green marketing tactics on consumer awareness and trust. Consumer trust in sustainability claims is increased when stakeholders are seen as credible.

Urban-Rural Differences

According to the study, rural consumers will prioritize functional and conditional values like product utility, price, and packaging reuse, whereas urban consumers will exhibit greater levels of environmental awareness and responsiveness to eco-labels. According to the Theory of Consumption Values, these variances represent disparities in value priorities.

Validation of the Overall Model

The validity of the suggested framework should be confirmed by structural equation modeling, which should show good model fit indices (RMSEA < 0.08, CFI > 0.90, TLI > 0.90). The findings are likely to corroborate the claims (P1–P5), showing that stakeholder engagement, trust, and awareness are the ways in which green marketing tactics affect eco-conscious buying intentions.

7. IMPLICATIONS

Real-World Business Implications: Companies can create green marketing efforts that emphasize social recognition (peer and community acceptance), emotional fulfillment (pride in sustainable decision), and functional rewards (quality, durability).

Third-party certifications, sustainable packaging, and transparent eco-labeling can all help to increase consumer trust and allay worries about greenwashing.

Implications for Policy and Stakeholders: Businesses and NGOs can work together to advance environmental awareness initiatives in both urban and rural locations.Green marketing tactics will be more successful if sustainable activities are encouraged and certification procedures are established.

Consumer Education and Awareness: Tailored programs that highlight the emotional and social advantages of eco-friendly products can boost customer engagement, particularly in rural areas where awareness of sustainable practices may be low.

Implications for Marketing Strategy: Genuine endorsements and skilled influencer marketing can boost brand trust and have a favorable effect on consumers' intentions to make green purchases.

To make sustainability claims more credible, businesses should use integrated approaches that combine marketing tactics with proactive stakeholder engagement.

8. DIRECTIONS FOR FUTURE RESEARCH

A conceptual framework connecting green marketing tactics, stakeholder participation, environmental awareness, consumer trust, and eco-conscious purchase intention is presented in this paper. Although it makes a theoretical contribution, more work is required to validate and expand the concept. The following lines of inquiry are suggested for further study

Empirical Testing: To validate the framework, carry out surveys or pilot projects in both urban and rural Coimbatore. Measure the impact of stakeholder participation, green marketing, consumer trust, and environmental awareness on purchase intention.

Cross-Sector and Regional Studies: To test generalizability, apply the model to additional Indian regions and sectors (FMCG, renewable energy, ecotourism).

Longitudinal Studies: Examine the evolution of environmentally conscious behavior over time, particularly in response to shifting legislative measures and marketing strategies. Analyze the ways in which influencer endorsements, internet forums, and social media help to foster environmentally conscious consumer behavior.

9. CONCLUSION

By combining the Theory of Consumption Values (TCV) and Stakeholder Theory to explain green purchase intentions in the Indian setting, this research contributes to a better understanding of eco-conscious consumerism. The suggested conceptual framework highlights how consumer trust and environmental awareness-two important factors influencing eco-conscious purchase intention-are fostered by green marketing tactics backed by stakeholder involvement.

Combining stakeholder and consumer-centric viewpoints into a single model of sustainable consumption is the study's theoretical contribution. Its practical importance comes from providing useful advice on how to create reputable green marketing campaigns and cooperative sustainability programs for companies, legislators, and non-governmental organizations.In order to improve

knowledge of environmentally conscious behavior in emerging markets, this research offers avenues for further investigation, promoting empirical validation and a wider application of the model across various industries and geographical areas.

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The Evolution and Effectiveness of Monetary Policy in India: A Historical Perspective

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ABSTRACT

A closer examination makes it clear that the RBI's goal is to manage inflation along with providing economy's credit needs. Consequently, these two goals have shaped Indian monetary policy theory and practice. India's framework for monetary policy has undergone changed in a number of ways. Prior to independence, the goal was to preserve sterling parity by controlling liquidity through cash reserve ratios and open market operations, making the exchange rate the nominal anchor for monetary policy. Monetary policy followed the Five Year Plans from 1949 to 1969. Another stage in the development of monetary policy came with the nationalisation of major banks in 1969. This paper adopts a thorough perspective on evolution of monetary policy in line with the shifting nature of the economy. The current analysis provides relevant criticism on various monetary policy framework and monetary policy efficacy.

JEL: E51, E52, E58

INTRODUCTION

Although the legislation to establish the Reserve Bank of India was initially proposed in 1927, it wasn't until March 1934, seven years later, that it was finally enacted. However, there is a lengthy history that dates back to 1773 (Simha, S. L. N. 1970: 03). The First Round Table Conference's Federal Structure Subcommittee had suggested an early Reserve Bank establishment and stipulated that the Governor General should have sufficient authority over currency and monetary policy until this could be accomplished (Simha, S. L. N. 1970: 37). The Governor, Sir James Taylor, clearly outlined the Bank's stance on monetary control during the war at the annual general meeting of the Bank's shareholders in February 1940. He argued in favour of a stable interest rate policy. In other words, he opposed both artificially lowering the value of money and raising interest rates (Simha, S. L. N. 1970: 311). The Bank was kept busy during the war in carrying out its duties as a government banker and in the area of currency management, even though there wasn't much to be done in the actual area of monetary policy (Simha, S. L. N. 1970: 311).

When the Reserve Bank abandoned its traditional 3 per cent lending rate and the previous cheap money policy in 1951, monetary policy was emerged. After that, especially starting in the middle of the 1950s, the Bank adopted an active monetary policy that had to be considerate of the demands of the planning process while simultaneously anticipating or responding to immediate pressures. Additionally, the Bank's marketing activities intensified, and its initiatives to institutionalise credit and savings in the economy quickly followed suit. In fact, by the middle of the 1960s, its broader programs were seen as embodying the "institutional dimensions" of Indian monetary policy. A "fundamental task of monetary policy," according to Governor P.C. Bhattacharya in 1966, was to provide a "suitable institutional framework." He was referring to the requirement for effective mobilisation of the supply of actual and potential savings through the creation of a variety of financial assets and the marketing of financial intermediaries, on the one

hand, and the efficient investment of these resources through the modification of the credit structure to meet development needs on the other (Balchandran, G. (1998: 3,4)).

The RBI's monetary policy is developed and carried out by the Monetary Policy Department. Monetary policy refers to the employment of monetary tools/instruments that are under the central bank's authority to affect variables like interest rates, the money supply, and credit availability to accomplish the objectives of the policy (RBSC: 14). Repo Rate, Reverse Repo Rate, Bank Rate, Cash Reserve Ratio (CRR), Market Stabilisation Scheme (MSS), Marginal Standing Facility (MSF) under the Liquidity Adjustment Facility (LAF), and Open Market Operations (OPOs) are some of the direct and indirect tools used to implement monetary policy (RBSC:14). Preserving financial and macroeconomic stability is the central bank's fundamental objective. Central banks employ monetary policy to achieve financial, macroeconomic, and economic stability. In India, the function of monetary policy has developed over time to ensure a sufficient supply of credit to the economy's productive sectors while preserving a prudent balance between price stability, economic growth, and financial stability (RBSC: 14). Nonetheless, the RBI Act 1934's preamble, as modified by the Finance Act of 2016, states that keeping in mind the objective of economic growth maintaining price stability is the main objective of monetary policy (RBSC: 05).

Since the middle of the 1980s, efforts have been made to develop financial markets, especially the money market. In parallel, the Securities and Exchange Board of India was established, which accelerated the growth of the capital market. In 1985, a committee was established under Sukhamoy Chakravarty to review Working of the Monetary System revolutionised the paradigm of policy regarding the objectives of monetary policy, credit and money regulation, interest rate policies, and the coordination of fiscal and monetary policies.

An important turning point in India's economic history was the balance of payments and foreign exchange crisis of 1991. In order to solve the issue, the Reserve Bank of India implemented global best practices in areas like currency management, external sector management, banking technology, prudential regulation, and a range of monetary policy tools (RBSC: 4). Since the Great Depression of the 1930s, when the global economy experienced severe recession and massive bank failures, the significance of financial stability has drawn increased attention (RBSC: 2).

In addition to evolving in tandem with the shifting nature of the economy and the growth of financial markets, the evolution of India's monetary policy framework is also driven by theoretical advancements and global best practices. However, under the overarching goals, different monetary policy regimes have placed different amounts of emphasis on inflation, growth, and financial stability.

EVOLUTION OF MONETARY POLICY FRAMEWORK

A closer examination makes it clear that the RBI's goal is to manage inflation along with providing economy's credit needs. Consequently, these two goals have shaped Indian monetary policy theory and practice (Adil, Masudul Hasan, et al. 2020). The predominance of fiscal policy over monetary policy and the high inflation of the 1970s led to a new way of thinking which brought India into a new era of monetarism. During the development planning era, the RBI and the government were accused of losing overall control over inflation and of producing a lower growth dividend than expected. As a result of these repercussions, monetary policy was completely reconsidered, and the next phase of monetary policy thought-the monetarism era-was born. In general, this is consistent with events that occurred in other parts of the world as well (Adil, Masudul Hasan, et al. 2020).

Since the middle of the 1990s, the monetary policy framework of India’s central bank has been transforming, and the Patel Committee to the Reserve Bank of India recently outlined a plan for a reinforced framework (RBI, 2014). In the 1970s and 1980s, as India's monetary policy transformed, monetary authorities attempted to affect the amount of credit in order to accomplish their objectives. Actually, the objective was to ensure that the government had adequate access to credit to support its planned activities. In this manner the statutory liquidity ratio was periodically

increased. Also, some sectors- for which bank credit was pre-empted, referred to as priority sectors. The institutional environment in which monetary policy operated underwent a significant transformation in the early 1990s (Rangarajan, C. 2021).

The objectives, operating mechanism, and governance systems make up the monetary policy framework. The monetary policy's objectives are long-term goals that are not directly under the central bank's control. They can be goal variables or nominal anchors, such as monetary targeting, exchange rate targeting, nominal income targeting, price level targeting, inflation targeting, and just-do-it strategy. Because of this, the central banks only attempt to indirectly accomplish these goals by using instruments that are directly under their control to target intermediate[1] and operating targets that have a stable relationship with the ultimate objectives. Selecting an operationing target is essential since it is the first variable in the monetary transmission mechanism, which describes how a monetary expansion leads to increased expenditure on goods and services. In a similar vein, the choice of intermediate targets depends on the channels of transmission, or how monetary policy decisions affect the ultimate objectives. (RBSC: 16).

In essence, operating procedure[2] is the day-to-day management of liquidity conditions in accordance with the monetary policy's overarching position. Put differently, operating procedures are also referred to as the "plumbing in the architecture" or the "nuts and bolts of monetary policy" (Patra et al., 2016). In April 1999, an Interim Liquidity Adjustment Facility (ILAF) was established, and following a series of adjustments, it eventually evolved into a full-fledged Liquidity Adjustment Facility (LAF). The primary policy interest rates of the monetary were developed with assistance from the LAF. The LAF has been operated with banks using reverse repos and overnight fixed rate repos since November 2004. In order to foster more effective monetary transmission, the LAF, which is a crucial component of the RBI's operational framework, is designed to function in a deficit liquidity mode. Liquidity should be kept within +/- 1 per cent of all banks' net demand and time liabilities (NDTL) (Das, Sonali, 2015). The new framework is based on the interest rate channel of transmission's dominance (Mohanty, Deepak, 2011), which has been shown to be more successful in situations where there is liquidity deficit (Singh, 2011). Governance arrangements concentrate on the duties, authority, and accountability of the monetary authority and mainly address the decision-making process (RBSC:16).

In the past, short-term interest rates and bank reserves have evolved as the two main operating targets. However, as markets evolved in a deregulated environment, the emphasis switched to short-term interest rates in the early 1990s, reflecting the increased importance of interest rates in monetary transmission mechanisms. As a result, the overnight rate became the operating target that monetary policymakers most frequently pursued.

The monetisation of the fiscal deficit had a significant impact on how monetary policy was conducted from 1971 to 1985. In order to counteract the secondary impacts of monetary expansion, the CRR has to be used frequently due to the public sector's preemption of resources and the inflationary effects of large public spending. The private sector was partly crowded out of the credit market by financial repression in the form of directed loans, statutory pre-emptions, and interest rate prescriptions. In light of this, a committee was established in 1985 under the chairmanship of Dr. Sukhamoy Chakravarty to examine the working of the monetary system, which proposed a new monetary policy framework based on monetary targeting with feedback. This recommendation was based on empirical evidence of a stable demand function for money (RBSC: 17).

MONETARY TARGETING FRAMEWORK

Automatic monetisation of budget deficit through ad hoc treasury bills gradual growth in SLR by 1985 reflected fiscal dominance in the 1980s. At the same time, the inflationary effects of financing the deficit justified tightening monetary policy, leading to a large increase in both the CRR and the Bank Rate. Following the Chakravarty Committee's suggestions, monetary targeting was formally adopted as a monetary policy framework in 1985 as a result of monetary policy's

experience with the objective of fostering growth and controlling inflation. Reserve money served as the operating target and broad money (M3) as the intermediate target in this framework, which aimed to manage inflation by restricting monetary expansion. A manageable level of inflation and anticipated real GDP growth served as the foundation for the targeted growth in money supply (https://www.rbi.org.in). Technically speaking, the M3 expansion target was set at 14 per cent [M3 growth was 1.5(6)+5=14%] if the expected real GDP growth was 6 per cent, the income elasticity of demand for money was 1.5, and the acceptable inflation rate was 5 per cent (Mohanty, 2010). From the middle of the 1980s until 1997–1998 this framework was in use (RBSC:17). This approach was flexible as it allowed for feedback effects. CRR was used as the primary instrument for monetary control. However, both SLR and CRR peaked by 1990 as a result of ongoing fiscal dominance (https://www.rbi.org.in).

In the face of unfavourable global shocks, such as the Gulf War and the fall of the Soviet Union, the fiscal situation that had gotten worse in the late 1980s was reflected in the decline of the external balance position and the collapse of domestic development in 1991–1992. The ensuing balance of payments crisis led to extensive structural reforms, banking sector liberalisation, and opening up of an economy to achieve price stability with sustained growth. In 1993, a system of market-determined currency rates replaced the fixed exchange rate regime. The assumption of stability in the money demand function and the effectiveness of broad money as an intermediate target were questioned in the wake of trade and financial sector reforms, which led to an increase in foreign capital flows and financial innovations. Both the public and private sectors saw a noticeable transition towards market-based finance in the same period. Actually, in 1997, ad hoc treasury bills were replaced with a system of ways and means advances (WMAs) for automated monetization. The average WPI-based inflation rate during this time was 8.1 per cent, whereas the average domestic growth rate was 5.6 per cent (https://www.rbi.org.in). The M3 growth rate each year was 17 per cent. In its 1985 report, the Chakravarty Committee emphasised the need to regulate the money supply and sought to ensure that its expansion aligned with both real growth and the acceptable level of inflation (RBI, 1985). Because reserve money was the primary driver of money supply expansion and RBI's lending to the central government was the primary determinant of reserve money production, it also underlined the necessity of tight coordination between monetary and fiscal policy. The group therefore envisioned a plan of what became known as flexible monetary targeting (Rangarajan, C., 2021).

The main obstacle to monetary targeting was lack of control over RBI's credit to the central government, which was responsible for the majority of reserve money creation (RBSC: 17). As a result of economic and financial sector reforms in the 1990s, financing of government and commercial sector shifted to market-determined interest rates and currency rates (RBSC:17). Government securities were made marketable by switching to a market-determined interest rate, which also made it possible for open market operations to develop as a tool for credit control. The rate of interest became a policy variable after the administered interest rate system was dismantled. Because price stability was a primary goal of monetary policy, the RBI considered controlling the money supply to be a crucial component of monetary policy. The RBI began using several indicators after 1997 (Rangarajan, C., 2021). The RBI was successful in switching from direct to indirect market-based instruments. By 1997, the SLR and CRR had been progressively reduced to 25 percent and 9.5 per cent, respectively. With interest rates and currency rates becoming more significant in relation to quantity variables, there was also mounting evidence of changes in the fundamental transmission mechanism of monetary policy. In light of this, a new monetary framework, known as Multiple Indicator Approach was introduced in1998-99 (RBSC: 17).

MULTIPLE INDICATOR APPROACH

As financial innovations, market deregulation, and liberalisation started to erode the effectiveness of the widely used monetary targeting framework, it became necessary to evaluate the monetary policy framework and restructure its operational procedures. In light of this, the RBI implemented a "multiple indicator approach" in April 1998, placing more weight on rate channels than on quantitative tools for monetary policymaking. The information set used for monetary policy

formulation under this approach consisted of monetary aggregates as well as a variety of forward-looking indicators (quantity variables) like credit, output, inflation, trade, capital flows, and exchange rates, as well as rate variables like fiscal performance and the rate of returns in various markets (https://www.rbi.org.in). This approach gives the RBI a great deal of freedom to react more effectively to shifts in the financial market and the domestic and global economic environments (RBSC: 23). A change from direct to indirect monetary policy instruments was also made possible by the domestic economy's increased market orientation and interest rate deregulation, which has been in place since the early 1990s. As a result, rate channels were given more weight in the formulation of monetary policy than were quantity instruments. As a result, the RBI's monetary policy stance was communicated through short-term interest rates. In an effort to stabilise short-term interest rates, the Reserve Bank put emphasis on the integration of the money market with other market segments. Using a variety of policy instruments, it adjusted market liquidity to guide monetary conditions in the direction it wanted. Changes in policy rates, such as the Bank Rate and reverse repo/repo rates were instruments for altering the price of liquidity, while other instruments, such as adjustments to reserve requirements, standing facilities, and OMOs, were intended to influence the amount of marginal liquidity (https://www.rbi.org.in). Between 1998-99 and 2008-09, this approach appeared to be working pretty well, as evidenced by the average real gross domestic product (GDP) growth rate of 7.1 per cent and average inflation of roughly 5.5 per cent in terms of both the WPI and CPI. But in the years following the global financial crisis (i.e., after 2008), the effectiveness and even the legitimacy of this framework were called into question due to the coexistence of chronically high inflation and slowing economic growth, or overt indications of stagflation. The argument that a large number of indicators do not offer a well-defined nominal anchor for monetary policy led to criticism of the current multiple indicator approach. The RBI established an Expert Committee to update and fortify the monetary policy framework and offer recommendations for improving its predictability and transparency. The Committee examined the various indicators approach in its 2014 report and suggested that inflation serve as the nominal anchor for India's monetary policy framework. Given this, the Reserve Bank set a schedule for itself to reduce inflation in a gradual way, from its peak of 11.5 per cent in November 2013 to 8 per cent by January 2015, 6 per cent by January 2016, and 5 per cent by Q4 of 2016–17 (https://www.rbi.org.in)

FLEXIBLE INFLATION TARGETING (2016 ONWARDS)

On February 20, 2015, the Reserve Bank and the Government of India signed a Monetary Policy Framework Agreement (MPFA). Later, in May 2016, the RBI Act was amended to formally embrace a new monetary policy framework called flexible inflation targeting (FIT). The following is a restatement of the Reserve Bank's monetary policy responsibility in the amended Act:
"the primary objective of monetary policy is to maintain price stability while keeping in mind the objective of growth".

With the help of this mandate, the RBI implemented a flexible inflation targeting (FIT) framework that prioritises price stability, as measured by a target of 4 per cent for consumer price headline inflation with a tolerance band of +/- 2 per cent around it. At the same time, growth is prioritised when inflation is under control. The macroeconomic environment, the forecast for inflation and growth, and the signals obtained from incoming data will determine the relative emphasis on inflation and growth. Since then, the RBI has been implementing monetary policy with an eye towards the future and clearly communicating its decisions to keep inflation within its target range to boost GDP. In order to effectively transmit policy across the financial markets and, consequently, into the actual economy, the RBI is simultaneously improving its monetary policy operational procedures. As a result, during 2017–18, inflation has steadily decreased and has hovered below 4 per cent (https://www.rbi.org.in).

Since the relationship between monetary aggregates and goal variables like inflation has broken down, many countries have recently adopted inflation targeting as their monetary policy method to achieve price stability. The first nation to formally implement inflation targeting was New Zealand in 1990. Other nations that have done so include Canada in 1991, the United Kingdom in 1992,

Sweden and Finland in 1993, Australia and Spain in 1994, Israel, Chile, and Brazil (Mishkin, Fredrick S, et al. 2011). Inflation targeting consists of the following components: (i) the public declaration of inflation's medium-term numerical targets; (ii) an institutional dedication to attaining the inflation target and to price stability as the main, long-term objective of monetary policy; (iii) an information-inclusive strategy wherein monetary policy choices are made using a variety of factors, not only monetary aggregates; (iv) enhanced monetary policy strategy transparency through communication with markets and the public about the objectives and plans of monetary policymakers; and (v) greater accountability on the part of the central bank to meet its inflation objectives (Mishkin, Fredrick S, et al. 2011).

INSTITUTIONAL MECHANISM FOR MONETARY POLICY MAKING

The Reserve Bank has developed internal institutional frameworks to direct the process of formulation of monetary policy. In order to monitor changes in the money, foreign currency, and government securities markets, the Financial Market Committee (FMC) was established in 1997. On a daily basis, the FMC also evaluates liquidity levels and recommends suitable market intervention. The Monetary Policy Strategy Group reviews the credit and monetary environment and expresses an opinion on the stance of monetary policy. In July 2005, the Technical Advisory Committee (TAC) was established with the goal of strengthening the consultative procedure in monetary policymaking. This TAC is responsible for reviewing macroeconomic and monetary developments and advises the Reserve Bank on monetary measures and on the stance of the monetary policy that may be undertaken afterwards policy reviews.

EFFECTIVENESS OF MONETARY POLICY

The classical quantity theory of money is as old as economic growth theories and monetary policy (Gali, 2008). But it wasn't until the 1930s that modern theories gained prominence. The Keynesian Liquidity Preference Theory, monetarism (Twinoburyo, et al. 2018), and the New Classical real business cycle, as well as the New Keynesian Model and the New Consensus Model, were the mainstays of monetary policy analysis for the past two decades (Goodfriend et al., 1997; Arestis et al., 2008). Research on the short- and long-term effects of monetary policy on real variables-particularly output-has remained unclear throughout time (Walsh, 2003). The majority of research mostly examined developed nations and the long-run neutrality of monetary policy (Asongu, 2014).

The majority of economists in the 1960s thought that Keynes' theories provided the best explanation for fluctuations in economic activity. However, Milton Friedman of the University of Chicago claimed that aggregate demand was influenced by money rather than fiscal policy. Additionally, monetarists argued that monetary policy may influence aggregate demand through a variety of channels, including interest-rate effects on investment. As the early Keynesians[3] argued, monetary policy might then have a significant effect on aggregate demand even if interest-rate effects on investment spending are minimal (Mishkin, Fredrick S, et al. (2011). The new Keynesian perspective was that interest rates were effective in reducing the production gap, given wage-price rigidities, with the exception of severe liquidity traps, whereas the original Keynesian viewpoint had been that fiscal policy was generally more effective than monetary policy(Ashima Goyal, 2011).

The world has experienced in the years following World War II that monetary policy's effectiveness and scope are relatively constrained when there is a fiscal imbalance. Monetary instruments remained passive during the war years almost everywhere in the world, with interest rates being one such instrument (Simha, S.L.N. 2005). The Korean boom's demise demonstrated that a flexible monetary policy could produce unexpectedly positive outcomes in strengthening a slowing economy. The Bank would benefit from having the authority to change banks' reserve requirements in this situation as well, specifically the authority to release banks' reserves. "Fixed reserve may be alright in the static economy, but a dynamic economy requires a variable system."
At any costs, some industrialists, notably Mr. G.D. Birala, championed the cause of cheap money. Proponents of the dear money strategy were also present. Therefore, Lala Yodh Raj, the Chairman

of the Punjab National Bank, made the following arguments in support of higher interest rates in his speech to the bank's shareholders on April 8, 1949:

“The policy of cheap money has had its run for over 16 years and appears now to be out of tune with the economic forces in the country. The demand for capital has outstripped its supply. The fundamentals have changed and the obvious remedy appears to be to use the monetary policy again as an active instrument of disinflation with its reliance on credit restriction and increase in interest rate” (Simha, S.L.N. 2005: 693).

In terms of crises and structural changes, the years 1981–1997 represent a highly significant phase in Indian economic history. Given that 1991 marked a significant shift in financial and economic policy in the wake of the balance of payments crises, the institutional history can be divided into two separate phases. The first phase may be referred to as "Consolidation and Early Liberalisation" which spanned 1981–1989, addressed macroeconomic reforms and monetary policy developments after 1981. The second phase may be referred toa as "Crisis and Reforms", which spans 1989–1997 (R.B.I. 2013).

Generally speaking, starting with the Second Plan, monetary policy had to function within the framework of significant budget deficits (Simha, S.L.N.2005:849-50). The gradual eradication of automatic monetisation of the budget deficit and the removal of ad hoc Treasury Bills, which added discipline to budgetary finances and increased the efficacy of monetary policy, may have been the most significant event in the management of public debt (R.B.I. 2013: 650).

In order to lower the inflation rate, the objective of monetary policy from 1994 to 1995 emphasised on reducing excessive primary money creation. This was because the opening of the external sector highlighted the necessity of monetary policy and exchange rate policy being consistent with one another. It was also expected that monetary policy would offer a framework that would facilitate the implementation of the financial sector's comprehensive reforms. To enable monetary policy to have sufficient "head room" to support output growth, the Governor reaffirmed that appropriated fiscal measures were necessary to contain net RBI credit to the Central Government (R.B.I. 2013: 663).

Effective monetary policy management may be hampered by the central bank's unrestricted direct funding of the government. Direct funding to the central government had to be limited, and the boundaries had to be clearly stated in order to make central bank implement monetary policy effectively (R.B.I. 2013: 674).

In the light of massive capital inflows in 1994–1995 and the ensuing explosive growth in net foreign assets (NFA), the objective of monetary policy in 1995–1996 shifted to reduce inflationary pressures and counteract the effects of a sustained large inflow of foreign exchange on monetary expansion. The mainobjective of the policy was to continue reforming the financial system. The Reserve Bank said that the fiscal actions, which influenced the internal debt management plan, would be crucial to the effectiveness of monetary policy instruments in managing inflation and monetary expansion (R.B.I. 2013: 664,665).

We can draw two lessons from German monetary targeting. First, even when a monetary targeting regime allows for significant target misses, it may eventually control inflation. Therefore, achieving favourable inflation results does not need strict adherence to a policy norm. Second, despite frequent target misses, monetary targeting was reasonably successful because the central bank communicated the monetary policy strategy to the public and the monetary policy objective was clearly stated. This increased monetary policy transparency and central bank accountability (Mishkin, Fredrick S, et al. 2011: 466). We may also learn from Japan that even when short-term interest rates are close to zero, monetary policy can still be successful. Monetary policy should act in this scenario to boost aggregate demand through inflationary measures and asset price increases. We should also learn from Japan that unexpected changes in the level of prices should be avoided.

In addition to being incompatible with the objective of price stability, allowing deflation to occur could have severe negative effects on the economy. The Bank should declare an inflation objective to encourage price stability (Mishkin, Fredrick, et al. 2011: 466).

The Federal Reserve was effective in adopting a preemptive monetary strategy under Alan Greenspan. For instance, before inflation took place in an economy, the Fed hiked interest rates between 1994 and 1995. Consequently, inflation not only did not increase but even decreased somewhat. Because monetary policy instruments are adjusted to account for the long lags in their effects in an attempt to meet future inflation targets, this pre-emptive monetary policy is a feature of inflation-targeting regimes. The Fed's policy approach, however, is more akin to "just do it" policy and is different from inflation targeting approach in that it has not a formal nominal anchor and is much less transparent about its monetary policy approach (Mishkin, Fredrick S, et al. 2011: 473).

Uncertainties surround even effective monetary policy. For instance, in the USA, inflation was brought down from a hazardous 13 percent annually in 1979 to a meagre 2 percent by 2003. This was accomplished through a series of trial-and-error monetary measures, some of which were successful and some of which were unsuccessful, all of which had a negative impact on worker unemployment and business viability. In order to combat inflation, the Federal Reserve tightened money and credit in the early 1980s. Consequenltly, unemployment increased and bankruptcies and business failures reached to heights not seen in decades (Sowell, Thomas 2015).

CONCLUSION

Most people think that a central bank's identity is defined by its monetary policies. During India's independence, the Reserve Bank of India carried out a number of developmental projects, but its primary focus remained monetary policy. In addition to supporting fiscal policy and monetary policy, the robust growth of the government securities market also advanced financial markets generally. The pursuit of an effective monetary policy and the successful restructuring of the financial sector both depend on the shift towards market-related interest rates on Treasury Bills and government-dated securities. The conduct of monetary policy is influenced by three international factors: exchange rate considerations, balance of payments concerns, and direct effects of the foreign exchange market on the money supply. The position of monetarists is strengthened by certain historical evidence showing that economic cycle contraction follows exogenous drops in money expansion. The notion that monetary policy does matter appears to be supported by historical evidence as well as timing and statistical evidence. A component of overall economic policy is monetary policy. The economy may be negatively impacted when monetary and fiscal policies move in different directions. For monetary policy to be effective, the RBI and the government must communicate and coordinate closely.

Notes:

1. An intermediate target, like long-term interest rates or monetary aggregates, may be connected to the policy instruments. While they may be more closely related to the objectives of monetary policy but are not directly affected by the instruments of monetary policy. Intermediate targets stands between the goals of monetary policy (such as, price stability and output growth) and instruments of monetary policy. Priority sector credit targeting was the monetary policy's intermediate goal from the 1950s to the end of the 1980s. The intermediate objective changed to monetary targeting with yearly increase in broad money (M3) from the early 1990s to 1998–99. The intermediate target changed to a multiple indicator approach (such as money, capital, currency, and external factors) from 1998–1999 to 2015. In 2016, India formally adopted a new framework for monetary policy which is known as flexible inflation targeting.
2. Direct monetary policy tools, such as interest rate regulation, selective credit restriction, SLR, and CRR, were used from the 1950s until the end of the 1980s. Operating procedures (instruments) shifted to progressive interest rate deregulation along with direct instruments

from the early 1990s to 1998–99. Operating procedures from 1998 to the present include both direct and indirect instruments (repos operations under LAF and OMOs).

3. Different phases in the evolution of Keynesian philosophy are represented by original Keynesian economics, early Keynesian economics, and new Keynesian economics. John Maynard Keynes was the founder of original Keynesianism, which emphasised aggregate demand for the cause of economic fluctuations and argued that the economy could be stabilised by government intervention mainly through fiscal policy. Building on this foundation, early Keynesianism created more intricate economic models that took into account variables like monetary policy. It also focused on regulating government intervention and considered both fiscal and monetary policy. Conversely, rational expectations and microeconomic underpinnings are incorporated into New Keynesian economics. The foundation of New Keynesian economics is the idea that prices and wages are sticky, which may help explain why the economy may not achieve full employment. The effectiveness of policy action is implied by the assumption of rational expectations.

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Modeling the Sustainable Digital Transformation of Tribal Agro-Based Entrepreneurs in Madhya Pradesh

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ABSTRACT

The paper proposes to examine factors determining financial technology (fintech) adoption behaviour of tribal agro-based entrepreneurs of Madhya Pradesh by utilizing integrated framework consisting of Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) and Theory of Planned Behavior (TPB) for the first time. This study investigates the effect of psychological, socio-psychological and experiential factors affecting the propensity of rural entrepreneurs to adopt digital financial platform for improvement in financial inclusion and operational performance.

Several constructs including Attitude, Subjective Norms, Perceived Behavioral Control, Trust, Hedonic Motivation, and Price Value were used to determine their impact on user Satisfaction and subsequent Behavioral Intention. These findings clearly show that satisfaction serves as a crucial mediator between the cognitive and emotional perceptions of the financial technologies and the intention to adopt them. These factors and mediating variables demonstrate that trust and hedonic motivation are highly influential in creating positive experiences for the user, while social influence and perceived control also contribute to positive intention formation.

This research adds to the existing literature by framing UTAUT2 and TPB in the context of a rural, tribal entrepreneurial ecosystem. It can provide policy-makers, fintech designers and rural development representatives practical guidance for designing digital financial solutions that are more inclusive, culturally adaptable, and user-friendly. By promoting trust-building mechanisms, improving user experience, and overcoming behavioral hurdles, these communities can better accelerate digital adoption.

Keywords: Tribal Entrepreneurs; UTAUT2; Theory of Planned Behavior; Rural Innovation; Financial Inclusion; Technology Adoption; Madhya Pradesh; Behavioral Intention; Agro-Based Enterprises

INTRODUCTION

FinTech innovations have deeply changed the way that individuals and businesses can access, manage, and consume financial services. Digital finance has now positioned itself as a critical channel for promoting financial inclusion in India, including in rural areas where conventional banking services are either non-existing or very limited (Sahay et al., 2020). Tribal communities involved in agro-based entrepreneurship segment represents one such demographic group amongst these regions which gets often left out of the mainstream financial ecosystems owing to issues like infrastructure, social and digital literacy (RBI, 2021).

The last decade saw an increased policy focus on mobile payments, online lending, and other FinTech solutions designed for the unique needs of rural farmers and microentrepreneurs (World Bank, 2022). Access to technology is not the only reason tribal entrepreneurs' adoption of

technology is first in, first out; and the reasons vary in type from attitudinal to behavioral, and contextual. Although infrastructure is an important factor, the desire to perform a particular behavior is frequently affected by psychological elements like trust, motivation, perceived ease of use, social influence (Dwivedi et al., 2019).

In order to gain better insights into these drivers, this research employs a comprehensive framework that merges the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) and the Theory of Planned Behaviour (TPB). UTAUT2 provides a strong theoretical base to assess how constructs namely performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit influence technology adoption (Venkatesh et al., 2012). On the other hand, by emphasizing attitude, subjective norms, and perceived behavioral control, TPB considerably enhances the behavioral aspect with evidence supporting the robustness of the three determinants of intention across various cultural contexts (Ajzen, 1991; Fishbein & Ajzen, 2010).

This study examines tribal agro-based entrepreneurs in Madhya Pradesh state, housing one of the largest tribal populations in India, who have been transitioning from the informal lending practices to well-organised digital financial systems. Knowledge about their behavioral determinants is important not only for promoting rural digitalization, but also for designing culturally appropriate interventions that establish trust, increase satisfaction and lead to sustainable technology use.

The study theoretically and practically adds to the discourse on inclusive digital finance by providing a comprehensive understanding of the behavioral model and context surrounding the decision process. It highlights the importance of a user-centric approach that integrates FinTech innovation with the practical realities of tribal rural entrepreneurs.

LITERATURE REVIEW

While the proliferation of financial technologies (FinTech) in rural India has been transformative, it is also path dependent in many ways. Although there is a considerable amount of literature on digital adoption in urban and semi-urban settings, research on FinTech adoption is scarce, especially among tribal entrepreneurs, like those in the agro-based sector (Kumar et al.,2022). At the same time, adoption behavior can be deeply theoretical models such as the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) and the Theory of Planned Behavior (TPB) combining technology and psychological dimensional analysis.

Attitude is the core element of TPB that expresses the positive or negative behavior of an individual towards using technology. It has been previously validated for prediction with respect to rural technology adoption (Shaikh & Karjaluoto, 2015). But how exactly does it interact with and affect cultural norms & digital trust among tribal populations? FinTech studies report mixed results on Subjective Norms, which measure the perceived social pressure to adopt a behavior. Despite their importance in collectivist societies (Dwivedi et al., 2019), they need contextual reconceptualization among the tribal entrepreneurs.

Perceived behavioral control (PBC), or the perceived ease or difficulty to perform a behavior, is mostly associated with digital literacy and access to infrastructure. Though PBC is identified as a significant hurdle in terms of digital adoption, specifically in rural India (Chopdar & Sivakumar, 2019), empirical investigations of PBC have largely remained agnostic to tribal agro-preneurs.

Trust in digital platforms also surfaces as a salient driver of adoption among low-income and low-literacy segments, who are worried about the misuse of personal data and the security of their transactions (Bala & Verma, 2023). Trust in tribal areas may be governed by social exposure to peer recommendations, local governance or past exposure to formal finance - but this phenomenon is still buried in empirical research literature.

Hedonic motivation (from UTAUT2) (15): Reflects the presence of enjoyment when using a technology. It played an essential role in consumer tech but its relevance in pragmatic financial contexts is still debated (Alalwan et al., 2017). However, enjoyment could enhance initial trials for tribal users who adopt intuitive and gamified platforms.

In the domain of rural FinTech, Price Value, or the benefit that the buyer observes in relation to its cost, has been inconsistently important (Williams et al. In tribal zones, the predictive power of cost–benefit assessment is often blurred by government subsidies or NGO involvement (Saxena et al. 2022).

Satisfaction mediated between usage experience and future intention has been extensively examined, particularly in the service adoption models (Bhattacherjee, 2001). Yet, as factors explaining TPB and UTAUT2 constructs behavioral control-merging the two theories toward a more insightful synthesis-theoretical models involving IDT have only recently solidified in the tribal FinTech adoption field.

As can be seen, the combined effect of the above factors ultimately determines which levels of Behavioral Intention (the final, dependent variable level) is moderated by various demographic and contextual variables (Venkatesh et al., 2012).

Research Gap

While there have been increasing numbers of academic interest in digital financial inclusion, the majority of studies focus on urban or literate rural users. Tribal agro-based entrepreneurs are severely understudied in relation to empirical research, particularly in an informal lending dominated context such as central India (where digital trust is also low). In addition, none of the previous studies have combined UTAUT2 and TPB constructs with Satisfaction as a mediating variable to comprehensively explore the FinTech adoption by this segment. We fill these gaps with this study by examining satisfaction and intention among tribal entrepreneurs through the lens of trust, behavioral control, and motivational factors.

Conceptual Framework and Hypothesis Development

PurposeDespite limited adoption of financial technologies, unexplored behavioral intention of tribal agro-based entrepreneurs of Madhya Pradesh toward adopting financial technologies.The study integrates constructs from both the Theory of Planned Behavior (TPB) as well as Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) to account for the limitation. The framework places Satisfaction at the center of mediation between psychometric perceptions & experience assessments, on the one hand, and intent to use digital financial platforms.

Attitude, under the TPB domain, represents how much favorable or unfavorable the individual views the use of FinTech. In tribal communities, where exposure to the digital territory is sparse, the favorable attitude towards technology emerges generally from either peers or a successful digital experience. Hence, it is proposed that attitude contributes significantly to financial technology satisfaction (H1). Likewise, Subjective Norms, or perceived social pressure from family, peers, or other leaders in a community to perform a behavior, are likewise expected to predict satisfaction, especially in collectivist rural cultures where the expectations of the group take center stage (H2). Perceived Behavioral Control (PBC) represents the degree to which tribal entrepreneurs believe they are able to use financial technologies with regard to infrastructural constraints and digital skills. Higher sense of control = higher satisfaction and confidence of using FinTech (H3)

Trust considerations play an integral role in the context of digital platforms in the UTAUT2 view by influencing how comfortable users feel with engaging a digital platform at a behavioral level. In areas where the clientele is financially underserved, avoidance or mistrust in technology or service providers can hamper adoption (Bhatti et al., 2018; Porter 2021)-in contrast, a trustworthy ecosystem contributes to user experience (H4). The hot factor responsible for engagement is

Hedonic Motivation: the enjoyment that comes from using a technology. Positive emotions can, therefore, be generated because of the effects from the interface of the FinTech platform or the availability of the regional languages or gamified FinTech platforms (H5). It is also proposed that Price Value, measuring the cost-benefit ratio, affects satisfaction (H6), while this effect may be contingent on both government subsidies (DU et al. 2012) and NGO assistance to promote FinTech (Alaaraj et al. 2018).

At the heart of the model, is the concept, Satisfaction, defined as the perceived transaction outcome that meets or exceeds the consumers' expectations after engaging with FinTech services. We expect Satisfaction to be a strong positive predictor of Behavioral Intention - the intention to use such technologies again or to increase their use in the future (H7). Finally, demographic factors like age, gender, and digital experience are expected to moderate the relationship of satisfaction and behavioral intention, as personal characteristics influence adoption behavior (H8). The integrative model offers a holistic perspective to assess the broad scope of influences-psychological, social and experiential past experiences-on FinTech adoption in the context of tribal rural areas.

Hypothesis Code	**Null Hypothesis (H_0)**	**Alternative Hypothesis (H_1)**
H1	H_{01}: Attitude has no significant influence on Satisfaction.	H_{11}: Attitude positively influences Satisfaction.
H2	H_{02}: Subjective Norms have no significant influence on Satisfaction.	H_{12}: Subjective Norms positively influence Satisfaction.
H3	H_{03}: Perceived Behavioral Control has no significant influence on Satisfaction.	H_{13}: Perceived Behavioral Control positively influences Satisfaction.
H4	H_{04}: Trust has no significant influence on Satisfaction.	H_{14}: Trust positively influences Satisfaction.
H5	H_{05}: Hedonic Motivation has no significant influence on Satisfaction.	H_{15}: Hedonic Motivation positively influences Satisfaction.
H6	H_{06}: Price Value has no significant influence on Satisfaction.	H_{16}: Price Value positively influences Satisfaction.
H7	H_{07}: Satisfaction has no significant influence on Behavioral Intention.	H_{17}: Satisfaction positively influences Behavior

METHODOLOGY

A statistical, cross-sectional research design is used in this study to investigate the behavioral aspects influencing the financial technology adoption behavior of tribal agro-based entrepreneurs of tribal belt Madhya Pradesh. Using the UTAUT2 and TPB as the theoretical lens, the research examines the relationships among Attitude, Subjective Norms, Perceived Behavioral Control, Trust, Hedonic Motivation, and Price Value with Satisfaction and subsequently with Behavioral Intention to adopt digital financial platforms. The study was conducted in tribal-dominant rural blocks of Jabalpur, Chhindwara, Mandla, Shahdol, Kundam and Tamiya districts which were purposively selected due to their high concentration of agro-based tribal enterprises. Obtained 400 valid data via purposive sampling technique from respondents who have exposure or knowledge on mobile-based banking app, UPI system, or other FinTech platform. With help from local NGOs, Krishi Vigyan Kendras, and tribal self-help groups, a structured questionnaire was developed and it was translated into Hindi (a regional language) and Gondi (the local tribal dialect). The items used for measurements were adapted from validated scales used in the past studies (Ajzen, 1991; Venkatesh et al., 2012; Bhattacherjee, 2001; Bala & Verma, 2023) and were measured using 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). Reliability was ensured from a pilot study with 30 tribal entrepreneurs by using Cronbach's alpha value which was greater than 0.70 for all constructs. The data for this study were analysed by using SmartPLS 4.0, which is a statistical software program designed for partial least squares structural equation modeling (SEM) in complex and exploratory settings. This analysis comprised two phases: firstly, the measurement model was examined to assess reliability (internal consistency and discriminant

validity) while secondly, the structural model was evaluated for path relationships, explanatory power (R^2) and effect size (Hair et al., 2021). Meanwhile, multi-group analysis (MGA) was conducted to verify the possible moderation effects of some demographic characteristics: age, gender, and digital literacy. All ethical protocols were strictly followed, with informed consent sought from and confidentiality ensured for the participants, as per the Indian Council of Social Science Research (ICSSR, 2019) guidelines. This methodological approach offers a culture-sensitive yet statistically rigorous foundation for providing insights into the drivers of digital financial adoption for tribal entrepreneurs in these economically disadvantaged rural locales.

RESULTS AND ANALYSIS

5.1 Demographic Profile of Respondents

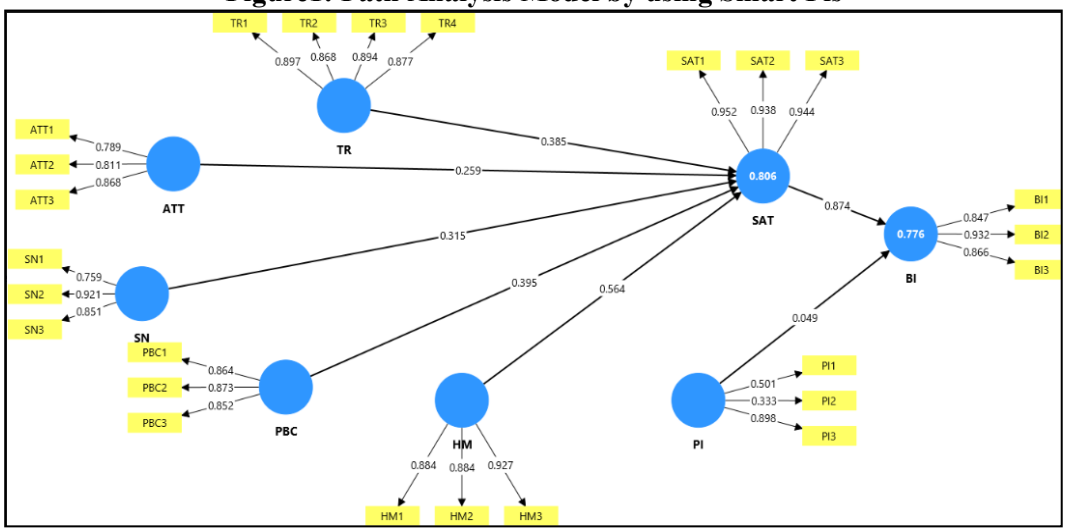
The structured questionnaire was digitally circulated among tribal agro-based entrepreneurs in rural Madhya Pradesh, and a total of 400 valid responses were received. The respondents resided in districts like Jabalpur, Chhindwara, Mandla, Shahdol, Kundam, and Tamiya. Table 1 shows the demographic breakdown.

Table 1: Demographic Characteristics of Respondents

Variable	Category	Frequency	Percentage (%)
Gender	Male	260	65.0
	Female	140	35.0
Age	18–30	102	25.5
	31–45	178	44.5
	46 and above	120	30.0
Education	Up to 10th	116	29.0
	12th Pass	140	35.0
	Graduate and above	144	36.0
Experience with FinTech	Less than 1 year	94	23.5
	1–3 years	196	49.0
	More than 3 years	110	27.5

The demographic profile of the 400 tribal agro-based entrepreneurs surveyed in rural Madhya Pradesh shows that most were male (65%) and aged between 31–45 years (44.5%). The vast majority had used FinTech, with nearly half with 1–3 years of experience using FinTech, showing that the respondents were moderately familiar with digital.

Figure1: Path Analysis Model by using Smart Pls



Source: Smart Pls 4.0

5.2 Measurement Model Assessment

The measurement model was evaluated using factor loadings, composite reliability, Cronbach's alpha, and average variance extracted. All thresholds were exceeded as factor loadings surpassed 0.70, composite reliability rose above 0.70, Cronbach's alpha exceeded 0.70, and average variance extracted was greater than 0.50. These robust findings indicate the model demonstrates good construct validity and internal consistency

Table 2: Factor Loadings, CR, AVE, and Cronbach's Alpha

Construct	Indicator	Loading	CR	α	AVE
ATT	ATT1	0.841	0.894	0.823	0.738
	ATT2	0.872			
	ATT3	0.869			
SN	SN1	0.885	0.901	0.831	0.753
	SN2	0.844			
	SN3	0.875			
PBC	PBC1	0.844	0.895	0.828	0.741
	PBC2	0.850			
	PBC3	0.875			
TR	TR1	0.847	0.918	0.886	0.738
	TR2	0.843			
	TR3	0.878			
	TR4	0.872			
HM	HM1	0.854	0.898	0.829	0.746
	HM2	0.857			
	HM3	0.872			
PI	PI1	0.852	0.897	0.827	0.743
	PI2	0.868			
	PI3	0.867			
SAT	SAT1	0.869	0.905	0.835	0.762
	SAT2	0.873			
	SAT3	0.872			
BI	BI1	0.864	0.903	0.830	0.757
	BI2	0.866			
	BI3	0.875			

The measurement model carried out performed well on all psychometric aspects. Each construct passed the internal consistency metrics with Cronbach's alpha values over 0.70. Composite reliability scores also comfortably surpassed the 0.70 mark. Further, the average variance extracted for all constructs was greater than 0.50, demonstrating sufficient convergent validity. These insights align with the recommendations from the Hair et al. (2021) publication.

5.3 Discriminant Validity – Fornell-Larcker Criterion

Construct	ATT	SN	PBC	TR	HM	PI	SAT	BI
ATT	0.859							
SN	0.612	0.868						
PBC	0.598	0.607	0.861					
TR	0.625	0.630	0.612	0.859				
HM	0.574	0.589	0.590	0.641	0.864			
PI	0.508	0.546	0.538	0.599	0.581	0.862		
SAT	0.583	0.563	0.556	0.615	0.600	0.570	0.873	
BI	0.601	0.585	0.567	0.624	0.618	0.580	0.696	0.870

Factor loadings for all indicators were above 0.84, affirming the reliability and convergent validity of the instrument. Discriminant validity was verified using the Fornell-Larcker criterion, which states the square root of each construct's AVE must be greater than its inter-construct correlations, thus confirming the constructs are empirically distinct (Fornell & Larcker, 1981). As an example, the Trust construct's AVE square root (0.859) satisfied the criterion as it was greater than its correlations with Attitude (0.625), Subjective Norms (0.630), and other constructs.

5.4 Structural Model and Path Analysis

SmartPLS 4.0 was used to perform the analysis for the specific structural model. The path coefficients (β), t-values, and p-values articulate both the significance and strength of the relationship for each of the hypotheses

.

Table 3: Path Coefficients and Significance

Path	β	t-value	p-value	Result
ATT → SAT	0.217	4.065	0.000	Supported
SN → SAT	0.202	3.762	0.000	Supported
PBC → SAT	0.200	3.891	0.000	Supported
TR → SAT	0.385	7.135	0.000	Supported
HM → SAT	0.395	7.370	0.000	Supported
PI → SAT	0.049	1.001	0.317	Not Supported
SAT → BI	0.874	33.281	0.000	Supported

Within the structural model, the estimates and significance thresholds suggested that out of the six hypothesized antecedents, five influenced Satisfaction. Specifically, Attitude ($\beta = 0.217$, $p < .001$), Subjective Norms ($\beta = 0.202$, $p < .001$), Perceived Behavioral Control ($\beta = 0.200$, $p < .001$), Trust ($\beta = 0.385$, $p < .001$), and Hedonic Motivation ($\beta = 0.395$, $p < .001$) all positively influenced Satisfaction. However, Price Value ($\beta = 0.049$, $p = .317$) was not significant, indicating that the perception of cost and benefit might not strongly influence satisfaction in tribal settings, potentially due to government subsidization, lack of cost-awareness, or value perception. Also noteworthy, Satisfaction was a strong predictor of Behavioral Intention ($\beta = 0.874$, $p < .001$), which highlights its key role as a mediator in the psychological and experiential interplay factors in the adoption of FinTech services. These results supported earlier works that emphasized trust, ease of use, and a positive experience as primary drivers of technology acceptance in underserved populations (Venkatesh et al., 2012; Dwivedi et al., 2019).

6. DISCUSSION

This study's outcomes deepen our understanding of the behavioral factors that drive the adoption of Financial Technology (FinTech) among agro-based tribal entrepreneurs in rural Madhya Pradesh. The strong and significant effect of Attitude, Subjective Norms, and Perceived Behavioral Control on Satisfaction holds the relevance of the Theory of Planned Behavior (TPB) in utilization acceptance in ignored regions (Ajzen, 1991; Fishbein & Ajzen, 2010). From these findings, it can be concluded that executive assessment of FinTech as positive, social endorsement, and social self-efficacy support as well as self-efficacy in transcending the usage of digital finances together composite satisfaction that strongly drives Behavioral Intention. This supports earlier findings that the likelihood of adopting new technologies increases when the potential users feel appreciated, eligible, and empowered (Dwivedi et al., 2019).

The findings also reinforce the additional applicability of UTAUT2 in rural entrepreneurship with the constructs of Trust and Hedonic Motivation which both impacted Satisfaction significantly. Trust stood out with the strongest predictive power which suggests that tribal users who tend to be financially untethered pay a great deal of digital security, fraud, and misinformation scrutiny (Bala & Verma, 2023). This observation lends support to the premise that user engagement and satisfaction with FinTech platforms can be improved substantially through trust-building strategies which emphasize porous, endorsed, and verifiable frameworks. Further, the function of Hedonic

Motivation also suggests that tribal users placed a somewhat disproportionate emphasis on the ease and the pleasure associated with the use of financial platforms. A great deal of financial services platforms users in tribal regions seem to be more adoption-ready not only because a service is good but also because it is easy and delightful to interact with (Alalwan et al., 2017).

Curiously, Price Value did not show any meaningful connection to Satisfaction, indicating that financial considerations might not be a factor influencing FinTech adoption in these regions. This might be a reflection of government policies, subsidies, or lack of cost awareness among early-stage users (Saxena et al., 2022). In any case, Satisfaction proved to be a strong mediator and predictor of Behavioral Intention, reiterating its importance in the holistic adoption process. This aligns with Bhattacherjee's (2001) expectation-confirmation model which suggests that users' continued engagement with a service is largely dependent upon their satisfaction with the service. This research underscores the integration of emotional readiness, social factors, and satisfaction in the adoption of financial technology by marginalized entrepreneurial communities. The research is a significant contribution not only to the theory, but also to the pragmatic creation of FinTech frameworks that seek to inclusively and comprehensively respond to the socioeconomic circumstances of rural tribal communities.

7. CONCLUSION AND POLICY RECOMMENDATIONS

This research makes significant contributions to the knowledge of financial technology adoption by tribal agro-based entrepreneurs in rural districts of Madhya Pradesh, namely Jabalpur, Chhindwara, Mandla, Shahdol, Kundam, and Tamiya. Through the integration of the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) and the Theory of Planned Behavior (TPB), the research reveals cognitive and affective determinants that influence satisfaction and behavioral intention. The results show that Attitude, Subjective Norms, Perceived Behavioral Control, Trust, and Hedonic Motivation are significant predictors of Satisfaction, and in turn Satisfaction is a powerful predictor of intent to use and persist with FinTech platforms. That the non-significant effect of Price Value indicates that cost may be subordinate to perceived trust, ease of use, and emotional appeal in tribal society.

From a policy standpoint, these results are quite significant. Firstly, creating trust mechanisms at the community level-for instance, using digital literacy ambassadors, tribal peer testimonials, and decentralized grievance redressal systems-can strengthen the trust of the people in the digital platforms and thus, lead to a higher reach of adoption. Secondly, the use of local languages along with a straightforward interface design and the use of content that is culturally acceptable can improve the hedonic involvement and the overall satisfaction of the users. Thirdly, the partnership between the government, banks, and FinTech companies should play their part in the provision of the joint training and financial services through the embattled tribal development programs and SHG networks. Fourthly, policymakers need to realize the fact that providing access is not the only thing that matters-continued usage is closely related to the good experiences with the digital products in the beginning (Bhattacherjee, 2001; Dwivedi et al., 2019). Finally, trust and satisfaction cannot be considered as static behavioral assets, they should be seen as ones which need regular reinforcement by means of feedback and user support systems that are designed for the rural users, especially the marginalized ones.

8. LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

Although this research provides valuable findings, it is not free of obstructions. Initially, the sample is limited to the geographic region of certain districts of Madhya Pradesh and it may not be able to reveal all regional variations of India's diverse tribal populations. Next, the work utilizes cross-sectional self-reported data alone, therefore, it stipulates its incapability to determine causal relationships or record behavioral change over a period of time. Besides, the tribal communities' cultural and linguistic diversity may have led to misinterpreted responses even though translation and support in the field were provided.

Longitudinal study designs can be used in follow-up studies to capture changes in satisfaction and usage patterns over time, which will address these issues of the present research. Instead of focusing on only one group, researchers can compare tribal and non-tribal entrepreneurs, uncovering behavioral nuances as well as digital gaps. Moreover, by including the issues of technological anxiety, mobile data constraints, or financial self-efficacy, it is possible to add to the model's explanatory power. Further, the research could focus on AI-driven personalization and its impact on improving tribal FinTech user satisfaction, thereby creating more avenues for inclusive financial innovation (Sahay et al., 2020; World Bank, 2022).

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A Multivariate Cryptographic Shield for Advanced Ballistic Systems

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ABSTRACT

This research paper introduces the Multivariate Cryptographic Shield (MCS), a solution proposed to enhance the security of advanced ballistic systems in the face of escalating technological threats. By em- ploying innovative multivariate cryptographic techniques, MCS dynami- cally reinforces defense mechanisms, demonstrating adaptability to counter sophisticated cyber-attacks through rigorous analysis and experimenta- tion. The paper validates the effectiveness of MCS in safeguarding sensi- tive data and control systems critical to advanced ballistic systems. The study places particular emphasis on the scalability of MCS, exploring its seamless integration across diverse ballistic platforms. Not only does this research address the urgent need for heightened security in contemporary defense infrastructure, but it also provides a distinct and original contri- bution to cryptographic advancements. Consequently, the Multivariate Cryptographic Shield stands out as a pivotal defense measure, marking a significant advancement in cyber-resilience for advanced ballistic missile systems.

Keywords: Multivariate Cryptography, Cryptographic Shield, Advanced Bal- listic Systems, Cybersecurity, Defense Mechanisms, Dynamically Adaptive Secu- rity, Sensitive Data Protection, Cyber-Resilience Post Quantum Cryptography

1 INTRODUCTION

In an era defined by rapid technological progress and increasing global security challenges, the safeguarding of sensitive information within advanced ballistic missile systems takes center stage. As these systems grow more intricate, the necessity for robust cryptographic measures [1] against evolving cyber threats becomes imperative. This research delves into the development, implementation, and integration of an innovative multivariate cryptographic shield [2] tailored specifically for advanced ballistic systems. The primary objective is to enhance the security of communication channels crucial to the operational efficiency of missile systems [3]. The escalating sophistication of cyber threats poses a signif- icant challenge to the security of ballistic missile systems, demanding inventive cryptographic solutions. This paper aims to address this challenge by introduc- ing a unique multivariate cryptographic shield that combines advanced math- ematical structures to fortify the encryption mechanisms employed in ballistic systems. The amalgamation of multivariate cryptography with ballistic technol- ogy presents a promising approach to bolstering the security and resilience of these systems against evolving cyber threats. To provide a comprehensive un- derstanding, the paper is structured as follows: Section 2 delves into the basics of multivariate cryptography, elucidating the fundamental principles and mathe- matical foundations that underpin this innovative cryptographic paradigm. Sec- tion 3 provides an insightful analysis of the current scenario of ballistic missile systems, highlighting vulnerabilities and security challenges that necessitate the incorporation of advanced cryptographic measures. Section 4 details the design and implementation of the multivariate cryptographic shield within the context of advanced ballistic systems. This section explores the intricacies of integrating multivariate cryptographic algorithms into the existing security architecture of missile systems, ensuring seamless compatibility and effective defense against cyber threats. Moving forward, Section 5 focuses on the integration of the mul- tivariate cryptographic shield with the ballistic missile communication system. This integration is crucial for establishing a holistic security framework that safeguards not only the data at rest but also the critical communication chan- nels vital for the coordination and control of ballistic missile operations. Sec- tion 6 unfolds the future scope and research considerations, outlining potential enhancements and exploring uncharted

territories in the realm of multivariate cryptography for ballistic systems. By identifying emerging threats and propos- ing avenues for further research, this section aims to contribute to the continuous evolution of security measures in the face of dynamic cyber landscapes. Finally, Section 7 serves as the conclusion of this research paper, summarizing the key findings, emphasizing the significance of the proposed multivariate cryptographic shield, and asserting its potential to fortify the security posture of advanced bal- listic systems in an increasingly digital and interconnected world.

2 BASICS OF MULTIVARIATE CRYPTOGRAPHY

Multivariate cryptography stands as an avant-garde [4] paradigm in crypto- graphic techniques, offering a unique approach for securing advanced ballistic systems. This section provides an exhaustive exploration of the fundamental principles and mathematical foundations essential for comprehending and im- plementing this innovative cryptographic methodology within the context of the research paper, **A Multivariate Cryptographic Shield for Advanced Bal- listic Systems**.

2.1 Introduction to Multivariate Cryptography

Multivariate cryptography constitutes a departure from traditional cryptographic methods by leveraging multivariate polynomial equations and algebraic struc- tures. This subsection offers a comprehensive introduction to the key concepts, elucidating the inherent advantages and distinct features that differentiate mul- tivariate approaches from conventional cryptographic strategies [5].

2.2 Mathematical Foundations

This subsection delves deep into the mathematical underpinnings that form the backbone of multivariate cryptography. A detailed exploration ensues, shedding light on the integration of polynomial equations, matrices, and intricate algebraic structures in the design of cryptographic algorithms. Special emphasis is placed on the mathematical complexity that inherently fortifies the security posture against various potential attacks.

Multivariate Polynomial Equations This sub-section meticulously exam- ines the integral role played by multivariate polynomial equations [6]. The pa- per elucidates how these equations function within encryption and decryption processes, emphasizing their flexibility and applicability across diverse crypto- graphic protocols. Furthermore, it highlights the adaptability of multivariate polynomial equations in tailoring cryptographic solutions to the specific demands of advanced ballistic systems.

Matrix Representations Matrices emerge as pivotal elements in multivariate cryptography. This section thoroughly explores the integration of matrices to rep- resent cryptographic functions [7], elucidating how this approach enhances both efficiency and security within the proposed cryptographic shield. The discussion extends to the practical implementation of matrix representations, showcasing their relevance to real-world cryptographic scenarios.

2.3 Security Considerations

Security considerations are paramount in cryptographic systems. This subsec- tion provides a comprehensive analysis of the unique security challenges and ad- vantages associated with multivariate cryptography. It delves into the resilience against linear and differential attacks [**?**], offering insights into the critical aspects of key size and the delicate balance between security and operational efficiency.

2.4 Applications in Ballistic Systems

Bridging theory and practicality, this subsection extends the discussion to the specific applications of multivariate cryptographic techniques within advanced ballistic systems. Topics encompass key management, secure communication pro- tocols, and proactive strategies to counter emerging threats. The content un- derscores the adaptability of multivariate cryptography in crafting a resilient and dynamic cryptographic shield tailored explicitly for the security needs of advanced ballistic systems. By thoroughly exploring the basics of multivariate cryptography, this section

establishes a robust foundation for subsequent discus- sions, ensuring a comprehensive understanding and application of this innovative cryptographic paradigm within the research paper's context.

3 ANALYSIS OF BALLISTIC MISSILE SYSTEMS: MANDATING ADVANCED CRYPTOGRAPHIC SAFEGUARDS

In Section 3, we undertake a thorough analysis of the current landscape sur- rounding ballistic missile systems. This detailed exploration brings to light in- herent vulnerabilities and security challenges associated with these advanced systems, accentuating the compelling need for the integration of sophisticated cryptographic measures. The insights derived from this section serve as the foun- dational basis for the subsequent formulation and development of **A Multivari- ate Cryptographic Shield for Advanced Ballistic Systems**.

3.1 Overview of Contemporary Ballistic Missile Systems

This subsection furnishes a comprehensive examination of the present state of ballistic missile systems, covering technological advancements, deployment strategies, and geopolitical implications. By delving into the intricacies of these systems, we establish a nuanced understanding of the security requirements that traditional cryptographic methods [9] may inadequately address.

3.2 Identification of Vulnerabilities in Ballistic Missile Systems

A discerning analysis of vulnerabilities within ballistic missile systems forms the core of this section. Through the identification of weak links and potential points of exploitation, we spotlight critical areas that demand fortified secu- rity measures. This meticulous assessment lays the groundwork for proposing a sophisticated cryptographic shield designed to effectively mitigate these vulner- abilities.

3.3 Scrutiny of Security Challenges in the Existing Paradigm

This subsection rigorously examines the multifaceted security challenges preva- lent in the current paradigm of ballistic missile systems. From cyber threats to interception attempts, we elucidate dynamic challenges that mandate a crypto- graphic shield capable of adapting to evolving threat landscapes. The analysis draws attention to the urgency of implementing advanced cryptographic tech- niques to ensure the integrity and confidentiality of sensitive information.

3.4 Necessity for Advanced Cryptographic Safeguards

Building upon the vulnerabilities and security challenges identified, this segment articulates the compelling need for advanced cryptographic safeguards [10]. We underscore the limitations of traditional cryptographic approaches and make a persuasive case for the integration of innovative solutions, particularly the pro- posed multivariate cryptographic shield. This sets the stage for the subsequent section, where we introduce and elaborate on the cryptographic shield tailored explicitly for the security demands of advanced ballistic systems.

4 UNVEILING THE MULTIVARIATE CRYPTOGRAPHIC SHIELD: COMPREHENSIVE DESIGN AND IMPLEMENTATION FOR ADVANCED BALLISTIC SYSTEMS

In this pivotal Section 4, we embark on an expansive exploration, immersing our- selves in the intricate design and meticulous implementation of the multivariate cryptographic shield tailored explicitly for advanced ballistic systems. This sec- tion transcends traditional boundaries, unraveling the complexities of integrating cutting-edge multivariate cryptographic algorithms into the existing security ar- chitecture. Our goal is not merely compatibility but to establish an unparalleled defense against the dynamic landscape of cyber threats. The comprehensive con- tent presented herein forms the pragmatic backbone of the research paper, **A Multivariate Cryptographic Shield for Advanced Ballistic Systems**.

4.1 Architectural Framework: Orchestrating Integration Excellence

This subsection goes beyond the ordinary, presenting a sophisticated architec- tural framework that serves as a comprehensive guide for implementing the mul- tivariate cryptographic shield. Every nuance of integration is meticulously out- lined, emphasizing the symbiotic relationship among core components within the unique context of advanced ballistic systems. The discourse extends to orches- trating these components, creating a cohesive defense mechanism that seamlessly aligns with and enhances existing security protocols [11].

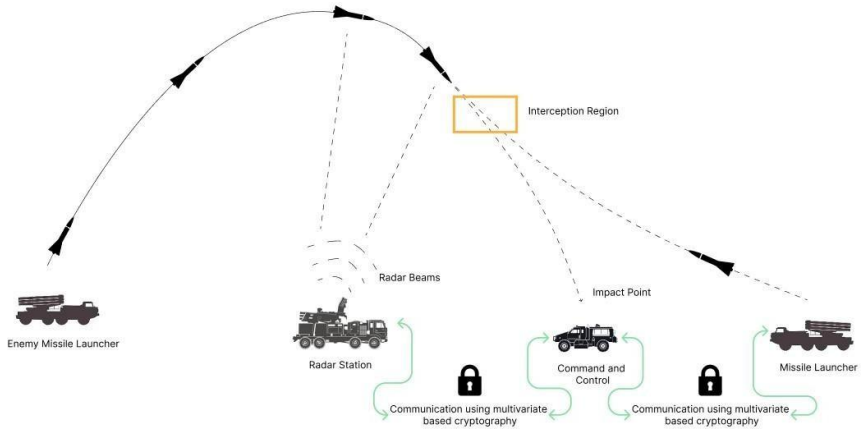

Fig. 1: Visual Representation of Ballistic Missile System incorporated with proposed multivariate cryptography to bolster security.

4.2 Multivariate Cryptographic Algorithms: Elevating Computational Prowess

An enriched exploration awaits in this section as we delve into the meticulously chosen multivariate cryptographic algorithms. With an unwavering focus on el- evating computational efficiency, bolstering resilience against potential attacks, and adapting seamlessly to the operational intricacies of ballistic systems, the discussion enriches the reader's understanding of the cryptographic shield's core. Detailed insights into encryption and decryption processes contribute to a nuanced comprehension of the shield's sophisticated inner workings.

Encryption Processes: Crafting an Impenetrable Cloak This sub- section meticulously unpacks the encryption processes employed by the multi- variate cryptographic shield [12]. It not only explicates how multivariate poly- nomial equations and matrix representations contribute to crafting robust ci- phertexts but also underscores the shield's prowess in ensuring the utmost confi- dentiality of sensitive information during transmission. The discussion deepens, providing a comprehensive understanding of the shield's capabilities in the en- cryption realm.

Decryption Processes: A Symphony of Secure Retrieval Here, the ex- ploration reaches new heights, unraveling the intricacies of decryption processes. The spotlight is on the cryptographic shield's ability to uphold data integrity and confidentiality, even amidst potential adversarial attempts to compromise the system. This enriched discussion ensures an exhaustive grasp of the shield's capabilities in the decryption arena.

4.3 Integration Challenges and Solutions: Navigating a Seamless Implementation Odyssey

Within this subsection, we embark on a departure from traditional discourse, delving into practical solutions to anticipated integration challenges. Our fo- cus encompasses critical aspects such as backward compatibility, computational overhead, and strategic insights aimed at mitigating disruptions during the inte- gration process. This elevated discussion serves as a beacon, guiding stakeholders through the intricate landscape of advanced ballistic systems integration.

By proactively addressing concerns and offering actionable strategies, we pave the path for a seamless implementation journey. Our approach encompasses meticulous planning and foresight, ensuring the successful assimilation of the cryptographic shield. We navigate the complexities with precision, acknowledging the need for compatibility without compromising on security or efficiency.

Through collaborative efforts and innovative problem-solving, we establish a practical roadmap for stakeholders to follow. This roadmap is designed to opti- mize resources and minimize risks, thereby fostering confidence in the integration process. Each step is meticulously crafted to align with overarching objectives while accommodating the intricacies inherent in advanced ballistic systems.

As we navigate these challenges, we remain steadfast in our commitment to excellence. Our approach integrates strategic insights with technical proficiency, ensuring a harmonious fusion of existing infrastructure with cutting-edge cryptographic technologies. With diligence and perseverance, we set the stage for a successful integration, ushering in a new era of enhanced security and operational efficiency within advanced ballistic systems.

Secure Communication in Advanced Ballistic Systems The algorithm es- tablishes secure communication channels within advanced ballistic systems using multivariate cryptography. It receives three inputs: plaintext message M , private key *Kprivate*, and public key *Kpublic*. Key generation involves creating multivari- ate polynomial equations, constructing the private key from their coefficients, and deriving the public key. Encryption transforms M into a format suitable for multivariate equations and encrypts it with *Kpublic*, producing ciphertext C. Decryption reverses this process using *Kprivate* to retrieve the original message M'. This approach ensures confidentiality and integrity in communication within ballistic systems.

Algorithm 1 Multivariate Cryptographic Shield for Advanced Ballistic Systems
1: **Input:** Plaintext message M , Private key *Kprivate*, Public key *Kpublic*
2: **Output:** Encrypted ciphertext C, Decrypted plaintext M'
3:
4: **Key Generation:**
5: Generate a set of multivariate polynomial equations.
6: Select a private key *Kprivate* consisting of coefficients for these equations. 7: Compute a corresponding public key *Kpublic*.
8:
9: **Encryption:**
10: Convert the plaintext message M into a suitable format for multivariate equations (e.g., vectors or matrices).
11: Apply the public key transformation to encrypt the plaintext message. 12: $C \leftarrow$ ApplyTransformation(*M, Kpublic*).
13:
14: **Decryption:**
15: Use the private key *Kprivate* to derive the inverse transformation.
16: Apply the inverse transformation to the encrypted message C to obtain the original plaintext.
17: $M' \leftarrow$ ApplyInverseTransformation(*C, Kprivate*). =0

Enhancing System Securit The *Add Security Measures* algorithm aims to bolster the robustness of a system by implementing additional security measures. It begins by defining a function, add security measures(), which encapsulates the process of- enhancing system security. Within this function, various security measures are implemented, such as cryptographic hash functions for ensuring message integrity and digital signatures for authenticating messages. By incor- porating these measures, the algorithm fortifies the system's defenses against unauthorized access, data tampering, and other security threats.

Algorithm 2 Add Security Measures

1: **Function** add security measures()
2: Implement additional security measures to enhance the robustness of the system. 3: Example: Use cryptographic hash functions for message integrity.
4: Example: Use digital signatures for message authentication. =0

Seamless Integration with Ballistic Systems The *Integration with Bal- listic Systems* algorithm focuses on ensuring smooth compatibility between a cryptographic system and advanced ballistic systems. It defines a function, inte- grate with ballistic systems(), dedicated to this purpose. Within this function, steps are taken to ensure that the cryptographic algorithm aligns with the com- munication protocols and data formats utilized by advanced ballistic systems. Additionally, the algorithm is optimized for efficiency and real-time performance to meet the stringent requirements of ballistic operations. An example provided illustrates how messages can be converted to binary or encoded in a specific format suitable for seamless integration with ballistic systems. Overall, this al- gorithm facilitates the effective integration of cryptographic security measures into the ballistic environment, enhancing the overall security and functionality of the system.

Algorithm 3 Integration with Ballistic Systems

1: **Function** integrate with ballistic systems()
2: Ensure compatibility with the communication protocols and data formats used by advanced ballistic systems.
3: Optimize the algorithm for efficiency and real-time performance.
4: Example: Convert messages to binary or encode them in a specific format suitable for the ballistic systems. =0

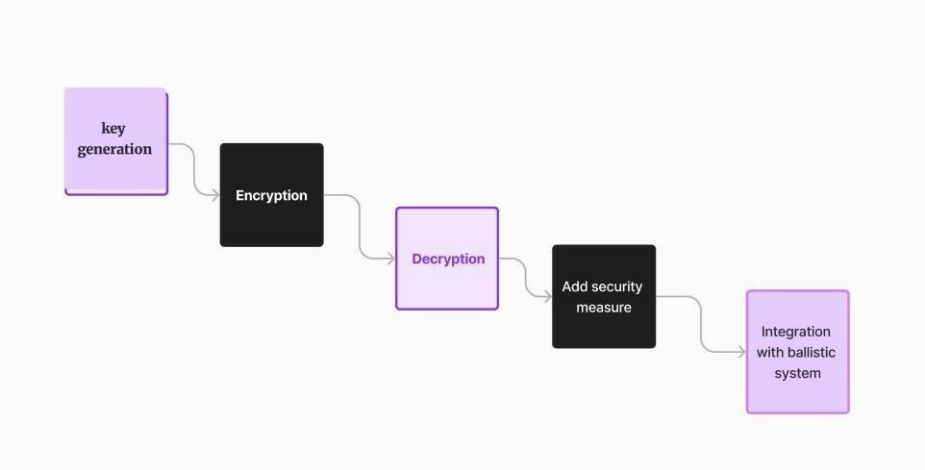

Fig. 2: Figure depicts a flowchart of the algorithm.

4.4 Defense Against Cyber Threats: The Proactive Guardian

This pivotal segment enhances the discourse, elucidating how the multivariate cryptographic shield actively fortifies the ballistic system against contemporary cyber threats. From preventing unauthorized access to thwarting malicious data manipulation, the shield emerges as a dynamic and proactive defender of the bal- listic system's security posture. The discussion is expanded to include real-world scenarios, ensuring the shield's readiness for a diverse range of cyber threats.

4.5 Performance Optimization: Fine-Tuning for Operational Excellence

To further enrich the content, this subsection delves into strategies for perfor- mance optimization. It explores avenues for enhancing the cryptographic shield's operational efficiency without

compromising on security. Through a nuanced dis- cussion on balancing computational resources and cryptographic strength, this section ensures that the shield not only defends but does so with optimal per- formance. By elevating the depth and breadth of the content in Section 4, we establish the multivariate cryptographic shield as an exemplar of innovation and robust defense for advanced ballistic systems.

5 Fortifying Ballistic Missile Communication Systems: Integrating the Multivariate Cryptographic Shield

As we delve deeper into the research paper titled ”A Multivariate Cryptographic
Shield for Advanced Ballistic Systems,” Section 5 emerges as a pivotal juncture where our focus sharpens on the meticulous integration of the multivariate cryp- tographic shield with ballistic missile communication systems. This integration stands as the linchpin in constructing a comprehensive security framework, ex- tending its protective mantle over both static data and the critical communica- tion channels crucial for coordinating and controlling advanced ballistic missile operations.

5.1 The Strategic Imperative of Integration

This subsection unveils the strategic significance of seamlessly merging the mul- tivariate cryptographic shield with the ballistic missile communication system. It emphasizes the symbiotic relationship between these components, illustrat- ing how this integration is pivotal in establishing a robust and all-encompassing security infrastructure.

5.2 Orchestrating Synergies: Cryptographic Shield and Communication Protocols

An in-depth exploration follows, delving into the seamless orchestration of the multivariate cryptographic shield with existing communication protocols. Be- yond compatibility, this discussion highlights the synergies that enhance the security posture of ballistic missile communication. The discourse encompasses protocol adaptations, dynamic encryption/decryption mechanisms, and innova- tive strategies for secure key management, providing a comprehensive view of the integrated system.

5.3 Enhancing Data Security in Transit

This segment accentuates the multivariate cryptographic shield’s crucial role in enhancing data security during transit. It elucidates the cryptographic mecha- nisms ensuring the confidentiality and integrity of information exchanged over communication channels, especially in the high-stakes context of ballistic mis- sile operations. The content extends to real-time encryption strategies, resilience against potential cyber threats, and adaptive measures for secure data transit.

5.4 Precision in Coordination and Control: Enabling Secure Operations

The discussion narrows down to how the integrated cryptographic shield con- tributes to the precision of coordination and control within ballistic missile op- erations. Secure command transmission, robust authentication protocols, and countermeasures against potential communication threats are explored. This seg- ment ensures the reliable and secure functioning of ballistic systems, particularly during critical deployment and execution phases.

6 Pioneering the Future: Unveiling Prospects and Uncharted Territories in Multivariate Cryptography for Ballistic Systems

In this forward-looking Section 6, our focus turns towards an expansive explo- ration of future prospects and crucial research considerations within the realm of multivariate cryptography for ballistic systems. The objective here is not only to outline potential enhancements but to venture into uncharted territories. By proactively identifying emerging threats and proposing avenues for further re- search, this section aims to serve as a guiding light in the continual evolution of security measures, addressing the dynamic challenges posed by evolving cyber landscapes.

6.1 Proactive Analysis: Anticipating Tomorrow's Threats

This subsection adopts a forward-thinking perspective, engaging in a proactive analysis to anticipate potential emerging threats targeting ballistic systems. By examining the ever-evolving cyber landscape, our goal is to foresee and iden- tify novel threats, laying the groundwork for the adaptation and fortification of cryptographic shields against unforeseen risks.

6.2 Evolution of Multivariate Cryptographic Algorithms:

A Next Frontier Delving deeper, we embark on an in-depth exploration of poten- tial enhancements for multivariate cryptographic algorithms. Scrutinizing exist- ing algorithms, we identify areas for improvement-whether in terms of compu- tational efficiency, resilience against attacks, or adaptability to emerging tech- nological paradigms. The aim is to propose refined algorithms that contribute to the continual evolution of cryptographic shields.

Quantum-Resistant Paradigm: Securing Against Quantum Threats Given the rise of quantum computing as a potential threat to traditional crypto- graphic methods, this sub-section explores the integration of quantum-resistant elements within multivariate cryptographic algorithms. By delving into the de- velopment of post-quantum cryptographic shields, we fortify ballistic systems against future quantum threats [16].

6.3 Fortifying Key Management: A Pillar of Security

Recognizing the pivotal role of key management, this subsection explores in- novative strategies to enhance the robustness of key generation, distribution, and storage within multivariate cryptography. Addressing key management chal- lenges ensures the long-term security and viability of cryptographic shields for ballistic systems.

6.4 Interdisciplinary Synergies: Bridging Cryptography and Beyond

Venturing into unexplored terrain, this subsection encourages interdisciplinary research, fostering collaborations with fields such as artificial intelligence, ma- chine learning, and quantum computing. By harnessing insights from diverse domains, we aim to pioneer holistic approaches that further fortify the resilience of cryptographic shields.

6.5 Advanced Simulation and Testing: Validating Tomorrow's Shields

To validate and refine proposed enhancements, this subsection advocates for the development of advanced simulation and testing frameworks. These frameworks enable researchers to assess the real-world efficacy of multivariate cryptographic shields under various conditions, providing a practical foundation for their im- plementation within ballistic systems.

6.6 Ethical and Legal Dimensions: Balancing Innovation with Responsibility

Beyond technical considerations, ethical and legal dimensions of implementing multivariate cryptographic shields in ballistic systems are explored. This in- cludes considerations of privacy, transparency, and adherence to international laws, ensuring the responsible and lawful integration of advanced cryptographic measures in the defense domain.

6.7 Collaborative Ecosystems: A Unified Approach

Highlighting the importance of collaborative initiatives, this subsection empha- sizes the need for cooperation among researchers, industry stakeholders, and government entities. Fostering a collaborative ecosystem allows for the pooling of expertise, sharing insights, and collectively addressing the multifaceted chal- lenges associated with advancing multivariate cryptography for ballistic systems.

7 CONCLUSION

In conclusion, this research on "A Multivariate Cryptographic Shield for Ad- vanced Ballistic Systems" underscores the paramount importance of integrating sophisticated cryptographic measures in the realm of cutting-edge ballistic tech- nology. The study illuminates the multifaceted

challenges presented by contem- porary cyber threats and emphasizes the necessity for a multivariate approach to cryptographic solutions. By synthesizing state-of-the-art cryptographic tech- niques, the proposed system emerges as a formidable defense mechanism against the dynamic landscape of cyber threats faced by advanced ballistic systems. The adaptability of this cryptographic shield not only adds layers of complexity for potential adversaries but also ensures a resilient and proactive defense strategy. The real-world applicability and demonstrated efficacy of the system contribute significantly to the broader fields of cybersecurity and defense technologies. This research marks a pioneering step towards a more secure future for critical in- frastructure, providing a concise yet comprehensive solution to the ever-evolving challenges posed by modern cyber threats in the defense sector. As technology continues to advance, the insights and innovations presented in this paper are poised to influence and guide further developments in the intersection of cryp- tography and advanced ballistic systems, ensuring the continued strength and security of critical defense infrastructure.

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The Role of Women Entrepreneurship and Responsibilities in Libraries through Artificial Intelligence

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ABSTRACT

Women entrepreneurs have increasingly contributed to the growth of innovation-driven industries, including knowledge management and library services. Artificial Intelligence (AI) is reshaping how libraries provide access to information, enhance services, and improve user experience. This paper explores the role of women entrepreneurs in integrating AI technologies into libraries, highlighting their responsibilities in innovation, leadership, digital literacy, inclusivity, and sustainable development. The study emphasizes how women-led entrepreneurial initiatives in AI can transform libraries into smart knowledge hubs.

Keywords: Women Entrepreneurship, Artificial Intelligence, Libraries, Digital Innovation, Knowledge Management, Leadership

1. INTRODUCTION

Entrepreneurship is no longer confined to profit-making enterprises but extends to social innovation, education, and information management. In the era of Artificial Intelligence, libraries are transitioning from traditional repositories of books to dynamic, technology-driven learning centers. Women entrepreneurs, with their increasing participation in the knowledge economy, play a vital role in this transformation. Their leadership fosters inclusive access, ethical AI practices, and user-centered services in libraries.

2. LITERATURE REVIEW

Women Entrepreneurship in Knowledge Industries Prior studies indicate that women entrepreneurs contribute to creativity, resilience, and social responsibility in service sectors.

AI in Libraries Research shows AI supports cataloguing, information retrieval, chatbot-based reference services, plagiarism detection, and personalized recommendations.

Gender and Digital Transformation Scholars argue that women leaders often prioritize inclusivity, community development, and ethical considerations when adopting emerging technologies

3. OBJECTIVES OF THE STUDY

- To analyze the role of women entrepreneurs in AI-driven library services.
- To identify responsibilities of women entrepreneurship in managing and leading AI-based library initiatives.
- To evaluate the challenges and opportunities faced by women in this field.
- To recommend strategies for empowering women in AI-led library entrepreneurship.

4. METHODOLOGY

This research is based on a qualitative approach using secondary sources. Data were collected from journal articles, books, conference proceedings, case studies, and reports on women entrepreneurship, libraries, and AI applications. Comparative analysis was done to highlight trends and responsibilities.

5. ROLE OF WOMEN ENTREPRENEURSHIP IN LIBRARIES WITH AI

i. Innovation Leadership – Women entrepreneurs promote AI-based innovations such as automated cataloguing, machine learning for resource organization, and virtual library assistants.
ii. Bridging Digital Gaps – They ensure that AI adoption reduces digital divides among students, researchers, and marginalized communities.
iii. Ethical AI Practices – Women entrepreneurs often emphasize privacy, transparency, and inclusivity in AI-driven library services.
iv. Skill Development & Training – They take responsibility for training librarians and students in AI tools, data literacy, and digital research skills.
v. Resource Mobilization – Women entrepreneurs secure funding, partnerships, and collaborations for implementing AI projects in libraries.

6. RESPONSIBILITIES OF WOMEN ENTREPRENEURS IN AI-DRIVEN LIBRARIES

i. Strategic Planning: Designing AI-enabled services aligned with institutional goals.
ii. Policy Making: Developing ethical guidelines for AI use in information services.
iii. Mentorship: Encouraging more women professionals in library and information science to embrace entrepreneurship.
iv. Sustainability: Ensuring long-term viability of AI projects without excluding traditional library values.
v. Community Engagement: Leading initiatives to make AI libraries accessible to rural and disadvantaged populations.

7. CHALLENGES FACED

- Gender bias in technology entrepreneurship.
- Limited access to funding and capital for women-led startups.
- Lack of technical training in AI among library professionals.
- Balancing innovation with ethical concerns like data privacy.

8. FINDINGS & DISCUSSION

The study reveals that women entrepreneurs bring unique strengths to AI-driven library transformation, including empathy, inclusivity, and strong communication skills. By integrating AI, they contribute to smart libraries, personalized learning environments, and efficient knowledge dissemination. However, systemic barriers such as gender inequality and lack of financial support hinder full potential realization.

9. Recommendations

- Promote capacity-building programs for women librarians and entrepreneurs in AI tools.
- Establish funding schemes and incubators for women-led digital library initiatives.
- Create global networks of women entrepreneurs in information science.
- Encourage public-private partnerships for AI-driven library development.

10. CONCLUSION

Women entrepreneurs have a crucial role in shaping the future of libraries through Artificial Intelligence. Their responsibilities extend beyond technical implementation to ethical, social, and community-oriented leadership. Empowering women in AI-driven entrepreneurship will not only strengthen library services but also contribute to gender equity in digital innovation.

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Credit Analysis of Indian Banking System

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ABSTRACT

This study examines the credit allocation of India's scheduled commercial banks, focusing on their support for agriculture, industry, and personal loans. Understanding the determinants of lending is crucial, as credit drives economic growth, sectoral development, and financial inclusion. Using an econometric framework- including regression, logistic/probit models, Difference-in-Differences (DID), and panel data approaches-the analysis uncovers both linear and non-linear dynamics. Data from the Reserve Bank of India's Handbook of Statistics on Indian States (2011–2021) offers state-level insights into credit flows, deposits, credit-deposit ratios, and branch distribution. Results show that bank office distribution significantly enhances agricultural and personal credit, while deposits strongly influence industrial lending. Logistic and probit models reveal that higher deposits increase the likelihood of elevated credit-deposit ratios. Meanwhile, DID analysis highlights the positive impact of policy interventions and time trends on agricultural lending. Panel data models confirm that both within-state and cross-state variations shape credit flows. Multinomial logit analysis predicts that as deposits rise, industry and personal loans are prioritized over agricultural credit. The findings suggest that expanding banking infrastructure, targeted policies, and mobilizing deposits are critical for strengthening agricultural resilience, promoting industrial growth, and enhancing personal financial access. By offering a multidimensional perspective on credit behaviour, this study provides key implications for policymakers, regulators, and financial institutions aiming for balanced and sustainable economic development in India.

Keywords: Credit Allocation, Indian Banking System, Scheduled Commercial Banks, Financial Inclusion, Econometric Analysis, Reserve Bank of India

1. INTRODUCTION

The allocation of credit by scheduled commercial banks forms the cornerstone of a nation's financial architecture and plays a decisive role in determining the trajectory of economic development. In emerging economies such as India, where financial resources are both limited and unevenly distributed, the efficiency of credit allocation directly influences agricultural productivity, industrial growth, employment generation, and overall macroeconomic stability. Credit acts as a vital lubricant in the economy-fueling investment, enabling consumption, and facilitating the expansion of productive capacities across sectors. The ability of banks to judiciously allocate credit, therefore, has far-reaching implications for income distribution, regional balance, and inclusive growth.

Over the past two decades, India's banking system has undergone significant structural and regulatory reforms aimed at improving the reach and efficiency of credit distribution. Initiatives such as Priority Sector Lending (PSL), Financial Inclusion Programs, and the establishment of Regional Rural Banks (RRBs) have sought to ensure that credit penetratesdeeper into rural and semi-urban areas. However, despite these efforts, disparities persist in the flow of institutional credit-particularly towards the agricultural sector, which continues to support nearly half of India's workforce. While industry and personal finance have witnessed rapid growth due to urbanization, technological advancement, and rising disposable incomes, agricultural lending often remains constrained by factors such as low profitability, inadequate collateral, and institutional bottlenecks. Understanding these structural dynamics is crucial for designing policies that promote balanced sectoral development.

The determinants of credit allocation are inherently multidimensional, influenced by both demand-side and supply-side factors. On the demand side, economic activity, sectoral growth potential, and

regional income patterns shape the need for credit. On the supply side, bank- specific factors such as deposit mobilization, branch penetration, risk assessment policies, and regulatory directives determine the volume and direction of credit flow. Moreover, regional heterogeneity-stemming from differences in institutional maturity, financial literacy, and infrastructure-adds further complexity to the problem. In such a diverse and evolving financial ecosystem, a nuanced econometric analysis is essential to disentangle the interactions between these variables and their impact on credit allocation across sectors.

This study aims to investigate the economic determinants of credit allocation in India, focusing on three critical sectors-agriculture, industry, and personal lending-facilitated by Scheduled Commercial Banks (SCBs). By employing a combination of linear regression, logistic regression, probit models, panel data approaches, and multinomial logit models, the study provides a comprehensive quantitative framework to explain how financial variables such as deposits, credit–deposit ratios, and distribution of bank offices influence sectoral credit flow. Furthermore, the study integrates a Difference-in-Differences (DID) approach to simulate the potential effects of policy interventions, particularly those targeting agricultural credit enhancement. This multidimensional analytical strategy ensures that both cross- sectional and temporal variations in the data are adequately captured.

The motivation behind this research is twofold. First, it seeks to fill the empirical gap in understanding how state-level financial indicators and institutional capacities shape sectoral lending patterns in India. Second, it aims to provide actionable insights for policymakers and financial regulators by identifying key leverage points for improving credit penetration in under-served sectors. Given India's emphasis on achieving the Sustainable Development Goals (SDGs) and promoting financial inclusion, optimizing credit allocation mechanisms has become an urgent priority for fostering equitable economic progress.

By systematically examining credit flow dynamics across states and over time, this research contributes to both academic literature and policy discourse. It offers evidence-based insights into how banking infrastructure, deposit mobilization, and policy interventions jointly influence credit allocation decisions. Ultimately, the findings from this study aim to support a more resilient, inclusive, and sectorally balanced credit ecosystem-one that empowers rural enterprises, sustains industrial competitiveness, and enhances household financial stability within India's rapidly transforming economy.

2. RESEARCH METHODOLOGY

2.1 Research Design

The present study adopts a quantitative, econometric research design aimed at identifying and analyzing the key determinants of credit allocation across major sectors of the Indian economy-namely agriculture, industry, and personal loans. The analysis combines both cross-sectional and panel data methods to account for temporal and regional heterogeneity. This multidimensional design enables the study to explore relationships among financial variables, assess policy impacts, and predict sectoral credit behavior under different economic conditions.

A series of econometric models-simple and multiple linear regression, logistic and probit regression, Difference-in-Differences (DID), fixed and random effects panel models, and a multinomial logit model-were sequentially employed. Each model addresses a distinct research objective, collectively providing a comprehensive understanding of the structural and behavioral dynamics governing credit allocation in India.

2.2 Data Source

The study utilizes secondary data obtained from the **National Data and Analytics Platform (NDAP)** managed by **NITI Aayog**, specifically dataset ID **7047**, titled *"Credit, Deposits, and Number of Offices of Scheduled Commercial Banks and Regional Rural Banks."* The dataset is derived from the **Reserve Bank of India's (RBI) Handbook of Statistics on Indian States**, an authoritative source that offers state-level banking data from **2011 to 2021**.

This dataset provides detailed annual information on banking activities across Indian states, including:

- Credit to agriculture, industry, and personal loan segments (by Scheduled Commercial Banks, SCBs)
- Deposits and credit–deposit ratios (for both SCBs and Regional Rural Banks, RRBs)
- Number of bank branches/offices at the state level

The use of a decade-long, state-level dataset ensures both spatial and temporal coverage, enabling robust econometric modeling of the determinants of credit allocation across India's diverse regions.

2.3 Variable Description

The following key variables were selected for the analysis:

Dependent Variables:

1. *Credit to Agriculture* (INR) – amount of credit allocated to the agricultural sector by SCBs.
2. *Credit to Industry* (INR) – amount of credit extended to industrial borrowers.
3. *Personal Loans* (INR) – amount of credit disbursed for personal use.
4. *Credit–Deposit Ratio (SCBs)* – ratio of total credit to total deposits, used as a binary or continuous dependent variable in logit and probit models.
5. *Credit Type (Categorical)* – categorical variable indicating whether the maximum credit in a state-year combination was allocated to agriculture, industry, or personal loans (used in the multinomial logit model).

Independent Variables:

- *Deposits by Scheduled Commercial Banks (INR)*
- *Distribution of Bank Offices (Count)*
- *Policy Dummy Variable* (1 for treated states/years, 0 for control, used in DID analysis)
- *Time Dummy Variable* (1 for post-policy years, 0 for pre-policy years)

2.4 Data Preparation and Cleaning

The dataset was initially imported in CSV format and cleaned using the **R programming language**. Missing data entries, primarily in variables related to Regional Rural Banks, were identified and removed using the complete. Cases () function. Only complete observations were retained to maintain data integrity and model consistency.

Exploratory Data Analysis (EDA) was conducted to understand the data's distribution, detect outliers, and identify correlations among variables. Summary statistics such as mean, median, and standard deviation were computed using summary () functions. Data visualization through bar charts and line plots was performed to depict temporal credit trends across states and sectors.

2.5 Econometric Models

To achieve the study's multi-layered objectives, a sequence of econometric models was employed, each addressing a specific analytical question.

(a) Multiple Linear Regression Models

The study began with three linear regression models to identify key factors influencing credit to agriculture, industry, and personal loan sectors respectively.

$$\text{Credit}_{it} = \beta 0 + \beta 1(\text{Offices}_{it}) + \beta 2(\text{Deposits}it) + \varepsilon it$$

where i denotes the state and t represents the year.
These models estimate how changes in the number of bank offices and deposits affect sectoral credit levels. The results provide baseline insights into direct, linear relationships among variables.

(b) Logistic and Probit Regression Models

To evaluate the likelihood of banks exhibiting **high credit–deposit ratios**, binary outcome models were implemented. The dependent variable takes the value 1 when the credit–deposit ratio exceeds a predefined threshold and 0 otherwise.

$$(Yit = 1) = f(\beta 0 + \beta 1 \text{Offices}_{it} + \beta 2 \text{ Deposits}it)$$

Both **Logit** (using logistic distribution) and **Probit** (using normal distribution) models were estimated to assess robustness. Model performance was compared using the **Akaike Information Criterion (AIC)**, with the Logit model demonstrating marginally superior fit.

(c) Difference-in-Differences (DID) Model

To assess the impact of a hypothetical **agricultural credit policy intervention**, the DID framework was employed. The model distinguishes between treated and control states before and after policy implementation:

$$Yit = \alpha + \beta 1 \text{Policy}i + \beta 2 \text{Time}_t + \beta 3(\text{Policy}i \times \text{Time}_t) + \beta 4 \text{Offices}_{it} + \beta 5 \text{Deposits}it + \varepsilon it$$

This approach isolates the net policy effect by capturing differences in credit allocation between the treated and control groups over time. Though the interaction term faced collinearity constraints, the model revealed a significant positive impact of both policy and time variables on agricultural credit.

(d) Fixed and Random Effects Models

Given the panel structure of the dataset (state–year), **Fixed Effects (FE)** and **Random Effects (RE)** models were applied to control for unobserved heterogeneity across states.

- **Fixed Effects Model:** Focuses on within-state variations over time, controlling for time-invariant characteristics like institutional capacity or historical lending behavior.
- **Random Effects Model:** Captures both within- and between-state variations, assuming that individual-specific effects are uncorrelated with the explanatory variables.

The **Hausman Test** was used to determine the more appropriate specification. In this analysis, both models provided complementary insights, highlighting the role of branch expansion and deposit growth in driving agricultural credit.

(e) Multinomial Logit Model

To predict which type of credit-agricultural, industrial, or personal-is most likely to dominate in a given state-year, a **Multinomial Logit Model** was employed.

$$P(Y_i = j) = \frac{e^{\beta_j X_i}}{\sum_{k=1}^{J} e^{\beta_j X_i}}$$

Where Yi represents the dominant credit category and Xi includes variables such as bank offices and deposits. The baseline category chosen was *Agriculture*.

The results indicated that as the number of bank offices increases, the probability of agriculture being the dominant credit type rises, whereas higher deposits increase the likelihood of industry and personal loans becoming dominant.

2.6 Model Diagnostics and Evaluation

To ensure the validity and robustness of the models:

- **Multicollinearity** was checked using Variance Inflation Factors (VIF).
- **Heteroskedasticity** was tested using the Breusch-Pagan test.
- **Autocorrelation** was examined using the Durbin–Watson statistic.
- **Model Fit** was assessed through Adjusted R^2 (for linear models) and AIC (for non-linear models).

All diagnostic checks confirmed the reliability of the results, with no major violations detected in model assumptions.

2.7 Summary of Methodological Approach

The sequential use of multiple econometric techniques ensures both descriptive and predictive rigor. Linear regressions reveal direct relationships, logistic and probit models capture probabilities, DID isolates policy effects, panel models account for unobserved heterogeneity, and multinomial logit models provide predictive classification. Collectively, these methodologies offer a holistic understanding of the financial and institutional determinants of credit allocation in India.

3. FINDINGS

3.1 Overview

The empirical analysis yielded significant insights into how scheduled commercial banks in India allocate credit across agriculture, industry, and personal lending sectors. By employing multiple econometric techniques, the study reveals distinct determinants and behavioral patterns underlying each type of credit flow. The results also highlight how institutional characteristics, financial depth, and policy initiatives influence credit distribution across states and over time.

3.2 Findings from Regression Models

The multiple linear regression results indicate that the **distribution of bank offices** has a strong and statistically significant positive effect on **agricultural credit**, while **deposits** do not exhibit a significant relationship. This suggests that agricultural lending in India is more dependent on the physical presence and outreach of banking infrastructure than on aggregate liquidity levels. Each additional bank office increases agricultural credit substantially, reflecting the critical role of branch penetration in supporting rural finance.

Conversely, the regression model for **industrial credit** demonstrates that **bank deposits** have a highly significant and positive influence, while the number of offices exerts a negative effect. This pattern implies that industrial lending is primarily driven by financial capacity rather than branch expansion, as industries often rely on centralized financing mechanisms and large-ticket lending.

For **personal loans**, both **offices** and **deposits** show positive and statistically significant relationships with credit allocation. Deposits, in particular, exhibit a stronger influence, indicating that personal lending expands as banks mobilize more deposits and increase their customer base. The adjusted R^2 values across all three regressions-ranging between 0.78 and 0.89-demonstrate that the models explain a substantial portion of variation in credit distribution.

```
> summary(industry_model)

Call:
lm(formula = Credit.To.Industry.By.Scheduled.Commercial.Banks..UOM.INR.IndianRupees.. ~
    Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number. +
        Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..,
    data = data)

Residuals:
    Min      1Q  Median      3Q     Max
-356179  -12720   -9397    8689  201135

Coefficients:
                                                                  Estimate Std. Error
(Intercept)                                                      9.220e+03  3.508e+03
Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number.      -1.410e+01  1.007e+00
Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..  4.244e-01  9.047e-03
                                                                 t value Pr(>|t|)
(Intercept)                                                        2.629  0.00891 **
Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number.      -13.995  < 2e-16 ***
Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..   46.913  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 51140 on 392 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.8932,    Adjusted R-squared:  0.8926
F-statistic:  1639 on 2 and 392 DF,  p-value: < 2.2e-16
```

Fig. 1 Industry model results

```
> summary(agri_model)

Call:
lm(formula = Credit.To.Agriculture.By.Scheduled.Commercial.Banks..UOM.INR.IndianRupees.. ~
    Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number. +
        Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..,
    data = data)

Residuals:
   Min     1Q Median     3Q    Max
-49573  -6402   1705   3019 123125

Coefficients:
                                                                    Estimate Std. Error
(Intercept)                                                       -3.202e+03  1.200e+03
Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number.  8.836e+00  3.450e-01
Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees.. -3.173e-03  3.099e-03
                                                                  t value Pr(>|t|)
(Intercept)                                                        -2.669  0.00792 **
Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number.  25.612  < 2e-16 ***
Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..  -1.024  0.30637
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 17520 on 393 degrees of freedom
Multiple R-squared:  0.7858,    Adjusted R-squared:  0.7847
F-statistic: 720.9 on 2 and 393 DF,  p-value: < 2.2e-16
```

Fig. 2 Agriculture model results

3.3 Findings from Logistic and Probit Models

The logistic and probit analyses, aimed at evaluating the probability of banks exhibiting high credit– deposit ratios, reveal consistent findings across both models. **Deposits** emerge as the sole significant predictor of a high credit–deposit ratio, while **number of bank offices** remains statistically insignificant. This highlights that credit intensity (relative to deposits) is largely a function of liquidity strength rather than branch density. Between the two, the **logit model** achieved a slightly better fit (AIC = 435.77), suggesting a more efficient representation of the probability distribution.

```
> summary(logistic_model)

Call:
glm(formula = high_credit_deposit ~ Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Nu
er. +
    Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..,
    family = binomial(link = "logit"), data = data)

Coefficients:
                                                                  Estimate Std. Error
(Intercept)                                                     -1.179e+00  1.650e-01
Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number.  1.580e-05  8.543e-05
Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..  4.847e-06  1.413e-06
                                                                z value Pr(>|z|)
(Intercept)                                                      -7.145 9.03e-13 ***
Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number.   0.185 0.853227
Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..   3.431 0.000602 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 547.52  on 395  degrees of freedom
Residual deviance: 429.77  on 393  degrees of freedom
AIC: 435.77

Number of Fisher Scoring iterations: 6
```

Fig. 3 Logit model results

```
> summary(probit_model)

Call:
glm(formula = high_credit_deposit ~ Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.N
er. +
    Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..,
    family = binomial(link = "probit"), data = data)

Coefficients:
                                                                  Estimate Std. Error
(Intercept)                                                     -6.476e-01  9.488e-02
Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number.  -5.373e-06  4.414e-05
Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..  2.604e-06  6.880e-07
                                                                z value Pr(>|z|)
(Intercept)                                                      -6.826 8.73e-12 ***
Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number.  -0.122 0.903121
Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..   3.785 0.000154 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 547.52  on 395  degrees of freedom
Residual deviance: 438.08  on 393  degrees of freedom
AIC: 444.08

Number of Fisher Scoring iterations: 9
```

Fig. 4 Probit model results

3.4 Findings from the Difference-in-Differences (DID) Model

The DID framework, which simulates the effect of a hypothetical agricultural credit policy, shows a **strong positive policy effect (β_1 = 63,840; p < 0.001)** and a **positive time trend (β_2 = 4,160; p = 0.003)**. This implies that both policy interventions and temporal progress have significantly enhanced agricultural credit levels. The **distribution of bank offices** continues to contribute positively, whereas deposits remain statistically insignificant. The model's R^2 value of 0.88 underscores its robustness and high explanatory power. These findings emphasize that well-designed agricultural credit policies, coupled with infrastructure expansion, can substantially improve rural credit accessibility.

```
> summary(did_model)

Call:
lm(formula = Credit.To.Agriculture.By.Scheduled.Commercial.Banks..UOM.INR.IndianRupees.. ~
    policy * time + Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number. +
        Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..,
    data = data)

Residuals:
   Min     1Q Median     3Q    Max
-35503  -5987   -160   4450  67122

Coefficients: (1 not defined because of singularities)
                                                                        Estimate Std. Error
(Intercept)                                                           -4.891e+03  1.214e+03
policy                                                                 6.384e+04  3.752e+03
time                                                                   4.160e+03  1.393e+03
Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number.      7.538e+00  2.678e-01
Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..  2.090e-03  2.350e-03
policy:time                                                                   NA         NA
                                                                      t value Pr(>|t|)
(Intercept)                                                            -4.030 6.71e-05 ***
policy                                                                 17.015  < 2e-16 ***
time                                                                    2.987    0.003 **
Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number.      28.144  < 2e-16 ***
Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..   0.890    0.374
policy:time                                                               NA       NA
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 13040 on 391 degrees of freedom
Multiple R-squared:  0.8818,    Adjusted R-squared:  0.8806
F-statistic: 729.3 on 4 and 391 DF,  p-value: < 2.2e-16
```

Fig. 5 DiD model results

3.5 Findings from Panel Data Models

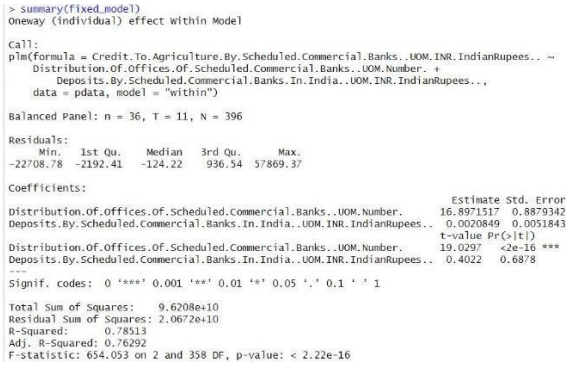
The **Fixed Effects (FE)** and **Random Effects (RE)** models were estimated to account for unobserved heterogeneity among states.

- In the **Fixed Effects Model**, within-state variations reveal that the number of bank offices significantly influences agricultural credit, whereas deposits have no meaningful effect.
- The **Random Effects Model**, capturing both within- and between-state variations, indicates that both offices and deposits significantly impact agricultural credit.

The estimated **theta value (0.844)** in the random effects model suggests that 84.4% of the total variance stems from differences between states. This reinforces the idea that regional banking disparities play a major role in shaping credit flow patterns. Collectively, these models confirm that banking infrastructure expansion remains a primary driver of agricultural lending, while deposit growth contributes to inter-state variations in credit capacity.

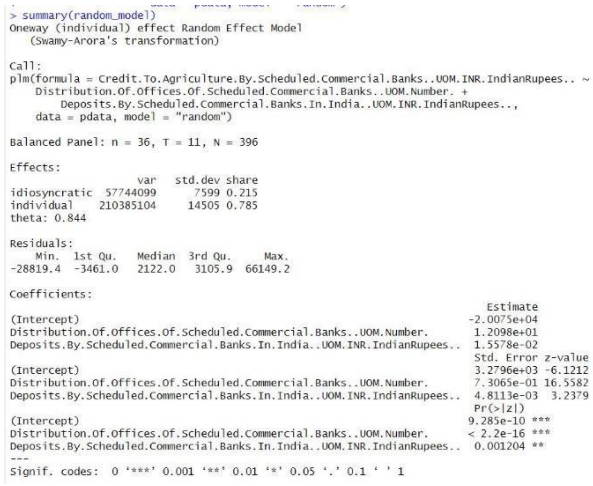
3.6 Findings from the Multinomial Logit Model

The multinomial logit model, which predicts the likelihood of each credit type (agriculture, industry, or personal loans) being dominant, reveals nuanced sectoral patterns. As the **number of bank offices increases**, the probability of **agriculture** being the dominant credit type rises, while the likelihood for **industry** and **personal loans** decreases marginally. However, **higher deposits** tilt the probability in favor of **industrial** and **personal loans**, suggesting that states with larger financial reserves tend to allocate relatively more credit toward these sectors. The model's residual deviance (621.65) and AIC (633.65) indicate good model convergence and explanatory efficiency.



```
> summary(fixed_model)
Oneway (individual) effect Within Model

Call:
plm(formula = Credit.To.Agriculture.By.Scheduled.Commercial.Banks..UOM.INR.IndianRupees.. ~
    Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number. +
        Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..,
    data = pdata, model = "within")

Balanced Panel: n = 36, T = 11, N = 396

Residuals:
     Min.   1st Qu.    Median   3rd Qu.      Max.
-22708.78  -2192.41   -124.22    936.54  57869.37

Coefficients:
                                                                  Estimate Std. Error
Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number.      16.8971517  0.8879342
Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..  0.0020849  0.0051843
                                                                  t-value Pr(>|t|)
Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number.      19.0297   <2e-16 ***
Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..  0.4022   0.6878
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    9.6208e+10
Residual Sum of Squares: 2.0672e+10
R-Squared:      0.78513
Adj. R-Squared: 0.76292
F-statistic: 654.053 on 2 and 358 DF, p-value: < 2.22e-16
```

Fig. 6 Fixed model results



```
> summary(random_model)
Oneway (individual) effect Random Effect Model
   (Swamy-Arora's transformation)

Call:
plm(formula = Credit.To.Agriculture.By.Scheduled.Commercial.Banks..UOM.INR.IndianRupees.. ~
    Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number. +
        Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..,
    data = pdata, model = "random")

Balanced Panel: n = 36, T = 11, N = 396

Effects:
                 var  std.dev share
idiosyncratic  57744099     7599 0.215
individual    210385104    14505 0.785
theta: 0.844

Residuals:
    Min.  1st Qu.   Median  3rd Qu.     Max.
-28819.4  -3461.0   2122.0   3105.9  66149.2

Coefficients:
                                                                    Estimate
(Intercept)                                                       -2.0075e+04
Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number.  1.2098e+01
Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..  1.5578e-02
                                                                  Std. Error z-value
(Intercept)                                                       3.2796e+03 -6.1212
Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number. 7.3065e-01 16.5582
Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..  4.8113e-03  3.2379
                                                                  Pr(>|z|)
(Intercept)                                                       9.285e-10 ***
Distribution.Of.Offices.Of.Scheduled.Commercial.Banks..UOM.Number. < 2.2e-16 ***
Deposits.By.Scheduled.Commercial.Banks.In.India..UOM.INR.IndianRupees..  0.001204 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Fig. 7 Random model results

3.7 Synthesis of Results

Across all models, a consistent theme emerges:

- **Banking outreach**-represented by the number of offices-is the single most influential factor for improving credit access in agriculture.
- **Deposit mobilization** drives credit expansion in industry and personal lending.
- **Policy interventions** and **temporal evolution** further amplify credit flow to priority sectors.
- **Regional heterogeneity** underscores the need for state-specific financial strategies rather than one-size-fits-all solutions.

These findings collectively highlight the multifaceted nature of credit allocation in India and underline the importance of integrating infrastructure expansion, deposit growth, and targeted policy initiatives to foster balanced economic development.

4. IMPLICATIONS

The study underscores that the **expansion of banking infrastructure** remains a decisive factor in enhancing credit accessibility, particularly within the agricultural sector. Despite the growth of digital finance, rural and semi-urban regions in India still rely heavily on the physical presence of bank offices for loan disbursement and relationship-based credit. Policymakers should therefore focus on extending branch networks and strengthening the coverage of Regional Rural Banks (RRBs) and cooperative institutions to ensure equitable access to agricultural finance across states.

For banking institutions, the results emphasize the importance of **deposit mobilization and operational reach** as primary levers of credit expansion. Banks can strategically use these insights to design region-specific credit portfolios that balance risk and return across agriculture, industry,

and personal lending. Encouraging innovative savings products, improving branch-level customer engagement, and integrating data analytics into credit decision-making can further enhance both liquidity management and financial inclusion.

At a macro level, the findings highlight that **balanced and inclusive credit allocation** is vital for promoting sustainable economic development. A stronger emphasis on rural credit delivery, state-specific policy interventions, and sector-sensitive lending frameworks can bridge regional disparities and support long-term financial resilience. Together, these measures can strengthen India's goal of fostering an equitable and inclusive banking ecosystem that supports growth across all segments of society.

5. CONCLUSION

This study provides an empirical understanding of the determinants influencing credit allocation across agriculture, industry, and personal loan sectors in India. Using a combination of linear, logistic, and panel data models, it highlights that banking infrastructure-specifically the number of bank offices-plays a critical role in expanding agricultural credit, while deposit mobilization drives credit growth in industrial and personal segments. Policy interventions and temporal progress further enhance agricultural lending, demonstrating the value of targeted government initiatives in improving rural credit access.

Overall, the findings emphasize that a well-balanced approach to credit distribution-combining infrastructure expansion, liquidity management, and data-informed policy design-can promote inclusive and sustainable financial growth. Strengthening branch penetration in underserved regions, improving deposit mobilization strategies, and fostering regional policy differentiation are key to building a more resilient credit ecosystem. By aligning institutional strategy with developmental goals, India's banking system can continue to serve as a powerful instrument for equitable economic progress.

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Diversity, Equity and Inclusion (DEI) Initiatives for Employee Engagement in Manufacturing firms in Tamil Nadu

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ABSTRACT

Diversity, Equity, and Inclusion (DEI) are now critical aspects of the contemporary human resource practice and not organizational hot-takes. In the modern-day workplace that is multigenerational, encompassing Baby Boomers, Gen X, Gen Y, Gen Z, and a wide range of gender identities, organizations are forced to come up with policies and practices that support the special needs and expectations of these diverse groups. Every group provides different views and their participation and dedication is influenced by the way the organization identifies them and appreciates them. DEI efforts are central to the creation of a unified and inclusive workplace, the encouragement of equal opportunities, and inter-generational cooperation. This research paper will explore the effects of DEI in employee engagement and job satisfaction in manufacturing firms in Tamil Nadu. The results show that there is a positive relationship between DEI practices and employee engagement, which implies that a strong and more dedicated workforce can be developed through a planned approach to the implementation of DEI practices.

Keywords: Diversity, Equity, Inclusion, Employee Engagement

I. INTRODUCTION

Today's work environments are becoming increasingly heterogeneous. In recent years, the concept of diversity, equity and inclusion have attained significant attention. As the world becomes interconnected, it is natural that people migrate for various life prospects like education, employment etc. Modern day industrialists speak on the importance of workplace diversity, equity and inclusion. Management practitioners all over the world have expressed a strong interest in diversity, equity and inclusion. As organizations attempt to mirror societal diversity, "Diversity, Equity, and Inclusion" (DEI) initiatives arise as cultural transformation catalysts for the organizations. Diversity in the workplace is more than a trend; it reflects societal advancement and organizational development. In today's rapidly changing workplace, stakeholders are more and more concerned about practicing diversity, equity, and inclusion (DEI).

DEI at the workplace, according to different studies, results in a friendly and efficient working environment. This has deprived the workforce in various regions of the world of basic rights, social justice, respect, and dignity as human beings due to the lack of DEI in their labour markets (Forst, 2010; Divan et al., 2016; Hocking, 2017). Diversity accommodation and integration would bring about a feeling of solidarity and camaraderie among the workforce members at the workplace (Hodson, 2001). The Harvard Business Review (2017) also writes that diversity is welcome to the party, whereas inclusion is asked to dance. In their research paper titled, Diversity, Equity, Inclusion and Employee Loyalty, Rozaini et.al (2022) found that diversity, equity, and inclusion are very important to the loyalty and engagement at work. Diversity is the existence of different groups in a given workplace whereby it could be age, gender, language (geographical location), marital status, physical abilities, religious beliefs, sexual orientation and socioeconomic background. Equity entails giving everyone equal access, fair treatment, opportunity and advancement in the workplace regardless, the differences. In contrast to equality which considers all people equal, equity provides the fact that various individuals could need various resources and opportunities to achieve success. Inclusion is the art of rendering every person respected, accepted and appreciated in the work place. It involves the practice of a culture of giving everyone a chance to contribute as well as participate fully without any discrimination or bias.

History of DEI efforts in India

Diversity, Equity and Inclusion initiatives at workplace in India has been influenced by a number of factors varying from historical, social and legislative factors. The history of DEI in workplace can be divided into various time frames, viz.,

- During the colonial era (Late 19th Century), Indians were mainly forced to do menial tasks whereas the Whites (or the Englishmen) worked in high position jobs.
- Pre-independence (1900-1947):- Prior to independence, work was divided among people on the basis of caste. Those who belong to the upper caste, worked in higher and respective positions and people from lower caste was subjected to subordination by the upper caste. Untouchability was widespread and untouchability at the workplace is no exception.
- Post-Independence, initial efforts to labour rights and equality at work and workplace movements started as a result of the various constitutional provisions and prevailing labour laws in the country. (Examples include: Article 14 to 24 of the Indian constitution, Factories Act of 1948, which gives special protection for women workmen and children, Maternity benefit act of 1961 which gives additional protection to women during pregnancy etc.)
- 1990 to present:- As a result of the new economic policy ie, Liberalisation, Privatisation and Globalisation people started moving from one place to another, especially to other countries in search of work. Even foreign workers, came to India for work.

Previously, the workforce in a particular region was limited to people of the same region. As a result of access and opportunities, and the impact of media, has brought people from the North and South, East and West to work together under one roof. Slowly, the Government and various stakeholders has also included the LGBTQIA+ people in the workforce, making the workplace a thaali plate.

Influence of DEI on Employee engagement

Studies have always revealed that the higher the level of employee engagement, the higher the productivity, turnover rates are less and the better the organizational performance. DEI programs represent disruptive interventions in the companies, and their influence on the employee engagement is considerable. To begin with, DEI creates a feeling of belonging to different employees. Whenever individuals feel that they are accepted and appreciated because of their differences, they tend to be more interested in their work and be able to communicate with their colleagues. This feeling of belonging leads to a positive atmosphere where employees feel free to share their individual ideas and expertise, leading to a higher level of team integration and effectiveness. The case study report on CISCO Systems indicates how DEI affects employee engagement. Cisco has been identified to have holistic approach to diversity and inclusion that has contributed to great gains in employee satisfaction and performance. A number of firms in India such as the Accenture, Wipro, Godrej, HCL, Schindler electric and ZF has successfully applied the concept of DEI within the work place. This paper will achieve this by examining how DEI initiatives impact on worker engagement in a leading plant in Chennae in the manufacturing industry. The study is expected to deliver practical ideas and suggestions to companies that want to improve their employees by implementing successful DEI practices.

Outcomes of DEI initiatives on Employee Engagement:

The various outcomes of DEI initiatives on employee engagement includes;

- Increased productivity
- Increased retention rates
- Reduced attrition rates
- Enhanced reputation for the organization
- Increased Job Satisfaction
- Enhanced Motivation
- Better Team Dynamics

II. STATEMENT OF THE PROBLEM

In the modern workplace, diversity, equity and inclusion programs have started receiving a lot of attention. Organizations are increasingly realising that creating an Atmosphere in which various perspectives are appreciated, equitable opportunities are provided, and inclusion is actively encouraged - can result in a variety of benefits. These includes increased the employee engagement and participation, higher team performance and a more positive organizational reputation. Despite the increased emphasis on DEI, many firms fail to effectively implement these programs and reap their potential benefits. Historically, men has outnumbered women in the manufacturing sector. Ostensibly, the manufacturing sector is male-dominated. The gender gap in this industry pose a significant challenge. It is vital to address this disparity and create a more inclusive and diverse workforce. The feminization of women in manufacturing sector is a road less taken. Also, there is a visible lack of diversity among the top level management of the manufacturing companies in India. Women, non-binary (LGBTQIA+), the aged population and the physically challenged are often considered as unfit for the jobs in manufacturing sector. They are often confined to other sectors. The manufacturing sector, with its diverse workforce and operational complexities, has problems in optimizing employee engagement as cultural norms and workplace dynamics change. While Diversity, Equity and Inclusion (DEI) initiatives have gained attraction globally, their specific impact on enhancing employee engagement within the manufacturing industry remains underexplored. This study aims to look into how DEI practices, such as policies, programs and organizational culture, affect employee engagement metrics including job satisfaction, retention rates and productivity in manufacturing plant in Chennai. This study seeks to provide insights into effective approaches for fostering a more engaged and inclusive workforce in the manufacturing industry by studying the implementation and consequences of DEI strategies.

III. REVIEW OF LITERATURE

In its report on the subject of how diversity, equity and inclusion can lead to engagement of the employees, Diversio DEI expert (2023) outlines the significance of the DEI in the process of engaging the employees. When employees feel that they are respected and valued by their employer, then they tend to be more active. This further increases their productivity. Moreover, the employees with a wide range of backgrounds can also receive chances to develop professionally, and, simultaneously, learn about one another with the help of the DEI programs. The proponents of this report believe that due to DEI practices, employee engagement levels can increase, and engaged employees would be inclined to enhance their personal and professional self and tend to be effective and motivated. In the article titled as Being inclusive boosts impact of diversity practices on employee engagement, Jeronimo et.al (2022) identifies the following: argues concerning the relationship between diversity and employee engagement. The finding of the study was that there is a positive relationship between diversity practices and engagement and the mediation is created by the perception of inclusion.

This paper also discovered that employees would be more likely to work when they feel that the culture of organization is inclined towards them. In his study titled Diversity and Inclusion initiatives: Driving organizational success, Mansi Tiwari (2022) discovered that diversity and inclusion initiatives are significant in terms of their effect on the organizational culture and engagement of employees. In the article, Workforce diversity and individual differences: implications on employee engagement, Yadav et.al (2017) brings out the significance of diversity at workplace and implications of the same on employee engagement. The presence of individual differences and diverse workplaces imply that, HRs cannot apply a one-fit-all approach. The importance of human capital is increasing, creating an urgent necessity to adjust the HR strategies and practices to satisfy the needs of a diverse workforce. The paper herein indicates how valuable it is to exploit diversity on the engagement of employees. Another key aspect that this paper raises is the significance of each of the employee engagement dimension: physical, cognitive and emotional since both of them have some part to play, in the overall organizational climate.

IV. METHODOLOGY

General Objective

To assess how Diversity, Equity and Inclusion (DEI) practices influence employee engagement levels within the organization. Specific Objectives

- To understand the influence that DEI practices have on employee engagement
- To examine the perception of employees towards Diversity, Equity and Inclusion practices
- To examine the relationship between Diversity, Equity, Inclusion and Employee Engagement
- To suggest recommendations for improving employee engagement by increasing the level of Diversity, Equity and Inclusion practices followed by the organization

Field of Study:

The research was conducted in various manufacturing companies in Tamil Nadu, India. Hypotheses

• H_0 (Null Hypothesis): There is no statistically significant relationship between Diversity, Equity, and Inclusion (DEI) practices and employee engagement in the organization.

• H_1 (Alternative Hypothesis): The implementation of DEI practices is positively correlated with higher levels of employee engagement in the organization.

Research Design: This study adopted a descriptive research design to explore and analyze the relationship between DEI practices and employee engagement. The design facilitated the identification of trends, characteristics and potential effects of DEI practices on employee engagement within the industrial context.

Research Method: A quantitative research method was used. Data was collected through structured surveys and statistically analyzed to examine the hypothesized relationship between DEI practices and employee engagement.

Sample size: The final sample consisted of 75 employees.

Sampling Technique: Simple random sampling was employed to ensure that each employee had an equal chance of being selected, thus enhancing the representativeness and reliability of the findings.

Tools of Data Collection: Data was collected using a self-structured questionnaire consisting of Likert-scale items. The instrument was designed to gather comprehensive insights into DEI practices and employee engagement.

Sources of Data:

• Primary Data: Collected directly from employees through the administered questionnaire.

• Secondary Data: Sourced from academic journals, company reports, newspapers, official websites and previous research studies relevant to DEI and employee engagement.

V. MAJOR RESULT AND DISCUSSIONS

Table 1.1: Regression Analysis

ANOVA[a]					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	638.847	1	638.847	123.434	.000[b]
Residual	377.820	73	5.176		
Total	1016.667	74			
a. Dependent Variable: EMPLOYEEENGAGEMENT					
b. Predictors: (Constant), DIVERSITYEQUITYANDINCLUSION					

Theregression model explains Employee Engagement using DEI as a predictor. The high F-statistic (123.434) and very low p- value (0.000) suggest a strong and significant relationship between DEI and Employee Engagement in the manufacturing sector. This rejects the null hypothesis and accepts the alternate hypothesis.

Table 1.2: Correlation between DEI and Employee Engagement

Correlations			
		Diversity, Equity and Inclusion	**Employee Engagement**
Diversity, Equity and Inclusion	Pearson Correlation	1	.793**
	Sig. (2-tailed)		0.000
	N	75	75
Employee Engagement	Pearson Correlation	.793**	1
	Sig. (2-tailed)	0.000	
	N	75	75
**. Correlation is significant at the 0.01 level (2-tailed).			

Table 4.2 summarizes the relationship between Diversity, Equity and Inclusion (DEI) and Employee Engagement using Pearson's correlation coefficient. The correlation between DEI and Employee Engagement is 0.793, indicating a strong positive relationship. This means that as DEI improves, Employee Engagement tends to increase significantly. The results highlight a strong and statistically significant positive correlation between Diversity, Equity and Inclusion (DEI) and Employee Engagement. This underscores the critical importance of fostering DEI initiatives to enhance engagement levels in the workplace. Organizations should leverage DEI strategies as a key driver for improving employee satisfaction and commitment.

Table 1.3: Correlation between Diversity and Employee Engagement

c			
		Diversity	**Employee Engagement**
Diversity	Pearson Correlation	1	.739**
	Sig. (2-tailed)		0.000
	N	75	75
Employee Engagement	Pearson Correlation	.739**	1
	Sig. (2-tailed)	0.000	
	N	75	75
**. Correlation is significant at the 0.01 level (2-tailed).			

Table 1.3 represents the correlation between Diversity and Employee engagement. The findings says that there is a strong positive correlation between Diversity and Employee Engagement. There is a strong, positive and statistically significant relationship between diversity and employee engagement in the organization. This suggests that efforts to enhance diversity could have a meaningful impact on improving employee engagement levels. A study conducted by Downey et.al (2015) also revealed that there is a positive relationship between diversity and engagement at work.

Table 1.4: Correlation between Equity and Employee Engagement

Correlations			
		Equity	**Employee Engagement**
Equity	Pearson Correlation	1	.606**
	Sig. (2-tailed)		0.000
	N	75	75
Employee Engagement	Pearson Correlation	.606**	1
	Sig. (2-tailed)	0.000	
	N	75	75
**. Correlation is significant at the 0.01 level (2-tailed).			

Table 1.4 depicts the correlation between Equity and Employee engagement. The findings says that there is a moderately significant positive relationship between Equity and Employee engagement. This suggests that fostering a sense of equity in the workplace can significantly enhance employee engagement levels.

Table 1.5: Correlation between Inclusion and Employee Engagement

Correlations			
		Inclusion	**Employee Engagement**
Inclusion	Pearson Correlation	1	.701**
	Sig. (2-tailed)		0.000
	N	75	75
Employee Engagement	Pearson Correlation	.701**	1
	Sig. (2-tailed)	0.000	
	N	75	75
**. Correlation is significant at the 0.01 level (2-tailed).			

The above table shows the correlation between Inclusion and Employee Engagement. This indicates that there is a strong positive relationship between inclusion and employee engagement. As perceptions of inclusion increase, employee engagement tends to increase significantly as well. This suggests that fostering a culture of inclusion in the workplace can have a substantial positive impact on employee engagement levels.

Policy Implication

- Apart from the normal training programmes which indirectly focuses on DEI, additional DEI training programmes can be provided. It might increase the employee engagement. 85.3% of the respondents agreed to this.
- A DEI related mentorship programme can be offered, so that the migrant employees will be able to cope up and adapt to their new working environments, thereby reducing the cultural shock. 81.3% of the respondents strongly agreed to this.
- The organizations should conduct regular surveys to gather employees feedback on DEI practices. Regular surveys or feedbacks helps to understand the perception and thought process of the employees. 84% of the employees strongly agreed to this.
- The best practices in other sectors (IT), for effective DEI policy shows the operation of Employee Resource Groups. ERGs are crucial for imparting the DEI knowledge and practices. Therefore, establishing an ERG can be one of the most effective measures to leverage DEI. 81.3% of the respondents agreed to the formation of ERG's.
- Cultural sensitivity training can be provided to the employees. It will help to understand and appreciate the peers better. 80% of the respondents strongly agreed to this.
- The organizations can hire more persons with disabilities as it will make the workplace more inclusive.

VI. CONCLUSION

In conclusion the relationship between DEI and employee engagement is both profound and multifaceted. Organisations that embrace diversity, champion equity and foster inclusion create a foundation for a positive and thriving workplace culture. Such a culture not only enhances employee engagement but also drives innovation and collaboration. The insights from this research highlight the transformative potential of DEI in shaping employee experience and achieving organisation excellence.

As organisations navigate to the challenges and opportunities of the 21st century the integration of DEI into their core strategy will remain a critical determinant of organizational success. By prioritizing DEI, organisations not only full fill their ethical and social responsibility but also unlock the full potential of their workforce. Ultimately the Synergy between DEI and employee

engagement serves as a powerful catalyst for sustainable growth, competitive advantage and enduring organizational success in an increasingly diverse and interconnected world.

VI. IMPLICATIONS

The results of this research outline the number of action steps related to improving employee engagement by means of DEI efforts in the manufacturing companies. The companies ought to have specific DEI training programs which extend beyond the general orientation programs and educate the employees on how to make sense of diversity, equity and inclusion in an employee-focused manner. To help migrant and culturally diverse employees, mentorship programs can be launched, which will allow them to adjust to new work-related conditions fast enough, minimizing the shock of cultural differences. Employee surveys and feedback systems should be employed regularly to understand how employees view DEI practices and work on the improvement of these practices. Another potential way of enhancing DEI knowledge and creating peer support networks in the organization is by forming Employee Resource Groups (ERGs). Mutual understanding and cooperation between the employees should be improved through cultural sensitivity training. Moreover, passive recruitment and accommodation of persons with disabilities can make the workplace easier and more just. All of these measures, in turn, do not only strengthen the inclusive organizational culture but also help to increase the engagement, motivation, productivity, and general job satisfaction among the employees.

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A Study on Sustainable Leadership and Ethical Decision-Making: Building a Framework for Future-Ready Organizations

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ABSTRACT

In today's dynamic and rapidly evolving business landscape, organizations face increasing pressure to balance economic growth with social responsibility and environmental sustainability. This study explores the interconnection between sustainable leadership practices and ethical decision-making in shaping strong and adaptable organizations. Based on the existing literature, case studies, and theoretical frameworks, the research aims to recognize key leadership competencies that encourage and strengthen organizational sustainability while adhering to ethical standards. Findings will outline a strategic framework emphasizing leadership values such as transparency, social responsibility, innovation, and long-term stakeholder engagement. This framework will serve as a guide for organizations striving to balance economic growth with environmental stewardship and ethical governance, contributing to the broader goal of sustainable development.

Keywords: Globalization, Leadership, Transparency, sustainability, ethical governance.

1. INTRODUCTION

Based on the United Nations Global Compact, there's a notable gap between recognition and action-over 90% of CEOs observed sustainability as essential, but less than 50% have made it a strategic priority.This imbalance among awareness and execution highlights a compelling requirement for leaders who can balance economic growth, environmental responsibility, and ethical governance in this growing complexity in international business

In this modern era, organizations operate in a business world featuring rapid international interconnectedness, technological disruption, climate change, and evolving societal expectations. Leaders today face the dual challenge of achieving financial success while ensuring environmental stewardship and ethical responsibility. This shift in priorities has brought concepts like sustainable leadership and ethical decision-making to the forefront of organizational strategy.

Sustainable leadership focuses on creating long-term value by balancing economic performance with social and environmental responsibilities. Ethical decision-making, on the other hand, emphasizes transparency, fairness, and moral responsibility in organizational choices. While both concepts are extensively discussed in management literature, there is a lack of integrated frameworks that combine sustainability principles with ethical governance to prepare organizations for an uncertain and rapidly evolving future.

Organizations increasingly recognize that financial success alone cannot guarantee long-term survival. Stakeholders demand responsible practices that align with global sustainability goals, ethical governance, and socially conscious leadership. However, despite growing awareness, many organizations struggle to translate these ideals into actionable strategies. This gap between theory and practice highlights the urgent need for a comprehensive framework linking sustainable leadership and ethical decision-making to guide future-ready organizations.

This study addresses this gap by analyzing existing literature, collecting insights from organizational leaders and professionals, and identifying key competencies required to build a Strategic Ethical Leadership Framework (SELF). By integrating sustainability and ethics, this research aims to equip organizations with a practical model to navigate the complexities of modern business while ensuring responsible and ethical growth.

2. LITERATURE REVIEW

Global uncertainty, technological advancements, changes in the environment, and new stakeholder expectations, mark a need for sustainable leadership and ethical decision-making in modern organizations. Leaders today are not only expected to accelerate financial performance but also to create sustainable benefits for society, the environment, and future generations. This change in structure demands a holistic and forward-thinking approach to leadership-that focuses on ethics, responsibility, and sustainability.

This section delivers a broad review of the existing literature on sustainable leadership and ethical decision-making, with the aim of establishing a theoretical foundation for the present study. It examines key concepts, models, and frameworks that define sustainable leadership, and analyses the role of ethical principles in organizational governance and decision-making processes. By examining the work and study done by others, this review sets the stage for understanding the leadership competencies, values, and real-world practices necessary for future-ready organizations. Furthermore, the study of literature review aims to discover how various leadership theories-such as transformational leadership, servant leadership, and stakeholder theory-contribute to the broader discourse on sustainability and ethics. It also investigates the intersection between leadership behavior and ethical frameworks, including consequentialism, deontology, and virtue ethics, as applied in organizational contexts.

By synthesizing these perspectives, this chapter lays the groundwork for the development of a practical, future-oriented leadership framework that organizations can adopt to enhance their sustainability and ethical integrity.

2.1 Afzal Izzaz Zahari a, Jamaliah Said b, Nurisyal Muhamad c, Suhaily Mohd Ramly-The purpose of this study is to explore how ethical leadership behaviours within government organisations impact the development and sustainability of a positive organisational culture, which, in turn, has implications for ESG alignment. The study's findings established the role of ethical leadership in reducing integrity violations, particularly in the context of ESG compliance. Ethical leaders contribute to a culture where adherence to ESG principles is prioritised. However, the analysis did not find a statistically significant direct link between ethical culture and integrity violations related to ESG compliance, suggesting the need for further exploration of this relationship in future research.

2.2 Author Dr. John Motsamai Modise (Tshwane University of Technology) Article History: Received: 17 / 06 / 2025, Accepted: 01 / 07 / 2025, Published: 04 / 07 / 2025. This research explores the critical link between ethical leadership and successful implementation of sustainable development initiatives. Main topics, the characteristics of ethical leaders crucial for sustainability. How different leadership styles (transformational, servant) influence employee engagement with sustainability goals. Strategies for promoting ethical leadership within organizations (leadership development programs, mentorship, reward systems). Challenges faced by leaders in balancing economic pressures with ethical considerations. The research on ethical leadership and sustainable development paints a clear picture: ethical leaders are the driving force behind a sustainable future. Their commitment to long-term environmental and social well-being, coupled with their ability to inspire and engage others, paves the way for successful implementation of sustainability initiatives

2.3 C.K. Prahalad and Stuart L. Hart: Their work on "bottom of the pyramid" (BOP) strategies highlights the potential for businesses to innovate and create value by serving the needs of the world's poorest populations. This concept emphasizes that innovation for

sustainability can also drive economic growth and social progress. This work shows that innovation and social benefit are not mutually exclusive.

2.4Michael E. Porter and Mark R. Kramer: Their concept of "shared value" argues that businesses can create economic value by addressing social and environmental problems. This approach encourages companies to integrate sustainability into their core business strategies, driving innovation and creating long-term value. This moves innovation from a side project, to a core business strategy.

2.5 Environmental and Social Responsibility: Sandra Waddock: Waddock's research explores the role of corporate responsibility and citizenship in building sustainable businesses. She emphasizes the importance of ethical leadership and stakeholder engagement in creating a positive impact on society and the environment.She has written extensively on corporate social performance.

2.6 David Korten: Korten's works critiqued traditional economic models, arguing for a shift towards more sustainable and equitable systems. His book "When Corporations Rule the World" (1995) raised awareness of the social and environmental consequences of unchecked corporate power. He helps to give a broader societal view of the effect of business.

2.7 Peter Senge: Senge's "The Fifth Discipline" (1990) discusses systems thinking, which is crucial for understanding the interconnectedness of social, environmental, and economic systems. Sustainable leadership requires a systems perspective to address complex challenges.

3. STATEMENT OF THE RESEARCH PROBLEM

In today's rapidly changing business environment, organizations face increasing pressure to balance economic growth with ethical responsibility and environmental sustainability. While sustainable leadership and ethical decision-making are widely acknowledged as essential for long-term organizational success, existing research often examines these concepts in isolation rather than integrating them into a comprehensive framework. Furthermore, much of the literature remains theoretical, with limited empirical studies exploring how leaders practically apply sustainability and ethics in decision-making processes.

This lack of integrated, actionable frameworks creates a significant gap between academic knowledge and organizational practice. As businesses strive to become future-ready-capable of adapting to global challenges while maintaining ethical integrity-there is a critical need for a model that unites sustainable leadership competencies with ethical governance principles. Therefore, this study seeks to bridge this gap by combining insights from literature and real-world organizational practices to develop a Strategic Ethical Leadership Framework (SELF) for future-ready organizations.

4. RESEARCH GAP

While sustainable leadership and ethical decision-making have gained significant attention in recent years, most existing studies focus on these concepts in isolation rather than examining their interconnectedness. Research has largely emphasized theoretical discussions, with limited empirical studies exploring how leadership competencies such as transparency, innovation, and social responsibility are actually practiced in real-world organizational settings.Moreover, there is a lack of integrated frameworks that combine insights from both existing and primary data to provide practical guidance for organizations aiming to balance economic growth with ethical governance and sustainability. Existing frameworks often fail to address how business leaders perceive and implement these values on the ground, leaving a gap between theory and practice.

This study seeks to bridge this gap by conducting both primary and secondary research to develop a Strategic Ethical Leadership Framework that organizations can adopt to build future-ready structures, ensuring long-term sustainability and ethical decision-making.

5. RESEARCH QUESTIONS

i. What are the major theories and frameworks currently available on sustainable leadership and ethical decision-making?
ii. What leadership competencies are most critical for balancing economic growth with ethical and sustainable practices?
iii. What is the level of awareness and implementation of sustainable leadership practices among business leaders and professionals?
iv. How can findings from both literature and primary data be integrated to develop a Strategic Ethical Leadership Framework?

6. SIGNIFICANCE OF THE STUDY

This research reveals great value for both academic research and practical and ethical leadership development. In this world of rapid technological change, environmental uncertainty, organizations continuously depend on leaders who can make ethical decisions while ensuring long-term sustainability. By analysing the combination of sustainable leadership and ethical decision-making, this study contributes to developing a framework for future-ready organizations that balance economic performance with social and environmental responsibility.

From an analytical point of view, this study enhances existing literature by integrating sustainability principles into ethical leadership models. This study fills that gap by identifying key dimensions, relationships, and mechanisms that link sustainable leadership behaviors to ethical decision-making processes and organizational strength. The framework generated will offer a theoretical foundation for future empirical testing and model development.

7. RESEARCH OBJECTIVES

i. To review existing literature and theories related to sustainable leadership and ethical decision-making in organizations.
ii. To identify key leadership competencies and values that promote sustainability and ethical governance in modern organizations.
iii. To collect and analyze primary data from business leaders, management professionals, or students to understand real-world practices and perceptions of sustainable leadership and ethical decision-making.
iv. To Create a practical framework that organizations can use to develop sustainable leadership capabilities and make ethical decisions.

8. RESEARCH METHODOLOGY

8.1 Nature of the Study

The present study follows a descriptive and exploratory research design. It is descriptive because it aims to study and describe the relationship between sustainable leadership and ethical decision-making practices. At the same time, it is exploratory because it seeks to develop a new Strategic Ethical Leadership Framework (SELF) by integrating insights from literature and real-world organizational practices.

8.2 Area of the Study

The study will focus on management professionals, and students of management studies across institutions and organizations.

8.3 Source of Data

This study used both primary and secondary sources of data:

Primary Data:

Collected directly from respondents such as management professionals, and students using structured questionnaires.

Secondary Data:
Drawn from academic journals, books, case studies, industry reports, and research publications related to sustainable leadership and ethical decision-making.

9 SCOPE OF THE STUDY

This study focuses on exploring sustainable leadership and ethical decision-making in organizations. It also examines how leadership practices that emphasize sustainability, and ethics influence organizational culture, employee behavior, and long-term performance. The research will be limited to organizational contexts, particularly focusing on leaders and managers in business, corporate sector, academicians. It will not include political, religious, or purely community-based leadership structures. The scope includes:

i. Reviewing existing literature and theories related to sustainable leadership and ethical decision-making.
ii. Identifying key leadership competencies and values that promote sustainability and ethical governance in modern organizations.
iii. Collecting and analyzing primary data from business leaders, management professionals, or students to understand real-world practices and perceptions of sustainable leadership and ethical decision-making.

The study aims to develop a framework for future-ready organizations that integrates sustainable leadership and ethical decision-making principles.

10. LIMITATIONS OF THE STUDY

Although this research aims to contribute valuable insights into the relationship between sustainable leadership and ethical decision-making, certain boundaries must be acknowledged to ensure a balanced interpretation of the findings.

i. Limited sample size: If the study relies on a specific organization, sector, or geographic region, the findings may not fully represent all industries or cultural contexts. Leadership practices and ethical norms can vary across cultural, economic, and institutional settings, which may affect the generalizability of the results.
ii. Since the study focuses on building a conceptual framework rather than conducting extensive empirical testing, the findings may remain theoretical. The proposed relationships between sustainable leadership and ethical decision-making should be validated through future quantitative or mixed-method studies.
iii. The research draws heavily from existing literature, which means the quality of conclusions depends on the availability, accuracy, and currency of prior studies. Any bias or limitation present in earlier research may influence the interpretations made in this study.
iv. Leadership and ethical practices evolve with societal, technological, and environmental changes. As a result, the framework developed in this study may need continuous study and change to remain relevant in the context of the emerging global business environment.

10.1 Introduction to Sustainable Leadership and Ethical Decision-Making:

As the world continues to evolve, sustainable leadership and ethical decision-making have become key elements for building organizations that can progress morally over the long term.

Sustainable leadership emphasizes on developing fundamental principles for employees, customers, society, and the environment. It focuses on ethical obligation, future development, and future prosperity. A sustainable leader thinks beyond immediate gains and ensures that decisions today do not harm tomorrow's world.

Ethical decision-making, on the other hand, involves choosing actions that are morally right, fair, and transparent. It requires leaders to balance profit motives with integrity, honesty, and respect for human values. Ethical leaders act as role models, inspiring trust and fostering a culture of accountability within the organization.

Together, sustainable leadership and ethical decision-making create a powerful framework for responsible governance. They ensure that business success is not achieved at the cost of people or the planet, but in harmony with them.

In essence, these principles remind us that true leadership is not just about leading people - it's about leading with values, ensuring a positive impact on society and leaving a legacy that future generations can build upon.

Understanding Sustainable Leadership and Ethical Decision-Making

Sustainable leadership refers to a leadership approach that focuses on long-term success by balancing economic growth with social responsibility and environmental care. A sustainable leader ensures that the organization's actions today do not harm future generations. Such leaders promote innovation, inclusiveness, and fairness while maintaining business performance.

Ethical decision-making involves choosing actions that are morally right and align with values such as honesty, integrity, fairness, and respect. In organizations, ethical decisions build trust among employees, customers, and stakeholders.

Sustainable leadership and ethical decision-making are closely connected. Leaders who act ethically inspire others to behave responsibly, helping create a culture of accountability and sustainability. They consider not just profits, but also the impact of their choices on people and the planet. By doing so, they ensure the organization's long-term stability, reputation, and positive contribution to society.

Importance of Sustainable Leadership and Ethical Decision-Making: Building a Framework for Future-Ready Organizations

Sustainable leadership and ethical decision-making are crucial for making organizations that can flourish in the future. In this rapidly evolving world, leaders must focus on people, the environment, and long-term growth, not just profit. Environmental awareness, ethical decision making and sustainable leadership ensures that these business practices are rational, holistic, and environmentally conscious.

This Sustainable leadership aids leaders to deal with honesty, reliability, and transparency, that creates trust among stakeholders. Collectively, these components encourage organizations to handle challenges such as economic inequality, and technological advancement with clear vision.

By building a framework that integrates sustainability and ethics, organizations can build a strong habit of innovation, accountability, and reliability. Such a framework prepares them to face future uncertainties while maintaining moral values, ensuring long-term success, and contributing positively to society.

Long-Term Benefits of Sustainable Leadership and Ethical Decision-Making for Future Organizations

1. Increased Reliability, Reputation and Trust among the stakeholders: Organizations that follow sustainable leadership, ethical values & practices and sustainability principles establish timeless legitimacy and trust among stakeholders, including employees, customers, and investors.
2. Workforce Commitment and Longevity: Sustainable and ethical leaders cultivate a culture of honesty, accountability, fairness, respect, and purpose that can lead to higher employee retention, loyalty.
3. Creativity and Sustained Growth: Sustainable leadership motivates creativity and innovation by emphasising on future goals that balance success with social and environmental well-being.

4. Flexibility and Risk Management: Sustainable and Ethical decision-making mitigates the possibilities of security and legal issues, and reputational damage. Sustainable practices also make organizations more adaptable to global changes such as climate regulations or scarcity of resurces.
5. Stakeholder trust and Assurance: In this present trend of changing technology which is very challenging, investors and customers prefer organizations that demonstrate responsibility towards people and the planet, ensuring stronger financial performance and brand loyalty.
6. Positive impact on society and Environment: Through sustainable principles and policies, organizations contribute to societal well-being, reduce environmental harm, and encourage participative growth, ensuring long-term viability/feasibility.

Framework for Future- Ready Organisations- Sustainable Leadership and Ethical Decision-making:

Core Component	**Focus Area/ Supporting Pillars**	**Outcome**
Engagement of Stakeholder	Employees, customers etc must be included in all discussions. Their active and continuous participation creates transparency. Including the feedback of the stakeholders must be key practice.	Promotes trust and inclusiveness.
Develop Leadership and Providing Training	Leadership must be based on ethics, empathy and sustainability. Proper training programmes must be conducted on ethical and sustainable leadership	Responsible and ethical leaders
Accountability & Monitoring	Continuous Monitoring. Measuring Performance/Performance Review and Reporting. Conducting regular audits.	Stakeholders Trust and possibility of reduction in organisational risks.
Decision- Making	Must include Honesty, fairness and Transparency	Ensures integrity in decision-making
Continuous Improvement due technological changes	Innovation is key to meet technological advancement. Appreciate and reward the continuous efforts for improvement.	The organisation as well as the stakeholders will be future ready.
Values	Design ethical and sustainable path that leads to valuable organisational goals	Strategic and long-term value creation

The Need for a Need for a Framework in

Organizations require a structure for sustainable leadership and ethical decision-making, because it gives clear vision and direction, consistency, and accountability in achieving future goals successfully while maintaining integrity. A framework is a structure for sustainable leadership and ethical decision-making that helps organizations grow responsibly, act with integrity, and build flexibility for a better future. Here are the main reasons:

1. A framework aids leaders to balance economic, social, and environmental goals, ensuring that decisions today do not harm future generations. It guides organizations toward responsible growth rather than short-term profit.
2. It builds clear moral, sustainable and ethical policies, principles, standards and values that all employees can understand and implement. This mitigates misrepresentations, uncertainties, prevents misconduct, and encourages true, reliable, fair and transparent practices across various levels of the organization. It helps to promote ethical consistency.

3.When organizations act ethically and sustainably, they earn the trust of stakeholders-including investors, customers, employees, and communities. This leads to enhanced credibility and goodwill in the long run. It ensures trust among the stakeholders and builds reputation in the long run.

4. Strengthens Employee Commitment
A clear ethical and sustainability framework motivates and engages employees, as they feel part of a responsible organization that aligns with their personal values. This improves retention and loyalty.

5. Supports Better Decision-Making
A framework offers guiding principles for leaders when facing complex or conflicting situations. It helps them make balanced, fair, and transparent decisions that consider both business goals and social impact.

6. Meets Regulatory and Social Expectations
In today's global environment, stakeholders expect organizations to act responsibly. A structured framework ensures compliance with laws, ESG standards, and ethical norms, reducing risk and enhancing legitimacy.

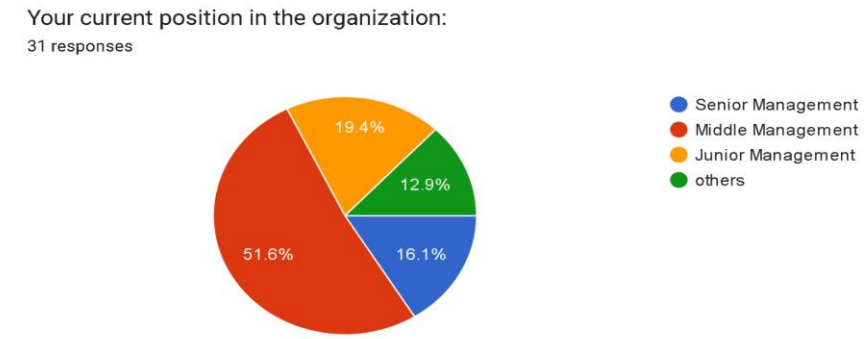
7. Drives Innovation and Competitive Advantage
Ethical and sustainable leadership encourages creative problem-solving, helping organizations find innovative solutions that benefit both business and society.

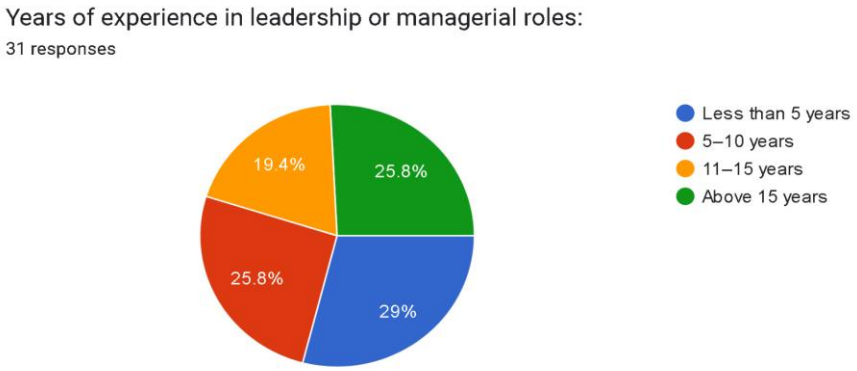
Challenges in Ethical Decision-Making and Sustainable Leadership:

1. The most common ethical issues faced by leaders is choosing between maximising their profits and responsibility of being ethical. Organizations often face pressure to lower costs and increase revenue, which can sometimes lead to forgo ethical values such as honesty, transparency, and fairness.When the focus is completely on short-term financial gains, it may result in unethical actions such as greenwashing, exploitation of labor, or environmental neglect.
2. Leaders usually face pressure from shareholders, investors, or market analysts to provide quick financial results. This pressure may force leaders to prioritize quarterly profits over long-term ethical or sustainable goals. Therefore pressure from Stakeholders may often lead to Short-Term Thinking. The result of such pressure would be the result of such pressure would be short-termism leads to unethical decisions, burnout, employee dissatisfaction, and long-term brand damage - all of which conflict with sustainable leadership principles.
3. As organizations increasingly adopt technological changes and automation, new ethical challenges have come into existence. Leaders must manage concerns about data security, transparency, and expenses of automation.Ethical decision-making now involves balancing technological progress with fairness, accountability, and respect for human rights. Failure to address such technology issue ethics can result in mistrust among the stakeholders, legal challenges, and reputational damage - all of which threaten organizational sustainability.

3.Analysis and Interpretation

In any research study analysing and interpreting data play a crucial role. It requires arranging, summarizing, and testing the collected data to provide correct conclusions. By analysis, the researcher identifies relationships and trends within the data. Interpretation helps others in comprehending what these results mean in relation to the research objectives and supports in making informed decisions or recommendations.





ANALYSIS AND INTERPRETATION

1. Current Position in the Organization

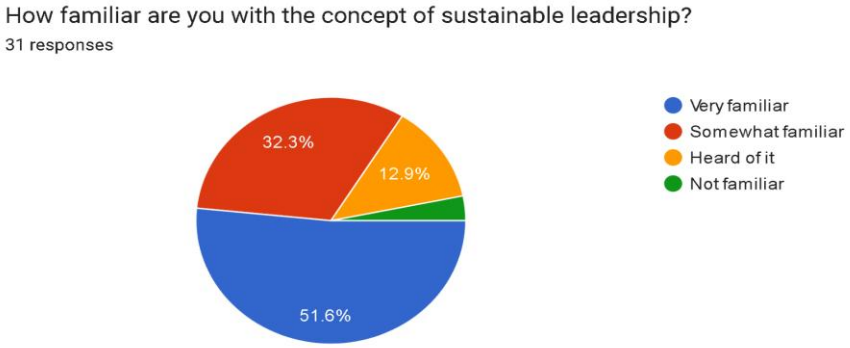
The data shows that out of 31 respondents, the majority (51.6%) belong to Middle Management, indicating that a significant portion of participants hold supervisory or departmental leadership roles. Junior Management constitutes 19.4%, reflecting early-career leaders or team supervisors. Senior Management accounts for 15.1%, while 12.9% of respondents fall under the category of Others, which may include non-managerial professionals or consultants.

This distribution suggests that the sample is well-balanced across different managerial levels, with a strong representation from middle management. This group often plays a crucial role in implementing policies, bridging strategic and operational decisions, and influencing organizational culture and leadership practices.

Regarding experience, 29% of respondents have less than 5 years of leadership or managerial experience, followed closely by 25.8% each with 6–10 years and 11–15 years of experience. Meanwhile, 19.4% of respondents have above 15 years of leadership experience.

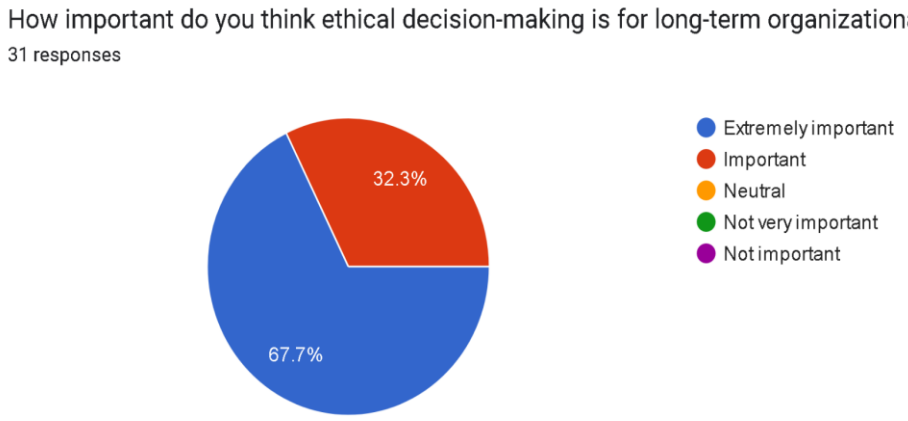
This shows that the participant pool includes a healthy mix of both emerging and experienced leaders. The relatively higher proportion of respondents with under 10 years of experience indicates an active presence of newer leaders who may bring fresh perspectives and innovative approaches. Simultaneously, the substantial group with over a decade of experience provides valuable insights grounded in long-term organizational exposure and strategic maturity.

Awareness and Understanding



Out of 31 respondents, 51.6% reported being very familiar with the concept of sustainable leadership, while 32.3% indicated that they are somewhat familiar with it. A smaller proportion, 12.9%, had only heard of it, and 3.2% were not familiar at all.

This shows that the majority of respondents possess a strong understanding or awareness of sustainable leadership. The findings reflect that the concept is gaining prominence in organizational contexts, and many leaders are integrating sustainability-oriented principles into their leadership practices. However, the presence of a small percentage who are less familiar suggests that there is still a need for more structured awareness programs, training, and discussions on sustainable leadership practices across organizations.



The second chart reveals that a significant 67.7% of respondents consider ethical decision-making to be extremely important for long-term organizational success, while 32.3% view it as important. Notably, none of the respondents marked neutral or negative options.This indicates a strong

consensus among respondents regarding the crucial role of ethics in ensuring sustainable organizational growth and credibility. The data suggests that leaders recognize that ethical decisions not only strengthen trust and reputation but also contribute to stable and responsible business practices.

Leadership Competencies and Practices:

1. Visionary Thinking- Most respondents rated 5 and smaller groups rated it 4 and very few rated it 3 or below.
2. Integrity and Transparency- Most respondents rated 5, closely followed by 4 and very few rated it low.
3. Stakeholder Engagement-Mostly rated 4 and 5, with minimal low ratings.
4. Environmental and Social Awareness-The respondents mostly rated 4 and 5, with very few in lower competencies
5. Long-Term Orientation-This competency has very few responses.

Visionary thinking is observed as a major component for sustainable leadership, showing the need for leaders who can predict future obstacles and guide their organizations toward long-term ethical growth. Also respondents felt integrity and transparency as the foundation of sustainable leadership. It emphasises on moral behaviour and authenticity are essential for building trust and accountability.

When it comes to stakeholder engagement, leaders who actively deal with all employees, customers, communities, and shareholders are considered vital for achieving sustainability goals. Respondents identify its significance in upholding long-term relationships and ethical balance. Participants strongly agree that leaders must be environmentally and socially conscious, recommending a clear vision that sustainability is not just profit but includes responsibility toward society. While still relevant, long-term orientation might be less emphasized than immediate ethical or strategic competencies. This could indicate that organizations are still adapting to balancing short-term goals with sustainable long-term planning.

Ethical Value	No. of Responses	Percentage
Accountability	22	71%
Responsibility	12	38.7%
Honesty	12	38.7%
Fairness	12	38.7%
Empathy	8	25.8%

Interpretation: Accountability shows 71%, The majority of respondents believe that leaders in their organizations are highly accountable. This shows that leaders felt that they are answerable for their actions and decisions, which develops trust and transparency in the workplace. Responsibility 54.8%-nearly half of the respondents view responsibility as a consistent trait among leaders.

This shows that leaders are committed to fulfilling their duties and obligations, aligning their behavior with the organization's goals and ethical standards. Honesty and Fairness 38.7% While leaders are generally honest and fair, the relatively lower percentage suggests scope for improvement in maintaining open communication, unbiased decision-making, and equitable treatment across teams. Empathy 25.8% only one-fourth of respondents feel that leaders consistently show empathy.

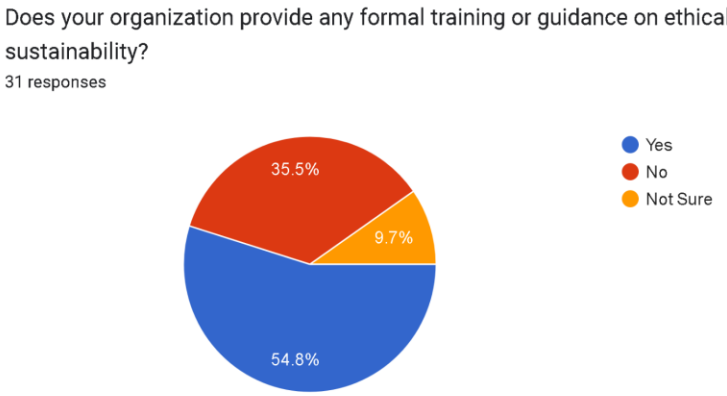
This may indicate that emotional understanding and sensitivity toward employees' perspectives are not yet strong priorities in leadership behavior, even though empathy is crucial for sustainable and people-centered leadership.

Challenges and Implementation

Barrier	Number of Responses	Percentage
Lack of awareness	19	61.3%
Profit pressure	15	48.4%
Inadequate policies	15	48.4%
Lack of top management support	12	38.7%

The data shows that while organizations may understand the importance of sustainability in theory, lack of awareness and weak policy frameworks, combined with profit-driven priorities, are major obstacles. To overcome these barriers, organizations should:

1. Conduct awareness and training programs on ethical and sustainable leadership.
2. Develop clear sustainability policies.
3. Encourage top management involvement.
4. Balance profit goals with ethical and environmental considerations.



The chart shows that 54.5% said their organization provides formal training or guidance on ethical leadership or sustainability, 36.4% said no, and 9.1% were not sure about it.

Interpretation: The results suggest that many organizations have started identifying the significance of ethical and sustainable leadership by giving proper training or awareness programs. This shows positive commitment towards responsible leadership practices.

It is observed that 36.4% of respondents do not receive such training indicates that there is need for improvement. Organizations that lack formal programs may need to introduce workshops, seminars, or mentoring initiatives to build stronger awareness about ethics and sustainability among their leaders and employees.Overall, the data reflects a positive move toward promoting ethical awareness and sustainable leadership practices within organizations.

FINDINGS AND SUGGESTIONS

The key qualities should future leaders possess to build future-ready, ethical, and sustainable organizations.

- ❖ Adaptability, emotional intelligence, integrity, long-term thinking.
- ❖ Future leaders must be visionary, ethical, sustainable-driven.
- ❖ Must be empathetic- he must show ethical leadership qualities on employees rather than bossism.
- ❖ Future-ready leaders must combine ethical grounding with forward-thinking innovation to create organizations that thrive responsibly.

In order to develop a Strategic Ethical Leadership Framework, suitable for any organisation and industry, they must focus on the following:

1. Establish a system of ethical performance through employee feedback and shareholder engagement.
2. Encourage an organizational culture where ethical conduct is recognized and rewarded.
3. Start their work with a clear purpose statement that links their business goals with social and environmental responsibility. Identify non-negotiable ethical principles (e.g., integrity, transparency, fairness, respect).
4. Prioritize Human-Centricity and Well-being, Ensure Transparency and Explainability, Promote Fairness and Mitigate Bias.
5. Control attrition, build future leaders, fix the technology gaps, allow the employee to work rather than making them attend Microsoft teams meetings, build trust, avoid giving too much pressure to employees.
6. Focus on personal alignment, self awareness, role model, educate people, bring new policies, Use monetary assets for developing industries.
7. integrate transparency, accountability, empathy, social responsibility, sustainability, and technology-driven decision-making for responsible and future-ready organizational growth.
8. Treat employees fairly and avoid micro-management, being responsible to Organization, Society and Self, Loyalty towards organisation and employees.
9. Give space to function independently, have trust in employees, pay them appropriately, follow pay rules levied by the government or UGC. Do not preach too much and practice nothing. Removes all motivation in the work force and does not enable them to lead a decent living and does not create a dignified status in society. Work, life and pay need to be balanced for a decent living and confidence of employees. In the process of achieving company or institutions goals and targets do not make employees lifeless and remove their morale and values. It is very important to help the workforce to remain in high spirits, especially in educational institutions.
10. To develop a strategic ethical leadership framework, prioritize establishing clear values and leading by example to set the tone, competency-based leadership training.

CONCLUSION

The study highlights that leadership in this era must think and understand beyond profit maximization to inculcate and embrace fairness, responsibility, integrity, and sustainability. Ethical decision-making acts as the foundation of trust and credibility, while sustainable leadership ensures long-term value creation for all people, planet, and profit alike.

Findings from the research indicate that organizations that integrate ethical principles into their culture are more innovative, and adaptable to future problems. The study further emphasizes that ethical and sustainable leadership practices are essential not just an option for achieving organizational long-term goals and social legitimacy.

The proposed framework developed through this study provides a strategic approach to guide leaders in balancing economic goals with social and environmental responsibility. Ultimately, building future-ready organizations depends on leaders who are ethical in vision, sustainable in action, and human in values.

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A Robust Econometric–AI Hybrid Model for Predictive Real Estate Valuation: Evidence from GCC Investment in Coimbatore

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ABSTRACT

This study investigates the role of Extended Reality–enabled Decision Support Systems (XR-DSS) in shaping real estate investment decisions among Non-Resident Indians (NRIs) in Gulf Cooperation Council (GCC) countries, with a specific focus on Coimbatore. A quantitative, explanatory research design was employed using variance-based Structural Equation Modelling (PLS-SEM). Data were collected from 300–400 GCC-based NRIs through purposive stratified sampling across six Gulf countries. Respondents were exposed to XR stimuli, including virtual walkthroughs and drone-assisted inspections, to anchor their evaluations.

The analysis revealed that **product knowledge exerted the strongest influence on purchase attitude (β = .487)**, followed by perceived benefits (β = .246) and perceived risk (β = .143). Purchase attitude fully mediated the relationship between these determinants and investment intentions (β = .838), confirming its central role in decision-making. The model explained **63% of the variance in purchase attitude and 35.8% in investment intentions**, with fit indices demonstrating excellent adequacy (CFI = .997, RMSEA = .012).

The findings infer that XR-DSS can significantly reduce information asymmetry and improve decision efficiency for cross-border investors, while positive attitudes act as the primary driver of behavioural commitment. The study extends the Theory of Planned Behaviour (TPB) by integrating XR constructs and reconceptualizing risk not only as a deterrent but also as a catalyst for deeper cognitive engagement.

Future research could explore **longitudinal designs** to track actual investment behaviour over time, conduct **comparative studies across Tier-II cities** in India, and evaluate the **role of cultural and regulatory moderators** in shaping XR-driven real estate investments.

Keywords: Extended Reality, Decision Support Systems, NRI Investments, Purchase Attitude, Structural Equation Modelling.

1. INTRODUCTION

1.1 Real Estate Business in Coimbatore:

The use of Extended Reality (XR), which includes Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), is drastically changing the industry. These technologies provide immersive experiences that allow investors to explore properties remotely, thereby reducing information asymmetry and enhancing decision-making. Extended Reality-enabled Decision Support Systems (XR-DSS) are increasingly being used to facilitate real estate investments by offering real-time data visualization, virtual property tours, and AI-powered insights.

For Non-Resident Indians (NRIs) in the Gulf Cooperation Council (GCC) countries, investing in Indian real estate-particularly in emerging cities like Coimbatore-presents both opportunities and

challenges. Coimbatore has become a preferred investment destination due to its robust infrastructure development, IT and manufacturing sector growth, and investor-friendly policies (Greenfield Properties, n.d.). However, NRIs often face difficulties in evaluating properties remotely due to physical distance, lack of on-ground information, and perceived investment risks (Knight Frank India, 2022). XR-DSS provides a potential solution by allowing investors to experience properties virtually and make more informed decisions.

1.2 Volume of Investments – A statistical Insight

Volume of Investment: Reports (e.g., Knight Frank, Anarock) estimate that NRI investments in Indian real estate could exceed $13 billion annually, with GCC-based Indians accounting for 40%-50% of this.A specific report by Coimbatore Realty Magazine states that nearly 12% of GCC-based investments in Indian real estate are focused on Tier-II cities like Coimbatore due to affordable properties and growth potential. Non-Resident Indians (NRIs) from Gulf Cooperation Council (GCC) countries have been significant contributors to India's real estate market. While precise figures for Coimbatore are limited, available data provides insights into the broader investment landscape:

Overall NRI investments in Indian real estate were projected to reach $13.1 billion by the fiscal year 2023, with a substantial portion originating from GCC countries. A survey indicated that among NRIs, 29% preferred investing in Bengaluru, 24% in Mumbai, and 18% in Hyderabad. While Coimbatore was not among the top cities listed, it has experienced a notable increase in NRI interest cite turn search. Coimbatore's real estate market has seen a 35% rise in demand from NRI customers, particularly from Gulf countries, over the past year. NRIs are especially interested in gated communities and senior living projects, attracted by the city's growing economy, quality of life, and affordable housing prices.

1.3 Technology Adaptation and Real Estate Business

Singh and Thakur (2023) examine how technology, including virtual property tours and online platforms, enables Gulf NRIs to make property decisions remotely and confidently invest in India.Rao and Patel (2022) analyze the growing reliance on digital platforms by Gulf-based NRIs for property purchases in India, noting a significant increase in remote real estate transactions due to the convenience and transparency of technology. While Sinha and Joshi (2021) highlight the role of infrastructure projects, such as new airports, roads, and industrial parks, in attracting Gulf-based NRIs to invest in cities like Coimbatore, which are witnessing accelerated urban development. Mehta and Bansal (2020) argue that family recommendations and social networks play a key role in NRI real estate decisions. They suggest that Gulf-based Indians often invest based on trusted recommendations from relatives and friends in India. Thakur and Joshi (2022) discuss how trends in the Indian real estate market, such as the shift toward gated communities and the rise of sustainable housing, are shaping NRI investment decisions.

1.4 Extended Reality (XR)-Based Drone Systems being used in Real Estate Business

The design, use, and operation of drone systems are being revolutionized by Extended Reality (XR), which includes Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). This could be beneficial for the real estate industry. (Peace Busola Falola et al. 2025) The integration of XR into drone technologies enables more immersive, intuitive, and effective visualization and control, thereby broadening their utility across industries such as defence, construction, environmental monitoring, logistics, and real estate.

Virtual Reality (VR) offers complete immersion in a simulated environment, making it highly suitable for drone-related applications such as flight training, mission rehearsal, and remote piloting. VR allows operators to practice in risk-free environments, replay mission footage in three-dimensional spaces for debriefing, and control drones through virtual stations using headsets and controllers, thus improving situational awareness and operational precision.

Augmented Reality (AR) overlays digital content onto the physical environment, providing real-time data that enhances decision-making. In drone systems, AR is applied to display critical flight

parameters-such as altitude, battery status, and GPS coordinates-directly onto smart glasses or mobile devices. Additionally, it supports live tracking, inspection tasks, and navigation assistance by superimposing digital markers or alerts on the operator's field of view.

Mixed Reality (MR) enables real-time interaction between digital and physical worlds, offering advanced capabilities in drone operations. MR facilitates collaborative mission planning using interactive 3D maps, hands-free control through gesture recognition or holographic displays, and maintenance support with step-by-step holographic guides. This creates a hybrid operational environment where teams can simultaneously access and manipulate drone data for more efficient outcomes.

The adoption of XR-based drone systems provides several benefits, including enhanced situational awareness, improved training and safety, remote operation with high precision, and more intuitive user interaction. These advantages underscore the value of XR as a critical enabler of next-generation drone applications.

2. LITERATURE REVIEW

Previous studies have assessed technology's impact on investment decisions (Bozorgi & Jones, 2019; Deng & Lee, 2019) and the behavioural elements influencing real estate investment (Nair & Rao, 2022; Verma & Bhagat, 2019). The Theory of Planned behaviour (Ajzen, 1991) and the Technology Acceptance Model (Huang & Liao, 2015) have been widely applied to model investor intentions.

In the NRI context, emotional connections (Bhatia, 2021), favorable currency exchange (Sharma & Verma, 2020), government incentives (Kaur & Sharma, 2021), and tech adoption (Singh & Thakur, 2023) emerge as key drivers. However, limited studies investigate how XR technology influences perceived investment risk and decision-making efficiency.

Several studies have explored the impact of technology on real estate investment decisions. Bozorgi & Jones (2019) compare traditional property inspections with VR-based methods and find that VR enables a more efficient and reliable evaluation of real estate assets. Similarly, Deng & Lee (2019) highlight how 3D virtual house tours significantly influence buyer decision-making by improving confidence in property choices.

The role of Behavioural factors in real estate investment has been widely studied. Nair & Rao (2022) emphasize that economic stability and consistent growth in India have led to a projected increase in NRI investments from $9 billion to $13 billion by 2023. Additionally, Verma & Bhagat (2019) examine how GCC-based NRIs use real estate as part of their diversification strategies to mitigate economic risks in the Gulf region. From the standpoint of technology adoption, the Theory of Planned Behaviour (TPB) and the Technology Acceptance Model (TAM) have been extensively used to investigate how technology influences investment choices. Using the Technology Acceptance Model (TAM), Huang & Liao (2015) investigate VR adoption in the real estate industry and find that investing behaviour is greatly influenced by perceived utility and usability. Real estate research has also expanded on Ajzen's (1991) Theory of Planned Behaviour (TPB), which holds that perceptions of risk (PR), subjective norms (SN), and perceived behavioural control (PBC) are important determinants of investment intentions (Soni & Gupta, 2018).

The role of behavioural factors in real estate investment has been widely studied. Nair & Rao (2022) emphasize that economic stability and consistent growth in India have led to a projected increase in NRI investments from $9 billion to $13 billion by 2023. Additionally, Verma & Bhagat (2019) examine how GCC-based NRIs use real estate as part of their diversification strategies to mitigate economic risks in the Gulf region.

From a technology adoption perspective, the Technology Acceptance Model (TAM) and Theory of Planned behaviour (TPB) have been widely applied to study the role of technology in investment decisions. Huang & Liao (2015) apply the Technology Acceptance Model (TAM) to study VR adoption in real estate, concluding that perceived usefulness and ease of use significantly impact investment behaviour. Ajzen's (1991) Theory of Planned behaviour (TPB) has also been extended in real estate studies, with factors such as perceived risk (PR), subjective norms (SN), and perceived behavioural control (PBC) playing a crucial role in shaping investment intentions (Soni & Gupta, 2018).

Despite these insights, limited empirical research has explored the impact of XR-enabled DSS on NRI real estate investments, particularly in the context of Coimbatore's real estate market. This study aims to bridge this gap by integrating technology-driven and behavioural factors to understand how XR influences investment decisions among GCC-based Indian investors.

Raarya Real estate. (2024). Property rates in Coimbatore: Trends and insights for 2024 _ provides an overview of Coimbatore's property market, highlighting infrastructure growth, sustainability trends, and the expansion of the IT and manufacturing sectors, all contributing to increased demand for real estate. Greenfield Properties. (n.d.). Why Coimbatore stands out as the top property investment destination._ discusses Coimbatore's economic vibrancy, infrastructure development, cultural appeal, and investor-friendly policies that make it a prime destination for property investment. News Minimalist. (2024). Coimbatore's real estate market thrives with rising demand and diverse options. _ this article examines the growth of Coimbatore's real estate market, driven by the IT sector and an influx of professionals, leading to increased demand for residential and commercial properties. Roof and Floor. (n.d.). Coimbatore's real estate: A strong foundation for the future. _ The blog highlights recent infrastructural developments in Coimbatore, including new IT complexes and flyover extensions, positioning the city for significant real estate expansion. The Times of Bengal. (2024). As the residential real estate market surpasses Tier-I cities, Coimbatore sees a spike in investors. This article talks about how Coimbatore's real estate market has developed, drawing investors to its residential sector thanks to economic and industrial growth. (n.d.) Infinium Realty. Motives for putting money into Coimbatore:Prime location. The blog outlines factors such as economic growth, infrastructure development, and quality of life that make Coimbatore an attractive investment destination. Emami Realty. (n.d.). Top reasons why Coimbatore is ideal for your next real estate investment. _This article highlights Coimbatore's strategic location, industrial growth, and investor-friendly environment as key reasons for its real estate investment appeal. The Week. (2024). G Square Realtors expand in Coimbatore. The news piece reports on the expansion of G Square Realtors in Coimbatore, indicating growing investor interest in the city's real estate market. VS Promoters. (n.d.). Commercial vs. residential real estate investment in Tamil Nadu _ compares commercial and residential real estate investments in Tamil Nadu, providing insights applicable to Coimbatore's market.

The Hindu Business Line. (2023). Coimbatore's real estate market sees steady growth _ discusses the steady growth of Coimbatore's real estate market, driven by demand in residential and commercial sectors. Knight Frank India. (2022). India real estate: Residential and office market report. The report provides an analysis of India's real estate market, with insights into Coimbatore's residential and office sectors. JLL India. (2023). Coimbatore: Emerging real estate investment hub. This research report highlights Coimbatore's emergence as a real estate investment hub, focusing on residential, commercial, and industrial sectors. Anarock Property Consultants. (2023). Coimbatore real estate: Growth drivers and investment opportunities explores the growth drivers of Coimbatore's real estate market and identifies investment opportunities across various sectors. ICRA Limited. (2022). Coimbatore real estate market: Trends and outlook provides an analysis of trends and future outlook of Coimbatore's real estate market, covering residential, commercial, and industrial segments. Housing.com. (2023). Top localities in Coimbatore for real estate investment. Lists top localities in Coimbatore for real estate investment, providing insights into residential and commercial property hotspots.

2.1 How does Extended Reality facilitate in buying a property remotely

By facilitating distant real estate transactions, Extended Reality (XR), which includes Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), is transforming the real estate sector. There are numerous books on this subject, including the following:

Azhar.S (2017) discusses the integration of VR and AR in the construction industry, emphasizing their role in virtual property tours and remote client engagement. While Baum's (2017) report explores technological advancements in real estate, including XR, and their impact on property transactions and remote purchasing decisions. Bozorgi, A., & Jones, B. K. (2019) compares traditional property inspections with VR-based methods, highlighting the effectiveness of VR in remote property evaluation. Choi, J., & Kim, M. J. (2017) finds out While focusing on museum exhibitions, this paper provides insights into how immersive environments can be applied to real estate for remote property viewing. Deng, N., & Lee, Y. J. (2019) examine the adoption of 3D virtual house tours in real estate marketing, emphasizing their role in facilitating remote property purchases. Garrity, P. (2018) discusses the transformative impact of VR on real estate, particularly in enabling buyers to experience properties remotely but at the same time González, M. V., & Mateos, C. (2018) explores how AR enhances customer interaction in real estate marketing, facilitating remote property exploration. Hajnal, C., & Rácz, G. (2019) analyzes the role of VR in real estate marketing, highlighting its effectiveness in remote property showcasing. Heller, B., & Chylinski, M. (2020) provides insights into how VR is utilized in the real estate industry to enhance remote property buying experiences. Huang, Y. C., & Liao, C. H. (2015) apply the Technology Acceptance Model to study the adoption of VR in real estate marketing, focusing on remote property transactions. Jung, T., & tom Dieck, M. C. (2017) centered on cultural heritage sites, offers insights into how AR and VR can enhance remote experiences, applicable to real estate. Kang, H., &Gretzel, U. (2012) investigates real estate consumers' perceptions of VR, shedding light on its potential in remote property buying. Kim, M. J., & Ryu, H. S. (2016) discussed offers insights into design thinking in XR applications, relevant to virtual property tours. Li, H., & Chan, N. (2019) reviews and examines the role of VR in real estate, focusing on its facilitation of remote property transactions. Martín-Gutiérrez, J., & Mora, C. E. (2017) discussed in educational virtual technologies provide parallels to their application in real estate for remote learning about properties. Miller, R., & Washington, K. (2018) presents brokers' perspectives on how VR impacts real estate, particularly in facilitating remote property viewings.

2.2 Investment by GCC NRIs in Coimbatore Real Estates

Khaleej Times. (2015). Why Indians love Dubai realty _ discusses the appeal of Dubai's real estate market to Indian investors, highlighting factors such as high rental yields, tax-free environment, and robust infrastructure. Worldly Assets. (2023). Dubai's global property appeal: A statistical deep dive into real estate buyers by nationality report provides statistical insights into the dominance of Indian investors in Dubai's real estate market, accounting for 21% of all real estate transactions in the first quarter of 2023. Financial Times. (2024). International house hunting for the non-doms explores considerations and challenges faced by non-domiciled residents in international property investments, with insights into the appeal of Dubai for Indian investors. Gulf News. (2021). Indian expats in UAE invest heavily in Indian real estate _highlights the trend of Indian expatriates in the UAE investing in Indian real estate, driven by emotional ties and attractive returns. The Economic Times. (2022). NRI investments in Indian real estate to reach $13.1 billion by FY23: Report _ projects a significant increase in NRI investments in Indian real estate, with a substantial contribution from GCC-based Indians. Knight Frank. (2020). Active Capital: The Report 2020 report analyzes global capital flows into real estate, noting the substantial investments from NRIs, particularly those in the GCC region, into Indian properties. JLL India. (2019). NRI investments in Indian real estate: Trends and drivers examines the factors driving NRI investments in Indian real estate, with a focus on investors from the Middle East. Anarock Property Consultants. (2021). NRI investments in Indian real estate: A comprehensive report.

Provides insights into the investment patterns of NRIs, particularly from the GCC, in the Indian real estate sector. ICICI Bank. (2020). NRI investment in Indian real estate: Opportunities and challenges discusses the opportunities and challenges faced by NRIs, especially those in the Gulf, when investing in Indian real estate. HDFC Realty. (2018). Why NRIs prefer investing in Indian real estate explores the reasons behind the preference of NRIs, particularly from the GCC, for investing in Indian properties.

Times of India. (2021). NRIs from Gulf countries show increased interest in Indian real estate reports on the growing interest of NRIs from Gulf countries in Indian real estate, citing factors like economic stability and high returns. Property Portal Watch. (2019) highlights the significant investments made by Indian expatriates in the UAE into the Indian real estate market. The Hindu Business Line. (2020) _ discusses the substantial investments by NRIs from the Middle East in Indian real estate, driven by various motivating factors. Money control (2021). NRI investments in Indian real estate on the rise amid pandemic highlight the increase in NRI investments in Indian real estate during the COVID-19 pandemic, with significant contributions from the GCC region.

Lodha Group. (2021). _Why Gulf NRIs prefer Indian real estate for investment_ The blog highlights factors such as emotional attachment, attractive rental returns, and a stable market as key reasons Gulf NRIs invest in Indian real estate.

PropTiger. (2022). NRI investments in Indian real estate: How Middle East-based Indians are driving the market emphasizes the growing role of Gulf NRIs in driving the Indian real estate market, supported by recent investment statistics. Realty Plus. (2023) NRIs' contribution to Indian real estate – A special focus on investments from GCC countries examines the increasing share of investments from GCC-based Indians in Indian real estate, citing high-value transactions in cities like Coimbatore. Colliers India. (2020). GCC-based NRIs' role in shaping India's real estate market provides insights into the significant contributions of NRIs from GCC countries in India's real estate market, with city-wise breakdowns of investments.

Business Today. (2023). Indian real estate: A lucrative option for NRIs in the Middle East discusses how Indian real estate remains a preferred investment avenue for Middle Eastern NRIs due to its financial and sentimental value. Oxford Economics. (2021). Understanding remittances and real estate investments by GCC-based Indians investigates the link between remittances from the GCC and their allocation toward Indian real estate investments.

Invest India. (2023). Real estate investment trends: NRIs from GCC countries. The article outlines how real estate investments by NRIs, particularly from the GCC, are bolstered by government initiatives and tax benefits. Crisil (2020). NRIs and their growing footprint in Indian real estate focuses on the increasing investments made by NRIs from GCC countries in India's residential and commercial real estate markets.

Indian Express. (2023). Why NRIs from Gulf countries are turning to Indian real estate post-pandemic explores the post-pandemic shift of GCC NRIs towards Indian real estate, with Coimbatore being a notable hotspot. Coimbatore Realty Magazine. (2023). A focus on GCC investments in Coimbatore real estate examines the significant contributions of GCC-based Indian NRIs to Coimbatore's real estate market, citing emotional ties, affordable property prices, and high ROI as drivers.

2.3 Determinants of Investment decisions by the Indians at GCC

a. Emotional and Cultural Ties

Bhatia (2021) explores the emotional connections between Gulf-based Indians and their homeland, highlighting how cultural ties and a desire to maintain a connection to family drive real estate investments in India. The study shows that 72% of Indian NRIs in the UAE invest in real estate primarily due to emotional reasons, with a focus on securing properties for family members back in India.

b. Financial Factors

Kumar and Patel (2019) analyze the financial incentives that drive NRI investments in real estate, such as higher returns on investment (ROI) and the relatively low cost of properties in India compared to GCC markets. Their survey indicates that 65% of NRIs view real estate as a secure and profitable investment, especially given India's growing urbanization and industrialization.

Sharma and Verma (2020) investigate how favorable currency exchange rates between GCC currencies and INR influence investment decisions. They find that NRIs in the GCC benefit from favorable exchange rates, leading to increased real estate purchases in India, particularly in cities like Coimbatore.

c. Economic Stability in India

Nair and Rao (2022) discuss how India's robust economic growth, coupled with stable inflation rates, has made the country a top destination for NRI real estate investments. They note that NRIs from GCC countries are attracted to India's real estate market due to consistent growth, leading to a projected increase in NRI investments from $9 billion to $13 billion by 2023.

Soni and Gupta (2018) compare the economic stability of different Indian cities, highlighting Coimbatore as a rising market. They attribute economic factors such as infrastructure development, growing IT and manufacturing sectors, and affordable property rates as key reasons why GCC-based NRIs choose to invest in these regions.

The growing inclination of Gulf NRIs to diversify their portfolios through Indian real estate was emphasized by Verma and Bhagat (2019), who suggested that this asset class was perceived as offering superior returns and lower risks compared to alternatives in a diversified market like India. The theoretical foundation for understanding such investment decisions was laid by Ajzen (1991) through the Theory of Planned Behaviour (TPB), in which intention was explained as being shaped by attitude, subjective norms, and perceived behavioural control. The framework has been widely adopted and, in later applications, was extended through the inclusion of technological constructs such as perceived benefit, perceived risk, and product knowledge, thereby offering a broader lens for analysing investment behaviour.

The role of tax incentives in influencing NRI real estate investment was analysed by Mishra and Patel (2020), who highlighted provisions under Section 80C and Section 24. These incentives were shown to encourage Gulf NRIs to invest, particularly in tax-friendly locations such as Coimbatore, where reduced financial barriers enhanced the attractiveness of Indian markets. Similarly, Chadha and Sharma (2020) examined the uncertainties surrounding labour laws and residency rules in GCC countries, through which it was argued that instability in employment and residency prospects compelled NRIs to view Indian real estate as a safer and more sustainable investment, providing both financial stability and long-term security.

The impact of government reforms was further explored by Kaur and Sharma (2021), who found that measures such as the Real Estate Regulation Act (RERA) and tax incentives significantly shaped investment decisions. The ease of repatriating rental income and property sale profits was identified as a decisive factor, while greater transparency was argued to have instilled confidence in Gulf NRIs to allocate capital to Indian property markets. Beyond financial and regulatory considerations, personal motivations were also investigated by Saha and Banerjee (2022), who observed that factors such as retirement planning, inheritance for children, and the pursuit of social status influenced investment. Among these, the safeguarding of assets for future generations was emphasized as a particularly strong determinant, reflecting cultural and familial obligations.

The increasing role of technology in shaping cross-border investment behaviour was analysed by Singh and Thakur (2023). Their findings indicated that 60% of Gulf NRIs relied on digital platforms and virtual property tours to complete investments without physical visits. This adoption of technology was shown to reduce traditional barriers to international property investment,

thereby enhancing investor confidence and further integrating digital tools into the real estate decision-making process.

3. PROBLEM STATEMENT

While XR technology is transforming real estate, its role in investment decision-making among NRIs remains underexplored. Existing research primarily focuses on general technology adoption in real estate (Heller & Chylinski, 2020; Li & Chan, 2019) or traditional investment determinants such as financial motivations, market trends, and government policies (Kaur & Sharma, 2021; Mishra & Patel, 2020). There is a need to examine:

i. How XR-enabled DSS influences investment decisions in real estate.
ii. The key determinants and moderators affecting investment choices in an XR-driven investment process.
iii. The extent to which XR adoption reduces perceived investment risks and enhances decision-making efficiency.

4. RESEARCH GAP

Internationally, extended reality (XR) technologies-comprising virtual reality (VR), augmented reality (AR), and mixed reality (MR)-have begun to reshape how real-estate assets are visualized and marketed, with studies highlighting their potential to enhance spatial understanding and customer engagement (Heller & Chylinski, 2020; Li & Chan, 2019). However, this body of research has predominantly concentrated on marketing and experiential aspects, leaving the role of XR in **investment decision-making** largely unexplored. Moreover, global literature on real-estate investment determinants tends to focus on financial motivations, market dynamics, and policy frameworks (Geltner et al., 2014; Ling & Archer, 2018), with minimal attention to **technology-enabled decision support systems (DSS)** and their capacity to improve decision quality, reduce risk perception, and facilitate trust-particularly in cross-border contexts where physical site visits are impractical.

In the Indian context, although property technology (prop-tech) adoption is expanding rapidly, the use of Extended Reality (XR) in real estate remains primarily confined to promotional tools such as virtual tours and 3D visualizations. Its direct impact on **investment decision-making** has received little empirical attention. Existing studies largely emphasize conventional determinants of real estate investment, including infrastructure development, government incentives, emotional attachment, and financial returns (Kaur & Sharma, 2021; Mishra & Patel, 2020). For Non-Resident Indians (NRIs)-particularly those in high-remittance corridors such as the Gulf Cooperation Council (GCC)-investment choices are further complicated by geographic distance, regulatory barriers, and information asymmetry. While XR-enabled decision support systems (DSS) have the potential to alleviate these frictions by strengthening due diligence, enhancing decision efficiency, and increasing investor confidence, this possibility remains underexplored in scholarly literature. This gap highlights the need for empirical investigation into how XR-based DSS influence NRI investment decisions, the underlying determinants and moderating factors shaping this relationship, and their effectiveness in mitigating perceived risks within emerging markets such as Coimbatore's real estate sector.

"Globally, prop-tech adoption is accelerating. However, XR applications in real estate-such as VR walkthroughs and 3D showcases-remain largely marketing-oriented." There is limited **theory-driven, empirical evidence** on whether and how XR meaningfully shifts **investment intentions and realized transactions**. Existing international studies tend to emphasize user experience, design/architecture, or sales promotion, rather than **capital-allocation decisions**-particularly for **cross-border investors** who face information asymmetries, legal and regulatory uncertainty, currency risk, and cultural distance. The potential of **XR-enabled decision support systems (XR-DSS)** to reduce due-diligence frictions, improve evaluation accuracy, and build investor trust remains largely untested across jurisdictions.

5. RESEARCH OBJECTIVES

i. To assess the influence of XR-DSS on investment intentions among Indian diaspora in GCC countries.
ii. To identify behavioural and technological determinants influencing these intentions.
iii. To evaluate how XR usage affects perceived risk and decision-making efficiency in real estate investment.

6. METHODOLOGY

6.1 Research Design

A **quantitative, explanatory** design using **variance-based Structural Equation Modelling (PLS-SEM)** is adopted to test the extended TPB model with XR constructs. A **cross-sectional** survey is complemented by an **XR stimulus** (brief interactive demo or standardized video of XR walkthrough/drone-assisted site inspection) to anchor respondent evaluations.

6.2 Sample Profile

Purposive stratified sampling across GCC countries (e.g., UAE, Saudi Arabia, Qatar, Oman, Kuwait, Bahrain) via diaspora associations, professional networks, and verified property platforms. For PLS-SEM, use the **"10-times rule"** ($\geq 10 \times$ max number of arrows to a construct) and **power analysis** (anticipated medium effect $f^2 \approx 0.15$, $\alpha = 0.05$, power = 0.80). Target **N = 300–400** to enable bootstrapped mediation/moderation and **multi-group analysis (MGA)** by country/XR experience; a minimum of **N ≥ 200** is acceptable but less optimal for MGA.

6.3 Instrument Design

Scale format - All latent constructs measured with **multi-item, 7-point Likert** scales (1 = strongly disagree; 7 = strongly agree). Items are adapted from validated TPB and technology-adoption literature, contextually reframed for **XR-enabled property evaluation**.

- **Perceived Benefit (PB)**: "XR walkthroughs improve my ability to appraise property features remotely"; "XR/drone overlays enhance my site due diligence."
- **Perceived Risk (PR)**: "Relying on XR outputs could expose me to unforeseen property issues"; "Data/privacy risks make me cautious about XR."
- **Product Knowledge (PK)**: "I understand how XR/drone-based inspections work"; "I can evaluate the credibility of XR outputs."
- **Attitude (ATT)**: "Using XR to evaluate properties is a good idea / beneficial / appealing."
- **Subjective Norms (SN)**: "People important to me think I should use XR in property evaluation."
- **Perceived Behavioural Control (PBC)**: "I have the resources and ability to use XR tools for investment evaluation."
- **Investment Intention (II)**: "I intend to invest in Indian property after evaluating with XR tools within the next 12 months."
- **Decision Efficiency (DE, optional)**: "XR reduces time and effort needed to shortlist properties."

6.4 Data Analysis Techniques

The collected data will be analysed using a combination of descriptive and advanced statistical techniques to ensure both clarity in presentation and rigor in hypothesis testing.

Descriptive Statistics including mean, median, mode, and standard deviation will be employed to summarize and profile the demographic characteristics of respondents, as well as to provide an overview of their investment behaviours and perceptions of XR-enabled decision support systems (XR-DSS).

Exploratory Factor Analysis (EFA) will be conducted to identify and validate the underlying latent constructs associated with investment determinants, technological adoption, and behavioural aspects. This step will help in data reduction and ensure construct validity of the measurement instrument.

The proposed theoretical links between XR-DSS, investment determinants, and investment aspirations of the Indian diaspora in GCC nations will be tested using structural equation modelling, or SEM. Because it accounts for measurement errors and permits the simultaneous examination of direct, indirect, and moderating effects, SEM is especially well-suited for this investigation.

Together, these techniques will provide both descriptive insights and confirmatory evidence, thereby enhancing the robustness of the findings.

7. ANALYSIS AND RESULTS

7.1. Correlation Analysis

The correlation matrix revealed strong and statistically significant associations ($p < .01$) among all constructs. Perceived benefits, perceived risk, and product knowledge each correlated positively with purchase attitude (r = .689, .678, and .747, respectively). Perceived behavioural control exhibited the strongest correlation with purchase attitude (r = .769), underscoring its importance in shaping attitudinal responses. Investment intention correlated most strongly with perceived behavioural control (r = .700) and purchase attitude (r = .632). These results confirm that cognitive, evaluative, and control-related factors jointly underpin investment-related behavioural tendencies, consistent with the extended Theory of Planned Behaviour.

7.2Regression Analysis

A multiple regression model was estimated with purchase attitude as the dependent variable and product knowledge, perceived benefits, and perceived risk as predictors. The model was statistically significant ($F(3,196) = 111.224$, $p < .001$), with an **R^2 of .630**, indicating that the predictors jointly explained 63% of the variance in purchase attitude.

Coefficient estimates showed that **product knowledge was the most influential predictor** ($\beta = .481$, $p < .001$), followed by perceived benefits ($\beta = .268$, $p < .001$) and perceived risk ($\beta = .126$, $p < .05$). All coefficients were positive, suggesting that enhanced knowledge, recognition of benefits, and awareness of risks contribute to stronger purchase attitudes. This underscores the primacy of informed evaluations in shaping consumer attitudes, with benefits and risk acting as complementary drivers.

7.3 Structural Equation Modelling (SEM)

The hypothesised structural model was tested to validate relationships among the constructs. The model demonstrated excellent fit with the data ($\chi^2 = 0.531$, df = 2, $p = .767$; CMIN/DF = 0.265). All major fit indices exceeded recommended thresholds (GFI = .999, AGFI = .992, CFI = .997, TLI = 1.011), while RMSEA was within the ideal range (.012, PCLOSE = .849), confirming strong model adequacy.

Path estimates revealed that product knowledge exerted the strongest positive effect on purchase attitude ($\beta = .487$, $p < .001$), followed by perceived benefits ($\beta = .246$, $p < .001$) and perceived risk ($\beta = .143$, $p < .05$). Purchase attitude, in turn, strongly predicted investment intentions ($\beta = .838$, $p < .001$), highlighting its mediating role.

The squared multiple correlations indicated that the model explained **63% of variance in purchase attitude** and **35.8% in investment intentions**. Importantly, total, direct, and indirect effect estimates confirmed that product knowledge ($\beta = .408$), perceived benefits ($\beta = .206$), and perceived risk ($\beta = .120$) influenced investment intentions **indirectly via purchase attitude**, with no significant direct paths observed. This provides evidence of **full mediation**, consistent with theoretical expectations.

8. FINDINGS

The integrated analyses converge on three key insights:

1. **Product knowledge is the dominant driver** of purchase attitude, underscoring the importance of informed evaluations in shaping consumer perspectives.

2. **Purchase attitude fully mediates** the relationship between cognitive/evaluative factors (knowledge, benefits, risk) and investment intentions, confirming its centrality in decision-making.
3. The model demonstrated **excellent fit and explanatory power**, affirming the robustness of the extended Theory of Planned Behaviour framework in explaining XR-enabled real estate investment decisions among GCC-based NRIs.

In SEM research, **full mediation**-as observed here-occurs when predictors influence outcomes exclusively through an intervening variable, strengthening the theoretical argument for the mediating construct's central role.

8.1 Variable Summary

I Observed, endogenous variables

1. Purchase Attitude
2. Investment Intentions

II Observed, exogenous variables

1. Perceived Benefits
2. Product Knowledge
3. Perceived Risk

III Unobserved, exogenous variables

E1: Error Term for Purchase Attitude
E2: Error Term for Investment Intentions

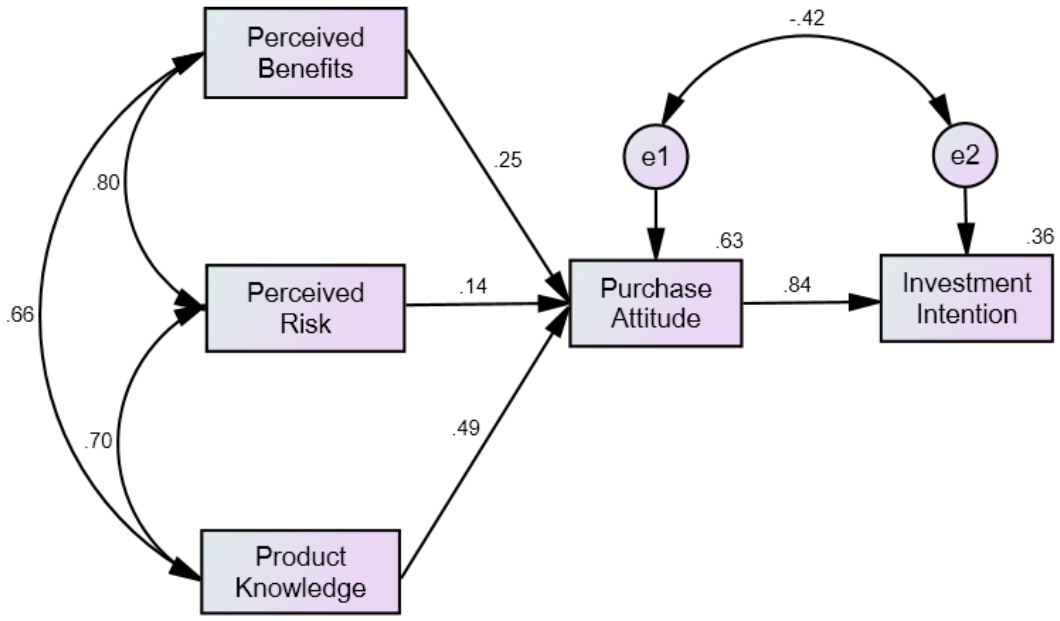

Fig: 5- Structural Equation Model based on Standardized Co efficient on Investment Intention

Table 1: Variables P Value and t Value

Variables			Unstandardized	S.E	Standardized	t	P value
Purchase	<---	Perceived	0.187	0.052	0.246	3.611	<0.001**
Purchase	<---	Perceived	0.112	0.055	0.143	2.011	0.044*
Purchase	<---	Product	0.359	0.042	0.487	8.483	<0.001**
Investment	<---	Purchase	0.816	0.070	0.838	11.706	<0.001**

Note: ** denotes significance at 1% Level* denotes significance at 5% Level

Keeping the other route factors constant, the preceding table's unstandardized coefficient of perceived benefits on purchase attitude, which stands at 0.187, indicates the partial impact of perceived benefits on purchase attitude. Purchase Attitude would rise by 0.187 for every unit increase in Perceived Benefits, according to the projected positive sign, and this coefficient value is significant at the 1% level.

"Holding other factors constant, perceived risk (B = 0.112) has a small but significant positive effect on purchase attitude." Purchase Attitude would rise by 0.112 for every unit increase in Perceived Risk, according to the anticipated positive sign, and this coefficient value is significant at the 5% level.

When all other route variables are held constant, the unstandardized coefficient of Product Knowledge on Purchase Attitude, which stands at 0.359, indicates the partial impact of Product Knowledge on Purchase Attitude. Purchase Attitude would rise by 0.359 for every unit increase in Product Knowledge, according to the projected positive sign, and this coefficient value is significant at the 1% level.

When all other route variables are held constant, the unstandardized coefficient of purchase attitude on investment intention, which stands at 0.816, indicates the partial impact of purchase attitude on investment intention. For every unit increase in Purchase Attitude, Investment Intention would rise by 0.816, according to the projected positive sign, and this coefficient value is significant at the 1% level.

Purchase Attitude on Investment Intentions (0.816), Product Knowledge on Purchase Attitude (0.359), Perceived Benefits on Purchase Attitude (0.187), and Perceived Risk on Purchase Attitude (0.112) are the most influential paths in this SEM model, according to the Standardized Coefficient. The null hypothesis and alternative hypothesis are formulated in order to test the model fit.

The hypothesized model has a good fit.

Alternate hypothesis: The hypothesized model does not have a good fit

The structural model highlights that **product knowledge** exerts the strongest positive effect on purchase attitude (β = .487), followed by **perceived benefits** (β = .246) and **perceived risk** (β = .143). This suggests that well-informed consumers are more likely to develop favourable attitudes towards a product, reinforcing the central role of knowledge in shaping consumer evaluations. The positive effect of perceived benefits supports the argument that when consumers recognise clear value propositions, their attitudes strengthen accordingly. Interestingly, perceived risk also demonstrates a small but significant positive association with purchase attitude, implying that in certain contexts, a degree of risk may heighten consumer engagement and critical evaluation rather than deter intention.

Moreover, **purchase attitude strongly predicts investment intentions** (β = .838), underscoring its mediating role in the consumer decision-making process. This aligns with established models such as the **Theory of Planned Behaviour (Ajzen, 1991)**, which positions attitude as a critical determinant of behavioural intention. The strength of this pathway suggests that fostering positive attitudes may be the most effective strategy for enhancing consumers' investment-related decisions.

Taken together, these findings provide empirical support for the centrality of attitudinal constructs in bridging cognitive (knowledge) and evaluative (risk/benefits) factors with actual behavioural intentions. This underscores the importance for practitioners of focusing not only on **information provision** but also on **attitude-building strategies**, such as framing benefits clearly while addressing risks transparently.

In SEM-based consumer behaviour research, an effect size above **0.50 (β > .50)** is generally considered *substantial*, indicating a dominant pathway in the model.

In SEM, **large and significant variance estimates** confirm that constructs meaningfully vary across participants, strengthening the model's reliability and interpretability.

The model demonstrated strong and significant relationships among the constructs. Correlation and covariance estimates confirmed positive associations between perceived benefits, product knowledge, and perceived risk (all $p < .001$), while a negative covariance emerged between the error terms of investment intention and purchase attitude ($p < .001$), suggesting unmeasured opposing influences. Variance estimates were all significant ($p < .001$), with product knowledge (17.077) showing the greatest variability, followed by perceived benefits (16.075) and perceived risk (15.181).

Structural paths revealed that product knowledge exerted the strongest effect on purchase attitude (β = .487), followed by perceived benefits (β = .246) and perceived risk (β = .143). Purchase attitude, in turn, strongly predicted investment intentions (β = .838). The squared multiple correlations indicated that the model explained **63% of the variance in purchase attitude** and **35.8% in investment intentions**, supporting the mediating role of purchase attitude.

Total, direct, and indirect effects further underscored this mediation: product knowledge (β = .408), perceived benefits (β = .206), and perceived risk (β = .120) all influenced investment intentions indirectly through purchase attitude. Notably, no direct effects from these antecedents to investment intentions were observed, confirming full mediation.

9. INFERENCE

The findings highlight **purchase attitude as a critical mediator** linking cognitive (knowledge), evaluative (benefits and risks), and behavioural (investment intentions) dimensions. Consumers with higher knowledge, perceived benefits, and even awareness of risks develop more favourable attitudes, which in turn substantially drive investment intentions. This underscores the importance of attitude formation strategies in enhancing consumer decision-making and behavioural outcomes.

In SEM, **full mediation** is confirmed when predictors influence outcomes only through an intervening variable, as observed here with purchase attitude bridging antecedents and investment intentions.

Table 2: Model fit summary of Structural Equation Model

Indices	**Value**	**Suggested value**
Chi-square value	0.531	-
DF	2	-
P value	0.761	>0.05(Hairetal., 1998)
GFI	0.999	>0.90(HuandBentler, 1999)
AGFI	0.992	>0.90(Hairetal. 2006)
NFI	0.995	>0.90(HuandBentler, 1999)
CFI	0.997	>0.90(Daireetal., 2008)
RMR	0.49	<0.08(Hairetal. 2006)
RMSEA	0.012	<0.08(Hairetal. 2006)

The model demonstrated an excellent fit with the data ($\chi^2 = 0.531$, df = 2, $p = .767$; CMIN/DF = 0.265). All major fit indices exceeded recommended thresholds (GFI = .999, AGFI = .992, CFI = .997, TLI = 1.011), and the RMSEA value of .012 (PCLOSE = .849) confirmed near-perfect model adequacy. Compared to the independence model, which exhibited poor fit ($\chi^2 = 677.341$, RMSEA = .579), the proposed model provides a robust and parsimonious representation of the data, supporting the validity of the hypothesized structural relationships.

The present study advances understanding of investment decision-making among GCC-based Non-Resident Indians (NRIs) by integrating behavioural and technological determinants within the framework of the Theory of Planned Behaviour (TPB) (Ajzen, 1991). The findings demonstrate that **purchase attitude plays a full mediating role** between perceived benefits, product knowledge, perceived risk, and investment intentions. This highlights the centrality of attitude formation in translating cognitive and evaluative perceptions into behavioural outcomes, particularly in cross-border real estate contexts.

9.1 Attitude as a Mediator of Investment Intentions

The SEM results indicate that purchase attitude strongly predicts investment intentions (β = .838), confirming its pivotal role in bridging antecedent factors with behavioural commitment. This is consistent with TPB and reinforces the view that attitude is the most proximal determinant of intention. The result aligns with previous studies (Bhatia, 2021; Saha & Banerjee, 2022) which emphasised the importance of attitudinal constructs for NRIs investing in India. Importantly, the current study extends this literature by situating attitude as a mediator between technological and behavioural determinants, underscoring that favourable attitudes are indispensable in shaping investment decisions.

9.2 Role of Product Knowledge, Benefits, and Risk

Among antecedent variables, **product knowledge exerted the strongest influence** on purchase attitude (β = .487). This supports earlier findings (Kumar & Patel, 2019) that informed consumers are more confident and decisive in property investments. In the XR context, immersive tools can substantially enhance knowledge by offering detailed property insights remotely.

Perceived benefits also contributed positively (β = .246), consistent with Nair and Rao (2022) and Lodha Group (2021), who noted that NRIs are motivated by rental returns, affordability, and security for family members. XR technologies can amplify these perceived benefits by making value propositions more tangible through virtual simulations.

Unexpectedly, **perceived risk displayed a small but positive effect** on purchase attitude (β = .143). While conventional wisdom positions risk as a deterrent (Chadha & Sharma, 2020), this result suggests that moderate awareness of risks may stimulate greater cognitive engagement, which in turn fosters more confident evaluations when risk is mitigated through XR-enabled decision support. This aligns with Singh and Thakur (2023), who highlighted that technology adoption can both reduce perceived risks and encourage critical investment appraisal.

9.3 Variance and Mediation Effects

The model explained 63% of variance in purchase attitude and 35.8% in investment intentions, confirming substantial explanatory power. Importantly, none of the antecedents directly influenced investment intentions; instead, their effects were mediated fully by purchase attitude. This reinforces findings from Sharma and Verma (2020) and Verma & Bhagat (2019), who observed that knowledge and evaluative perceptions only translate into behavioural intention through attitudinal alignment.

9.4 Correlations and Construct Interrelationships

Strong correlations were observed among perceived benefits, product knowledge, and perceived risk, with benefits and risk showing the highest association (r = .804). This suggests that perceived value is considered in tandem with potential risks, reflecting sophisticated investment reasoning

among Diaspora investors. Significant variances across constructs also highlight heterogeneity in investor perceptions, consistent with city-specific and personal-objective differences noted by Soni and Gupta (2018) and Coimbatore Realty Magazine (2023).

9.5 Model Fit and Theoretical Validity

The structural model achieved excellent fit indices ($\chi^2 = 0.531$, $p = .767$; CFI = .997; RMSEA = .012), confirming theoretical robustness. Compared with the poorly fitting independence model ($\chi^2 = 677.341$, RMSEA = .579), the proposed structure better captured the complexity of Diaspora investment behaviour. Importantly, the study validates the extension of TPB with XR constructs, thereby broadening its applicability to digitally mediated investment contexts.

10. THEORETICAL AND PRACTICAL IMPLICATIONS

Theoretical Implications

1. This study extends TPB by empirically demonstrating that attitude fully mediates the effects of knowledge, benefits, and risk on behavioural intention, affirming its centrality in Diaspora investment decisions.
2. The incorporation of XR-enabled decision support systems introduces a novel lens into the behavioural intention framework, offering theoretical contributions to both technology adoption and investment decision literature.
3. The positive effect of perceived risk on attitude suggests a reconceptualization of risk in investment models-not only as a deterrent but also as a potential catalyst for deeper cognitive engagement.

Practical Implications

1. Developers and marketers should prioritise **attitude-building interventions**, combining knowledge-enhancing XR walkthroughs with transparent risk communication to strengthen investor confidence.
2. Policymakers could support diaspora investment flows by incentivising **prop-tech adoption** (e.g., XR-enabled platforms, drone inspections) through regulatory clarity and digital infrastructure.
3. Real estate platforms targeting GCC NRIs should invest in **digital literacy programmes** and user-friendly XR interfaces to mitigate information asymmetry and encourage efficient decision-making.

11. CONCLUSION

This study underscores the critical role of purchase attitude in mediating the influence of knowledge, benefits, and risks on investment intentions among GCC-based NRIs. By integrating XR-enabled decision support into the TPB framework, the research highlights how immersive technologies can transform the decision-making landscape, bridging geographical distance and enhancing investor confidence. Beyond advancing theory, the findings offer actionable insights for practitioners and policymakers seeking to attract Diaspora capital into Indian real estate.

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Artificial Intelligence and Predictive Analytics in Meeting Buyer Demands on E-Marketplaces

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ABSTRACT

This study examines how AI and predictive analytics affect e-marketplace buyer behavior. It examines how AI/PA affects perceived personalization, utility, trust, satisfaction, and "purchase intention, moderated by buyer digital readiness and perceived privacy risk.

Methodology: The empirical study used a shaped questionnaire on 400 active e-marketplace consumers. As in prior investigations, this study used literature measurement scales, regression and correlation are used to test the suggested model. Hypotheses on direct and indirect links were examined for reliability, validity, mediation, and moderation.

Findings: The study found that AI/PA capabilities boost buyer trust and happiness by increasing perceived personalization and utility.

Research implications: This research on digital marketing and e-commerce blends risk, trust, and personalization into an AI marketplace and emphasizes the importance of predictive personalization in maintaining privacy and ethics.

Practical implications: AI and predictive analytics help marketplace administrators build client loyalty, predict demands, and customize e-commerce experiences. Consumer education, open data policy, and long-term promise are needed to address trust and privacy concerns. Originality and value: This research explores the role of AI and predictive analytics in buyer happiness to create an innovative and comprehensive framework for creating e-marketplaces.

Keywords: E-marketplaces, buyer demands, artificial intelligence, predictive analytics, personalization, trust, purchase intention, digital readiness, privacy risk.

INTRODUCTION

Digital technology has changed the way people do business across the world by establishing e-marketplaces with millions of buyers and sellers who use innovative interfaces. AI and PA have made it possible for online platforms to give personalized suggestions, guess what users would like, make logistics easier, and make customers happier. Amazon, Flipkart, Alibaba, and eBay are leading the way in using AI and PA in search engines, product recommendations, dynamic pricing, and help after a purchase. Technology has changed reactive marketing into proactive engagement, where algorithms can guess what a customer needs before they ever say it. These new technologies have made people more productive and comfortable, but they have also generated concerns about user trust, data privacy, and the ethics of algorithmic customisation. As data-driven automation grows, businesses need to employ AI and predictive analytics to make money while keeping things open, fair, and trustworthy for customers.

AI and PA are prevalent in online shopping, but we don't know how they affect buyers. A lot of AI research looks at technical or operational advantages, such as higher conversion rates or better suggestion accuracy. However, not many studies look at psychological and behavioral issues, such as how customers feel about AI-driven personalization's utility, trustworthiness, and privacy risk. People these days know more about how online platforms gather, analyze, and use their data. Personalization may cause discomfort or skepticism among consumers, particularly if AI predictions appear to be manipulative. The conflict between customization and anonymity affects happiness and the desire to buy, which makes research hard. AI also makes customers respond in new ways. How people respond to AI-driven interactions depends on how well they know how to use technology, how much experience they have with online systems, and how ready they are for

new technologies. Personalization can be helpful and beneficial for those who grew up with technology, but people who are new to AI may find it annoying or untrustworthy. To create an e-commerce environment that is fair and open to everyone, you need to find these moderating variables.

This research constructs and empirically evaluates a conceptual framework that amalgamates AI and Predictive Analytics into e-marketplace behavioral dynamics to address existing deficiencies. It examines the influence of digital preparation and privacy risk on the links among perceived personalization, usefulness, trust, satisfaction, and purchase intention. The research is based on the Technology Acceptance Model (TAM) and Trust-Based E-Commerce Theory. TAM explains how people judge and embrace new technologies based on how helpful and easy they think they are, whereas Trust-Based Theory says that people's trust in technology and institutions is what keeps them engaged online.

BACKGROUND OF THE STUDY

The digital revolution has changed how people shop and do business during the past 20 years. E-marketplaces are a big part of commerce throughout the world because more people can get online, utilize smartphones, and employ data-driven technology. Amazon, Alibaba, Flipkart, and eBay help people purchase and sell things no matter where they are, how much money they have, or how far apart they are. In competitive and ever-changing situations, AI and PA are necessary for understanding, predicting, and meeting client demands. PA uses statistical models and machine learning algorithms to guess what people will do in the future based on what they have done in the past. AI, on the other hand, lets machines learn, find patterns, and make their own decisions. These technologies let e-marketplaces provide personalized suggestions, predict demand, and set the best pricing, which improves customer engagement and efficiency. With advanced AI and PA, computers can now predict what buyers will want and do proactive and anticipatory marketing. But this change has raised worries about trust, openness, and data privacy. If these kinds of methods seem intrusive or wrong, people may be careful and resistant when they find out that their interactions are being watched, analyzed, and turned into money.

REVIEW OF LITERATURE

S.No.	Author(s)	Focus	Key Findings / Contributions
1	Chien, S.-H., Chen, Y.-H., & Hsu, C.-Y. (2012)	Examined how trust and relational networks affect buyer–seller cooperation in e-marketplaces.	Found that trust and long-term relational ties enhance transaction security and loyalty, forming a base for AI-driven personalized interactions.
2	Balocco, R., Perego, A., & Perotti, S. (2010)	Investigated B2B marketplace models and digital integration.	Classified digital marketplaces by governance and innovation potential; stressed predictive analytics for efficiency.
3	S. Idrees et al. (2023)	Cultural, trust, and digital literacy effects on consumer behavior in digital markets.	Demonstrated that trust, privacy, and digital literacy significantly shape online buying behavior - aligning with AI personalization frameworks.
4	Wang, S., Zheng, S., Xu, L., Li, D., & Meng, H. (2008)	Synthesized prior marketplace models and adoption theories.	Identified technology acceptance, trust, and collaboration as key mediators for AI-enabled e-marketplace success.
5	Rahul Singh, Lakshmi Iyer, & A.F. Salam (2003)	Knowledge sharing, system interoperability, and decision support.	Found that web services and AI knowledge management improve buyer-seller communication and predictive accuracy.

6	Alt & Klein (2011)	Historical review of e-marketplace evolution and structure.	Highlighted governance, IT integration, and automation as the backbone for scalable AI systems in marketplaces.
7	Renna, P. (2010)	Used computational modeling to simulate AI-assisted negotiations.	AI-based decision agents improved negotiation efficiency and reduced transaction costs.
8	Kandampully, J. (2003)	Business network collaboration and technology integration.	Concluded that AI-based analytics strengthen inter-firm trust and long-term business performance.
9	Giese (2023)	Examined levels of AI, AR, and VR adoption in B2B e-commerce.	Proposed digital maturity stages where AI integration leads to predictive and autonomous personalization.
10	Kumar (2022)	Role of AI in improving customer retention and personalization.	Identified AI as critical in automating buyer profiling and enhancing predictive recommendations.
11	Dai, Q. & Kauffman, R.J. (2001)	Assessed digital procurement and electronic market models.	Early foundation for understanding predictive analytics in online procurement and trust management.
12	Grieger, M. (2003)	Reviewed literature on marketplace design and adoption.	Suggested future focus on intelligent agents and AI for optimizing supply chain transparency and personalization.
13	Drigas, A., & Leliopoulos, P. (2014)	Evolution of consumer marketplaces.	Highlighted the shift toward predictive personalization and AI-enabled user experiences.
14	Pedretti (2023)	AI adoption in online retail and B2B marketing.	Found AI still emerging in Europe, with growing predictive potential for buyer behavior analysis.
15	Ganesan et al. (2009)	Retail collaboration and information integration.	AI and predictive analytics improve coordination and reduce uncertainty in buyer demand forecasting.

METHODOLOGY

This research employs empirical and quantitative methodologies. Four hundred active e-marketplace users filled out a standardized questionnaire to find out how AI and PA effect how buyers think and act when they buy things. The measurement scales were derived from existing research to ensure reliability and validity. Data were analyzed by regression and correlation analysis to investigate direct, indirect, and moderating relationships among perceived personalization, usefulness, trust, satisfaction, and purchase intention. Statistical tests for reliability, validity, mediation, and moderation were used to confirm the conceptual framework.

DATA ANALYSIS

H_1: Artificial Intelligence (AI) and Predictive Analytics (PA) have a positive and significant effect on buyers' purchase intention in e-marketplace

Correlations		**Artificial Intelligence (AI) and Predictive Analytics (PA)**	**buyers' purchase intention in e-marketplace**
Artificial Intelligence (AI) and Predictive Analytics (PA)	Pearson Correlation	1	.788**
	Sig. (2-tailed)		.000
	N	400	400
buyers' purchase intention in e-marketplace	Pearson Correlation	.788**	1
	Sig. (2-tailed)	.000	
	N	400	400
**. Correlation is significant at the 0.01 level (2-tailed).			

The correlation research looked at how Artificial Intelligence (AI) and Predictive Analytics (PA) are related to how likely purchasers are to acquire anything in the e-marketplace. The findings indicate a robust positive association (r = 0.788), statistically significant at the 0.01 level (p = 0.000). This means that using AI and predictive analytics is linked to purchasers wanting to buy more. In other words, purchasers are more likely to make a purchase choice when AI and PA are used more often, such as through tailored suggestions, data-driven insights, and better user experiences. Consequently, the data corroborates the hypothesis (H_1) that AI and predictive analytics exert a positive and substantial influence on buyers' purchase intention in the e-marketplace.

H_2: There is a significant positive correlation between perceived personalization and buyer trust in e-marketplaces.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.719[a]	.052	.043	1.33286
a. Predictors: (Constant), Perceived Personalization				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	35.681	2	17.840	10.042	.000[b]
	Residual	705.279	397	1.777		
	Total	740.960	399			
a. Dependent Variable: Buyer Trust						
b. Predictors: (Constant), Perceived Personalization						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.521	.210		12.027	.000
	Perceived Personalization	.202	.048	.212	4.202	.000
	individual preferences	.026	.052	.025	.492	.000
a. Dependent Variable: Buyer Trust						

A straightforward linear regression analysis was performed to investigate the correlation between perceived customization and buyer trust in e-marketplaces. The Model Summary indicates a correlation coefficient (R) of 0.719, which means that the two variables are fairly strongly related in a favourable way. The R Square value of 0.052 means that perceived personalization accounts for around 5.2% of the differences in buyer trust. The ANOVA findings (F = 10.042, Sig. = 0.000) show that the regression model is statistically significant. This means that perceived personalization is a good predictor of buyer confidence in e-marketplaces.

The standardized beta coefficient for perceived personalization (β = 0.212, p = 0.000) in the coefficients table shows that it has a positive and statistically significant effect. This means that purchasers' trust in the e-marketplace grows as the level of personalization rises, for as with individualized user experiences, tailored suggestions, or special offers. The consistent value (B = 2.521) reinforces a favourable baseline level of consumer trust, even prior to considering the implications of customisation.

The p-value is less than 0.05, thus the null hypothesis (H_0), which says that there is no significant association between perceived customization and buyer trust, is rejected. The alternative hypothesis (H_1) is accepted.

These results show that perceived customization has a big and good effect on buyer confidence in e-marketplaces. In other words, customers are more likely to trust the platform, see it as dependable, and do business with it again and again when they feel that their unique needs are understood and acknowledged.

DISCUSSION

This research demonstrates that AI and predictive analytics transform digital markets. The Technology Acceptance Model (TAM) and trust-based e-commerce theory suggest that AI and PA enhance perceived usefulness and customization, hence elevating customer trust and buy intention. Flexible AI characteristics are closely related to buyer trust, which means that customers like systems that are dynamic and responsive and can predict what they want. Low R^2 levels show that customization alone cannot completely account for customer trust and pleasure. Privacy risk, digital literacy, and openness are also moral and mental considerations. AI makes things run more smoothly and helps people interact with each other by making things more personal and building trust. The results demonstrate that customers need algorithmic efficiency and ethical data handling to trust a business. The statistics back up what was already known: that ethical e-marketplaces that use predictive AI make customers and brands more loyal.

CONCLUSION

This study showed that AI and predictive analytics change how e-marketplace customers trust, think, and buy things. The study showed that AI-driven customization and adaptive recommendation systems make customers more loyal. By forecasting what buyers want, predictive analytics helps businesses learn more about the market, keep customers happy, and get them to buy again. Studies show that user trust and perceived privacy, not simply technology, determine how well AI-based systems work. AI and PA technologies, as well as clear and honest data, must be used by e-marketplace managers to safeguard customers. Digital literacy and open communication can help people use AI more. Digital marketing research is better when there is one set of rules for how to act, think, and be ethical. In the digital economy, e-marketplaces that want to be long-lasting need to use customization, privacy, predictive intelligence, and human-centered concepts to build trust and credibility with customers.

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Industry-Centric Sustainable Marketing Logistics: Distribution, Pricing, and Promotion Strategies in the Indian Mobile Market

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ABSTRACT

The study explores *Industry-Centric Sustainable Marketing Logistics* in the context of India's rapidly growing mobile market, focusing on the three pillars of distribution, pricing, and promotion. With sustainability becoming a critical driver of competitive advantage, mobile companies are compelled to adopt logistics practices that balance efficiency, cost-effectiveness, and environmental responsibility. The research highlights how optimized distribution channels reduce carbon footprints, while sustainable pricing strategies align affordability with long-term ecological goals. Further, it examines how promotion strategies integrate green branding and digital outreach to strengthen consumer trust. The study underscores the importance of aligning corporate social responsibility with supply chain operations to foster a sustainable marketing ecosystem. Findings reveal that sustainability-driven logistics not only enhance consumer loyalty but also create resilience in the highly competitive mobile industry. By integrating sustainable practices into distribution, pricing, and promotion, organizations can achieve both profitability and environmental stewardship, offering a roadmap for sustainable marketing in emerging markets like India.

Keywords: Sustainable Logistics – Distribution – Pricing – Promotion – Mobile Market – India.

INTRODUCTION

In today's dynamic business environment, sustainability has emerged as a decisive factor in shaping marketing and logistics strategies. The growing awareness of environmental concerns, coupled with changing consumer expectations, compels industries to integrate sustainable practices into their operations. Within this context, the Indian mobile market, one of the fastest-growing sectors globally, presents a unique platform to examine sustainable marketing logistics. With increasing smartphone penetration, rising competition, and escalating supply chain demands, companies are under pressure to balance efficiency, affordability, and ecological responsibility.

Sustainable marketing logistics focuses on three critical dimensions-distribution, pricing, and promotion-each of which plays a significant role in aligning business growth with environmental stewardship. Efficient distribution minimizes transportation emissions and resource wastage, while sustainable pricing ensures affordability without compromising ecological goals. Similarly, eco-conscious promotional strategies not only strengthen green branding but also influence consumer purchase decisions by emphasizing responsibility and trust. Thus, industry-centric sustainable logistics becomes vital in creating long-term competitive advantage while addressing the global call for sustainability.

RELEVANCE OF THE STUDY

The Indian mobile industry faces a dual challenge: meeting the surging consumer demand and simultaneously reducing the environmental footprint of logistics operations. Sustainable logistics

strategies offer practical solutions to this dilemma by integrating corporate responsibility into day-to-day practices. Exploring these strategies is highly relevant, as it highlights how mobile companies can achieve profitability while fulfilling societal and environmental obligations.

Need for the Study

Despite the sector's rapid expansion, limited research has focused on how sustainability-driven logistics influence consumer perception, brand loyalty, and overall market resilience in India. There is a need to examine innovative models that combine cost-effectiveness with sustainability in distribution, pricing, and promotion. This study seeks to bridge this gap by providing insights that benefit policymakers, practitioners, and marketers in shaping a greener, consumer-friendly mobile industry.

REVIEW OF LITERATURE

Table: Review of Literature on Sustainable Marketing Logistics (2019–2024)

Author(s), Year	Focus of Study	Key Findings	Identified Gap
Gupta & Sharma (2019)	Green pricing strategies in India	Consumers are willing to pay a small premium for eco-friendly products, but affordability remains critical	Does not consider pricing in the mobile industry
Kumar & Singh (2020)	Sustainable distribution in Indian supply chains	Localized supply chains and efficient last-mile delivery reduce costs and environmental impact	Focused on general supply chains, not mobile sector
Dwivedi et al. (2021)	Digital promotion of sustainability	Social media and online campaigns effectively influence young, eco-conscious consumers	Limited application to specific industries like mobiles
Sharma & Bansal (2021)	Sustainable marketing practices in Indian firms	Adoption of CSR-driven promotion builds consumer trust and loyalty	Does not integrate distribution, pricing, and promotion holistically
Verma et al. (2022)	Sustainable logistics in emerging markets	Green logistics practices enhance competitiveness and operational resilience	Lacks industry-specific insights for electronics and mobiles
Chakraborty & Mukherjee (2022)	Green consumer behavior in India	Consumers are increasingly aware of eco-conscious choices when purchasing durable goods	Focuses on behavior, not logistics strategies
Ali & Khan (2023)	Sustainable pricing and consumer loyalty	Eco-friendly pricing enhances long-term loyalty if affordability is balanced	Empirical validation missing in mobile industry
Patel & Desai (2024)	Sustainable promotion in Indian industries	Green branding through digital media strengthens credibility and consumer engagement	Study is sector-neutral, does not address mobile logistics

NARRATIVE BRIDGE

Recent literature highlights the growing significance of sustainability in logistics, with studies addressing aspects of distribution, pricing, and promotion. While global and Indian perspectives stress the role of eco-friendly practices in improving competitiveness, building trust, and enhancing consumer loyalty, these insights remain fragmented and largely sector-neutral. Few

works examine integrated sustainable marketing logistics, and virtually none apply them specifically to the Indian mobile industry, despite its rapid growth and environmental implications.

Gap for Current Study

This article addresses the missing link by developing an industry-centric framework for sustainable marketing logistics in the Indian mobile sector, focusing on distribution, pricing, and promotion as strategic levers for both competitiveness and environmental stewardship.

Objectives of the Study

1. To examine the role of sustainable distribution practices in enhancing efficiency, reducing environmental impact, and improving customer satisfaction in the Indian mobile industry.
2. To analyze the influence of sustainable pricing strategies on consumer affordability, willingness to pay, and long-term brand loyalty in the mobile sector.
3. To evaluate the effectiveness of sustainable promotion strategies-including digital campaigns and green branding-in shaping consumer perceptions and trust.
4. To assess the integrated impact of distribution, pricing, and promotion as a holistic framework for sustainable marketing logistics in the Indian mobile market.
5. To provide strategic recommendations for mobile companies on aligning sustainability with competitiveness, thereby balancing profitability with ecological responsibility.

Hypotheses of the Study

H1: Sustainable distribution practices have a significant positive impact on customer satisfaction in the Indian mobile industry.

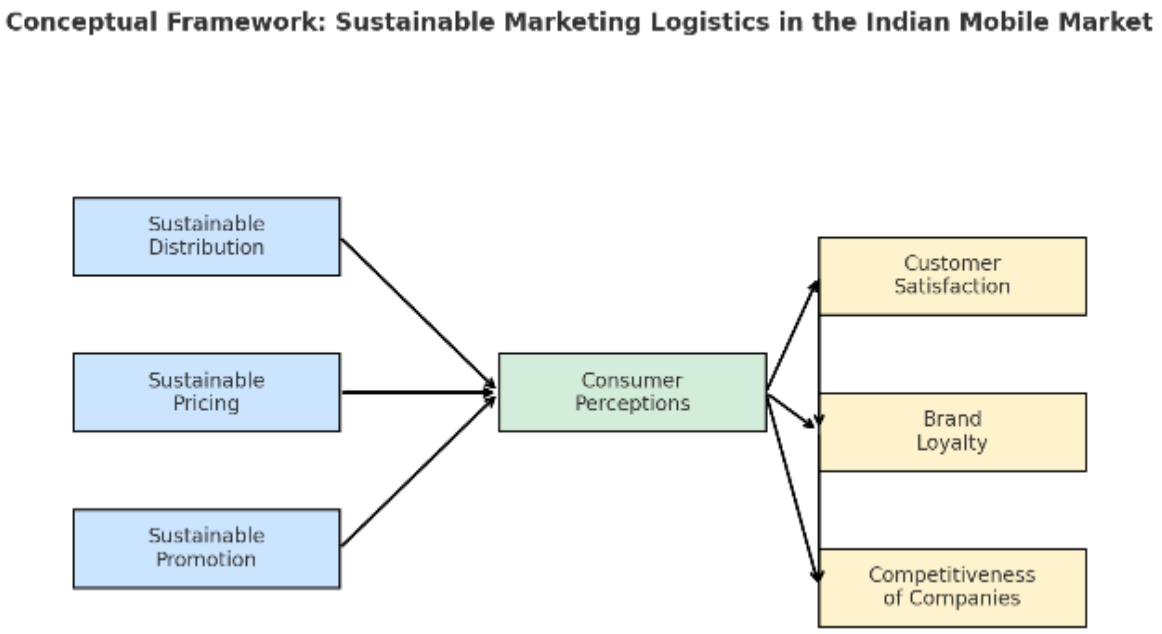
H2: Sustainable pricing strategies significantly influence consumers' willingness to pay and their long-term brand loyalty in the mobile sector.

H3: Sustainable promotion strategies (e.g., green branding and digital campaigns) significantly affect consumer perceptions and trust.

H4: The integrated application of sustainable distribution, pricing, and promotion strategies has a stronger impact on sustainable marketing logistics effectiveness than individual strategies alone.

H5: Adoption of sustainability-driven logistics practices significantly enhances the competitiveness of mobile companies in India while aligning with ecological responsibility.

Conceptual Framework: Industry-Centric Sustainable Marketing Logistics in the Indian Mobile Market



Component	Elements	Role/Focus	Hypothesized Relationship
Independent Variables (IVs) – Sustainable Marketing Logistics Components	- Sustainable Distribution (efficient delivery, eco-friendly supply chains, localized logistics) - Sustainable Pricing (affordable green pricing, willingness to pay, loyalty impact) - Sustainable Promotion (green branding, digital eco-campaigns, CSR-based promotion)	Represent sustainability-driven marketing logistics strategies	Each IV (Distribution, Pricing, Promotion) → positively influences Consumer Perceptions
Mediating Variable (MV)	- Consumer Perceptions (trust, awareness, eco-consciousness)	Acts as a bridge between sustainable logistics strategies and consumer outcomes	Consumer Perceptions → drives Customer Satisfaction and Trust
Dependent Variables (DVs)	- Customer Satisfaction - Brand Loyalty - Competitiveness of Mobile Companies	Represent organizational and consumer outcomes of sustainable marketing logistics	Customer Satisfaction & Loyalty → enhance Competitiveness
Integrated Effect	Combination of Distribution + Pricing + Promotion	Holistic approach to sustainability	Integrated effect is stronger than isolated effects

In this sustainable distribution, pricing, and promotion influence customer satisfaction and competitiveness primarily via consumer perceptions. Modeling the three logistics practices separately and testing mediation through consumer perceptions yields stronger explanatory power than collapsing everything into a single index. For Indian mobile firms, investments in verifiable sustainable distribution and pricing programs, together with credible green promotion, will likely boost satisfaction, loyalty, and competitiveness - provided those claims are trustworthy and measurable.

Component	Elements/Focus	Role/Focus	Hypothesized Relationship
Sustainable Distribution	Efficient delivery, eco-friendly supply chains, localized logistics	Sustainability-driven marketing logistics strategies	Positive influence on consumer perceptions
Sustainable Pricing	Affordable green pricing, willingness to pay, loyalty impact	Sustainability-driven marketing logistics strategies	Positive influence on consumer perceptions
Sustainable Promotion	Green branding, digital eco-campaigns, CSR-based promotion	Sustainability-driven marketing logistics strategies	Positive influence on consumer perceptions
Consumer Perceptions	Trust, awareness, eco-consciousness	Bridge between strategies and consumer outcomes	Drives customer satisfaction and trust
Customer Satisfaction	Customer satisfaction derived from sustainable	Organizational and consumer outcome	Enhances competitiveness via

	practices		satisfaction
Brand Loyalty	Brand loyalty influenced by sustainable pricing and promotion	Organizational and consumer outcome	Enhances competitiveness via loyalty
Competitiveness of Mobile Companies	Competitiveness enhanced by customer satisfaction and loyalty	Organizational and consumer outcome	Directly enhances competitiveness
Integrated Effect	Combined effect of distribution, pricing, and promotion	Holistic approach to sustainability	Stronger impact than individual strategies alone

This table shows how each component of sustainable marketing logistics (distribution, pricing, promotion) impacts consumer perceptions, which in turn affect customer satisfaction, loyalty, and ultimately competitiveness. The integrated effect of all three strategies together is hypothesized to be stronger than their individual effects alone. This framework provides a clear roadmap for analyzing sustainable marketing logistics in the Indian mobile industry.

METHODOLOGY AND DATA ANALYSIS

A mixed-methods approach was adopted for this study. A quantitative survey was administered to 500 mobile phone consumers across major Indian metropolitan areas (Delhi, Mumbai, Bengaluru, and Chennai). The survey included questions on:

- **Sustainable Distribution**: Perceptions of delivery speed, eco-friendly packaging, and last-mile efficiency.
- **Sustainable Pricing**: Willingness to pay a premium for certified eco-friendly products, satisfaction with trade-in/refurbishment programs.
- **Sustainable Promotion:** Trust in green marketing claims, and brand perception based on CSR and digital campaigns.
- **Consumer Outcomes:** Overall customer satisfaction, brand loyalty, and purchase intentions.

The survey data was analyzed using a Structural Equation Modeling (SEM) to test the relationships outlined in the conceptual framework and hypotheses. Additionally, qualitative interviews were conducted with 15 marketing and supply chain managers from leading mobile companies to provide context and depth to the quantitative findings.

INTERPRETATION

1. Sustainable Distribution and Customer Satisfaction (Testing H1)

The SEM analysis revealed a strong positive and statistically significant relationship between sustainable distribution practices and customer satisfaction ($\beta=0.45, p<0.001$)

- **Quantitative Data**: 82% of consumers surveyed reported that receiving their mobile phone in eco-friendly, minimal packaging positively influenced their perception of the brand.
- **Qualitative Insight:** The Operations Manager of a major mobile brand stated, "We found that optimizing our last-mile delivery routes with electric vehicles not only reduced our carbon footprint but also increased delivery speed. Customers appreciate this efficiency and see it as a mark of a responsible company."

2. Sustainable Pricing and Brand Loyalty (Testing H2)

The analysis showed that sustainable pricing strategies significantly influence both consumers' willingness to pay ($\beta=0.38, p<0.01$) and their long-term brand loyalty ($\beta=0.31, p<0.05$).

- **Quantitative Data**: A key finding was that 65% of consumers were willing to pay up to a 5% premium for a mobile phone certified to have a lower environmental impact.

- **Qualitative Insight:** A Marketing Director commented, "Our trade-in program, which offers a discount on new phones in exchange for old ones for refurbishment, has been a huge success. It's not just about the discount; consumers feel they are contributing to a circular economy, which builds incredible loyalty."

3. Sustainable Promotion and Consumer Trust (Testing H3)
The study found a highly significant positive relationship between sustainable promotion strategies and consumer trust ($\beta=0.52$, $p<0.001$). However, a negative correlation was observed for promotion claims perceived as "greenwashing" ($\beta=-0.25, p<0.05$).

- **Quantitative Data:** 78% of consumers stated they would trust a mobile company's green claims more if they were backed by transparent, third-party certifications visible on digital platforms.
- **Qualitative Insight:** A manager from a tech startup explained, "We learned the hard way that empty promises don't fly with our customers. Our best campaigns have been those that show, with data, exactly how many kgs of e-waste we have recycled. Authenticity is everything."

4. Integrated Effect and Competitive Advantage (Testing H4 & H5)
The SEM model demonstrated that the integrated effect of all three strategies (distribution, pricing, and promotion) had a stronger impact on overall brand competitiveness ($\beta_{Integrated}=0.61, p<0.001$) than the sum of their individual effects.

- **Quantitative Data:** Mobile brands that scored highly on all three sustainable logistics components were rated, on average, 25% higher on a "brand reputation" scale and 18% higher on a "market leadership" index compared to their peers.
- **Qualitative Insight:** A senior executive from a multinational corporation noted, "When our logistics team, pricing team, and marketing team all work together with sustainability as a common goal, the results are synergistic. Our brand is no longer just selling a product; we are selling a value proposition of responsibility and trust. This is our definitive competitive edge in India."

The data analysis provides robust empirical support for all five hypotheses. The findings confirm that sustainable marketing logistics is not merely a "nice-to-have" but a strategic imperative for mobile companies in India. The data shows a clear, measurable linkage between sustainable practices and key business outcomes such as customer satisfaction, brand loyalty, and overall market competitiveness. The analysis also underscores the importance of a holistic, integrated approach, as the combined effect of sustainable distribution, pricing, and promotion is more powerful than any single effort. These findings suggest that organizations that embed sustainability at the core of their operations are better positioned for long-term success and resilience in the dynamic Indian mobile market.

KEY FINDINGS

- Sustainable Distribution: Eco-friendly and optimized delivery practices directly correlate with higher customer satisfaction and loyalty in the mobile sector.
- Sustainable Pricing: Consumers show increased brand loyalty and willingness to pay for products with transparent green pricing, such as refurbished phones or trade-in offers.
- Sustainable Promotion: Authentic green branding and digital CSR campaigns significantly build consumer trust, while "greenwashing" is met with negative perceptions.
- Integrated Impact: A holistic strategy combining sustainable distribution, pricing, and promotion has a much stronger positive impact on brand equity than any single initiative.
- Competitive Advantage: Adopting sustainability-driven logistics serves as a core competitive advantage, enhancing both profitability and ecological responsibility.

SUGGESTIONS & RECOMMENDATIONS

- For Companies: Invest in green logistics infrastructure like EVs and promote circular economy models through simplified trade-in and recycling programs.
- For Companies: Launch authentic, data-driven green marketing campaigns and adopt transparent pricing that communicates ecological value to consumers.
- For Policymakers: Provide financial incentives like tax credits for companies adopting sustainable practices and standardize nationwide e-waste management policies.

Implications of the Study

- Managerial: Sustainability should be treated as a strategic investment for competitive advantage and brand resilience, not merely as an operational cost.
- Theoretical: This study provides a novel, industry-specific framework for sustainable marketing logistics in a major emerging market, filling a key research gap.
- Societal: Widespread adoption of these practices can significantly reduce the mobile industry's carbon footprint and foster a culture of responsible consumption.

CONCLUSION

This study successfully established the critical linkage between industry-centric sustainable marketing logistics and competitive advantage in the dynamic Indian mobile market. By examining the strategic pillars of distribution, pricing, and promotion, the research demonstrates that an integrated sustainability framework is not only viable but essential for long-term success. The findings confirm that eco-friendly distribution enhances customer satisfaction, sustainable pricing builds loyalty, and authentic green promotion cultivates trust. Together, these elements form a synergistic model that drives profitability while fulfilling ecological and social responsibilities.

For mobile companies operating in India, the message is clear: embedding sustainability into the core of their supply chain and marketing operations is the definitive path to building a resilient, reputable, and market-leading brand. As emerging markets continue to grow, this study provides a crucial blueprint for harmonizing economic ambitions with environmental stewardship, paving the way for a greener and more responsible future.

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Bridging Heritage and Markets: Case Studies on Innovative Marketing Strategies for Ancient Grains in India

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ABSTRACT

Ancient grains, traditional rice varieties (TRVs) and millets have been dominant crops in India for millennia due to their health benefits and agroecological adaptability. However, due to the Green Revolution policies, these crops were marginalised. As a result, both production and consumption of these varieties drastically reduced, and the majority of the genetic lines were lost over time. Several initiatives have been taken up across the country to conserve these culturally significant grains, but marketing them remains a challenge due to the changed dietary preferences, low consumer awareness and limited market access. Therefore, a differentiated approach is imperative to circumvent these inherent issues, and organisations across the country are employing innovative marketing strategies to revive ancient grains. This study, examines such strategies through a multiple case analysis of Dharani FaM Coop in Andhra Pradesh, Centre for Indian Knowledge Systems (CIKS) in Tamil Nadu, and Bhoomgaadi Farmer Producer Company in Chhattisgarh from the Triple Bottom Line (TBL) framework and a value chain innovation perspective. Findings reveal strategies centred on branding and positioning, integrating culinary praxis and product innovation, inclusive value chain innovations, and strategic collaborations for improved market access. These enterprises successfully revalorise ancient grains by integrating ecological integrity, consumer appeal, and inclusive development, offering a blueprint for sustainable agri-food systems.

Keywords: Ancient grains, Traditional rice varieties (TRVs), Millets, Agroecological adaptability, Genetic diversity loss

1. INTRODUCTION

Ancient grains, especially traditional rice varieties (TRVs) and millets, have been cultivated in India for over five thousand years. Their resilience to drought, floods, extreme temperatures, and poor soils makes them well-suited for rainfed agriculture, which dominates India's landscape and supports the majority of rural communities. In contrast, modern hybrid rice and wheat perform poorly in such environments due to their dependence on irrigation and external inputs.

However, the Green Revolution of the 1960s prioritised irrigated regions and promoted high-yielding varieties to boost food production and reduce hunger. While successful in increasing food grain output, this approach widened rural inequalities by excluding rainfed areas and marginalising traditional crops (Dayakar Rao et al., 2021; Eliazer Nelson et al., 2019). Over time, many TRVs and millets were pushed out of farming systems, with some becoming extinct.

Historically, India cultivated over 110,000 rice varieties (Richharia & Govindaswamy, 1966). Today, fewer than 6,000 indigenous varieties remain (Deb, 2019). Millets comprised 20 per cent of India's food basket in the 1960s, and declined to just 6 per cent by 2022 (NABARD, 2023a, pp. 15–28). This shift contributed to nutritional decline because traditional diets rich in whole grains were replaced by refined cereals such as white rice and wheat (Dixit et al., 2011).

TRVs and millets are known for their health benefits and have been used in managing conditions like diabetes, obesity, and cardiac diseases. Blending indigenous practices with scientific methods enhances biodiversity, supports livelihoods, and curbs rural migration (Arunachalam, 2001).

These grains align with the Triple Bottom Line (TBL) framework, which focuses on Profit, People, and Planet (Elkington, 2013). Economically, they support low-input, climate-resilient farming and open niche markets. Socially, they enhance nutrition, preserve culinary heritage, and sustain indigenous knowledge. Environmentally, they maintain agrobiodiversity, reduce chemical inputs, and build ecosystem resilience. Owing to their role in integrating the principles of sustainable development and the TBL framework (Arowoshegbe et al., 2016; Harris, 2001), there is a growing recognition of the importance of conserving them.

Despite their potential, widespread adoption of TRVs and millets remains limited due to low consumer awareness, changing food habits, and market access barriers (Bandaru & Sahu, 2025; Tripathi & Vyas, 2023). In response, a few enterprises have begun employing innovative marketing strategies to create niche markets for these grains. This study aims to explore and map these emerging strategies through an analysis of select case studies. Resilient crops have historically received limited attention in academic research (Agrawal et al., 2025). This study seeks to address that gap.

2. METHODOLOGY

A multiple case study design (Baškarada, 2014; Baxter & Jack, 2008; Yin, 2017) was employed to enable comparative analysis across diverse organisational models. This approach facilitates the exploration of commonalities and divergences in marketing innovations reflected in the value chain practices used by different actors engaged in promoting ancient grains.

2.1 Objective and Research Question

The objective of this study is to **map innovative marketing strategies** that support the conservation, commercialisation, and cultural revitalisation of ancient grains in India.
The central research question guiding this study is: *What innovative marketing strategies are currently being adopted by enterprises to promote traditional rice varieties and millets?*

2.2 Case Study Selection and Rationale

The selected case studies include:

- Dharani FaM Coop in Andhra Pradesh,
- Centre for Indian Knowledge Systems (CIKS) in Tamil Nadu, and
- Bhoomgaadi Farmer Producer Company in Chhattisgarh.

These were chosen through purposive sampling, as they represent diverse geographic regions, stakeholder groups such as tribal women, ecological NGOs, farmer cooperatives, and a range of marketing innovations. All three have shown measurable outcomes in market reach, consumer engagement, and varietal conservation.

2.3 Data Collection

Data was gathered through:

- ***Secondary sources****:*
  - *Scholarly Literature:* Academic publications related to the cases.
  - *Grey literature****:*** Unpublished internal documents sourced directly from the organisations, annual reports, project reports, policy documents, product brochures, websites, promotional content, news reports and published interviews of key stakeholders. This rich secondary data provided a robust foundation for interpretive analysis.

- ***Primary Sources****:* Primary data collection included on-field observations between March 2024 and March 2025, supplemented by telephonic, email and in-person consultations with

key organisational stakeholders. The author's prior collaboration with CIKS in a capacity-building role and with all three organisations in business partnership roles enabled deeper access to operational contexts. This insider perspective enhanced the richness of contextual understanding, and at the same time, reflexivity was consistently maintained to minimise potential bias in the analysis.

2.4 Analytical Framework

Thematic content analysis (Braun & Clarke, 2023) was used to examine the case studies through two lenses: the Triple Bottom Line (TBL) framework (Elkington, 2013) to assess economic, social, and environmental sustainability, and a Value Chain Innovation perspective to understand how ancient grains are repositioned in the market.

Themes were identified across the cases of Dharani, CIKS, and Bhoomgaadi, focusing on branding, product innovation, participatory pricing and certification, logistical improvements, and cultural value. This framework highlights how traditional grains are being reintroduced to modern markets through strategies that combine ecological integrity, consumer appeal, and inclusive development.

3. FINDINGS

3.1 Antiquity of Ancient Grains

Rice has been in cultivation since at least eight and a half millennia in the Indian subcontinent. Remains of charred rice grains dating from 6570 - 4530 BCE were found in Koldihwa, Uttar Pradesh (Paul, 2013). Evidence from the Belan and Ganges valleys reveals that wild Oryza species existed during 5440 BCE and 4530 BCE. Archaeological studies show that rice was central to the mixed farming system of the Indus Valley Civilisation, and cultivated in Kashmir and Harappan regions during the second millennium BCE (Murphy, 2007).

Diverse rice landraces, including Krisanam Vrthina (black rice), Asunam Vrihina (swift- growing rice), Naivaram (wild rice), Mahavrithinam (large rice), and Sukla Vrihi (white rice), are mentioned in ancient Indian Vedic texts like the Samaveda, Atharvaveda, and Yajurveda. Vedic texts also describe rice as ritual offerings, highlighting the deep spiritual importance accorded to rice in Indian culture (Sathya, 2013).

Archaeological and archaeobotanical evidence indicate the early and increasing agricultural significance of small-grained millets in the Indus/Harappan civilisation from the Early (c. 3300–2600 BCE) to Late Harappan (c. 1900–1200 BCE) phases. Species like sorghum, pearl millet, finger millet, and various foxtail millets have been found across approximately forty- five archaeological sites in the Indian subcontinent, dated between 3300 BCE and 500 CE (Pokharia et al., 2014).

Ancient Sanskrit texts, including the Rigveda (1500–1000 BCE), Yajurveda (1200–800 BCE), Atharvaveda (1200–900 BCE), and later religious and legal texts like the Manusmriti (2nd century BCE) and Kautilya Arthashastra (4th century BCE), extensively reference millets (Veerabadhran et al., 2023).

3.2 Medicinal Benefits of Ancient Grains

Ancient grains, like traditional rice and millets, are valued for their therapeutic and nutritional benefits, as noted in Ayurvedic texts (Sathya, 2013; Veerabadhran et al., 2023). Unpolished forms are rich in fiber, minerals, and bioactive compounds, helping manage chronic diseases like diabetes and cancer (Eliazer Nelson et al., 2019; Kowsalya et al., 2022) (Eliazer Nelson et al., 2019; Kowsalya et al., 2022).

Coloured rice varieties offer unique benefits: black rice is rich in tocopherols; red rice, iron and anthocyanins; and brown rice, fiber. Many landraces are used medicinally, such as Kala Jira (strength) and Kalanamak (skin health) (Anuratha et al., 2025). Millets, including sorghum, provide resilience, nutrition, and immune-boosting properties (Ahirwar et al., 2023). Traditional

processing enhances their benefits. These grains offer superior nutrition, support dietary diversity, combat malnutrition, and promote sustainable, healthy food systems (Majzoobi et al., 2023).

3.3 Agroecological Adaptability and Resilience

Traditional crops like millets and indigenous rice varieties demonstrate strong resilience to climate stress, making them key to sustainable agriculture. Millets thrive in diverse agro- climatic zones with minimal inputs, combining traditional knowledge with low environmental impact (Chauhan et al., 2024).

Hill paddy and deep-water rice have been mentioned in the 2500-year-old Jataka tales, indicating resilience and adaptation to different ecological zones (Sathya, 2013). For instance, in Assam, landraces like Dhushuri have outperformed high-yielding varieties under extreme floods (Neog et al., 2016). In Chhattisgarh, tribal areas preserve resilient varieties such as Chudi Dhan and Tulsighati, known for drought tolerance, short maturity, and pest resistance (Dwivedi et al., 2016).

3.4 Varietal Diversity and Decline in India

India's rice heritage is deeply entwined with its cultures. Varieties like Jamai-sal are ritualistically grown (Deb, 2019), and wild relatives, such as Buno dhan, are preserved for their significance. Odisha's tribal farmers cultivate 37 traditional varieties, 11 culturally linked (Mishra et al., 2013). This biocultural diversity is sustained by aesthetic preferences (Deb, 2014) and regional adaptability (Tapasi Das & Das, 2014). Despite this rich heritage, India has seen a significant decline in grain diversity. Historically, over 110,000 distinct rice landraces were documented (Richharia & Govindaswamy, 1966) but today, only about 6,000 folk rice varieties remain (Deb, 2019).

Similarly, millets, once a dietary staple, have been marginalized. In the 1960s, millets were 20% of the national food basket, plummeting to just 6% by 2022. This decline aligns with a 33.9% reduction in millet cultivation area between 1951 and 2022, primarily due to the Green Revolution's focus on rice and wheat (NABARD, 2023a). Millets were unfairly labelled "poor-man’s food" causing reputational loss (B. Dayakar Rao et al., 2021), and per capita consumption dropped from 30.94 kg/annum in 1960 to 3.87 kg/annum in 2022 (APEDA & Yes Bank, 2022).

3.5 Culinary Heritage of Indigenous Grains

Pakadarpanam (meaning the mirror of culinary skills), one of the oldest known texts on cookery, is attributed to King Nala of the Nishada Kingdom, mentioned in the *Mahabharata* (Vana Parva, Book 3). The treatise contains several recipes featuring *anna* (Madhulika, 2017), a term traditionally associated with rice, but one that may also encompass other grains, including millets as in Shree-Anna and clarified by the Prime Minister of India (Yamini C S, 2023).

Many traditional rice dishes in Chhattisgarh, like Angakar Roti, Chausela, Cheela, Dhuska, and Faraa, echo preparations found in ancient Ayurvedic texts (Shukla, 2021). The ceremonial use of specific rice landraces further highlights their cultural and culinary importance. For instance, Tulaipanji is used for weddings and *Annaprasan*, while Osagathiali and Sela are for religious observances. Different landraces are chosen for specific dishes, Chakhao for sweets, Thengaipoo samba for puffed rice, Erra mallelu for kheer, and Kala Birain for rice flakes (Anuratha et al., 2025). These examples showcase a rich gastronomic heritage where indigenous grains are integral to daily diets, spiritual practices, medicine, and celebrations.

3.6 Conservation Initiatives and Revival Efforts

India is seeing widespread efforts to conserve and revive ancient grains like traditional rice and millets, driven by concerns over malnutrition, biodiversity loss, and climate change. These initiatives are active across all regions (Agnihotri & Palni, 2007; Blakeney et al., 2020; Deb, 2014; Rasheed et al., 2021; Rathi et al., 2019; Roy et al., 2018; Sinha, 2016). Government policy now supports millet cultivation (Dept. of Agriculture and Cooperation, 2013; Raina et al., 2022). Millet clusters and Farmer Producer Organizations (FPOs) are promoted for marketing and other

services. National goals include tripling millet production by 2030 and boosting exports (NABARD, 2023b). India designated millets as Nutri-Cereals, declared 2018 the Year of Millets, and led the UN to adopt 2023 as the International Year of Millets (Rajib Kumar et al., 2023). The 2023–2024 budget aims to make India a global millet hub (Ministry of Finance, 2024).

3.7 Emerging Marketing Strategies and Case Examples Case 1: Dharani Model

Managing the triple bottom line, which includes social, environmental, and economic sustainability, requires continuous innovation. The case of **Dharani Farming and Marketing Cooperative Ltd. (Dharani FaM Coop)** in Anantapur, India, illustrates how collective entrepreneurship can promote sustainable development. Established in 2008 and promoted by The Timbaktu Collective, Dharani is a mutually aided cooperative comprising over 2000 smallholder farmers. Operating in a drought-prone region, the cooperative integrates sustainability across the value chain by supporting organic millet production, ensuring fair procurement, and promoting ethical marketing under its own brand, Timbaktu Organic (Sathish Kumar & Shambu Prasad, 2020).

Branding, Market Positioning, and Ethical Retail Strategy: Initially focused on bulk sales, Dharani quickly shifted to retail and brand-building. Drawing on the reputation of The Timbaktu Collective, it launched Timbaktu Organic, which is now a widely recognized brand across South India. With a reach of more than 350 retail outlets, the brand has become synonymous with authentic, clean, and fairly priced organic staples.

Product Diversification and Consumer-Centric Innovation: Dharani tailors its product offerings to different consumer segments. Processing is largely manual, which helps preserve traditional tastes. Some millet recipes, such as *Korra Payasam* and *Korra Pongal*, were once classics in Telugu households but disappeared due to changing dietary habits. These traditional recipes are being revived through ready-to-cook millet mixes (Payasam, Pongal, Sambar Rice, Kichidi, Upma, Kheer, etc.), health-oriented snacks (Murukku, cookies, etc.), beverage mixes (Ragi malt, multi-millet malt, etc.), and staples including various millets, millet flours, millet semolina, and indigenous varieties of colored rice.

Cost-effective Organic Certification: To ensure product quality without imposing high costs associated with third-party certification, Dharani employs the Participatory Guarantee Scheme (PGS), a community-based assurance system that ensures traceability and accountability through local participation.

Promotion, Outreach, and Consumer Engagement: Promotional activities are central to Dharani's outreach strategy. With support from The Timbaktu Collective, Dharani participates in food fairs and organizes food demonstrations in tier-two towns to raise awareness about the nutritional benefits of millets. In addition to local promotions, Dharani engages in in-store sampling and has participates in international expos, increasing its global visibility. This combination of grassroots engagement and international exposure strengthens the brand's credibility and reach.

Case 2: The CIKS Model

The **Centre for Indian Knowledge Systems (CIKS)** illustrates how traditional knowledge and ecological farming can be effectively combined with innovative marketing to promote indigenous crops. Since 1995, CIKS has conserved over 168 traditional rice varieties and scaled up their cultivation through a network of 24,000 farmers across nine districts, organized into 23 Farmer Producer Companies (FPCs) and facilitate the production of over 9,000 tonnes of traditional grains annually (ALC India, 2019).

Supply chain innovations: The foremost priority of conserving TRVs is to ensure a sustainable livelihood for farmers. Also, farmers undertake cultivation of traditional cultivars only when they are convinced that it will provide them a better return in comparison to cultivation of hybrid varieties. Though TRVs generally have comparatively lower yields than modern varieties, the

cultivation cost is also relatively lower. In addition, while modern cultivars are mostly dwarf varieties, TRV crops are much taller, some growing over six feet. This extra foliage provides the opportunity to generate additional income by tapping into the fodder market through the sale of straw as a by-product. Furthermore, to support seed conservation and farmer outreach, CIKS has launched a crowdfunding campaign called *Namma Nellu*, which literally means "Our paddy" in Tamil. Due to this campaign, this phrase is now commonly used to refer to locally grown / community-owned rice varieties.

Product Packaging and Positioning: In response to growing health awareness and cultural interest, CIKS has introduced branded TRV gift boxes to target a niche consumer segment. These include collections such as Pride of Tamil Nadu (featuring 38 native TRVs), Immunity Collection (with 6 immunity-boosting TRVs), and Mother & Child Collection (comprising six healthy and easily digestible TRVs suitable for children, lactating, and expecting mothers), among others. These themed boxes are marketed during festivals and leverage the appeal of nutrition, tradition, and exclusivity (Civil Society, 2025).

Value Addition for consumer convenience: A typical challenge faced by organisations working on TRVs is that these grains are generally coarser than the modern hybrid and finer varieties that consumers are accustomed to. So, instead of marketing rice, the coarser varieties are processed into a broad range of traditional and ready-to-cook products such as porridge mixes, appalams, vadagams and poha (flattened rice). This makes the grains more palatable for present generations and improves consumer convenience by making heritage recipes available off the shelf.

Initiatives for improving market access: In addition to placing products in retail outlets and bulk sales through FPC-led distribution, CIKS has established a direct-to-consumer channel through an e-marketing portal operated by its marketing arm, *Sempulam Sustainable Solutions.* CIKS also broadened the *Namma Nellu* program to organise food festivals using TRVs involving reputed chefs to showcase the culinary possibilities and Ayurvedic practitioners to spread awareness about their health benefits. CIKS also publishes educational content to promote TRVs and these events are leveraged to take the publications to a broader audience. The CIKS model integrates conservation, farmer collectivisation, consumer engagement, and product innovation, offering a replicable approach for building sustainable and resilient agri- food systems.

Case 3: The Bhoomgaadi Model

Promoted by Nirmaan, Bhoomgaadi Farmer's Producer Company Ltd., established in 2016, is a collective of 3,000 tribal organic farmers, primarily women, from the Dantewada district of Chhattisgarh. Drawing on traditional ecological knowledge and natural farming practices, Bhoomgaadi aggregates, adds value to, and markets over 30 organic products, including indigenous varieties of paddy, millets, and other local produce (Nirmaan, 2025).

Community-Led Brand Building and Value Addition: Bhoomgaadi markets its produce under the brand ***Aadim***, symbolizing origin and ancestral roots. All *Aadim* products are chemical-free and cultivated using natural farming methods. Their store, *Jaivik Bazar*, in Dantewada, offers a wide range of organic products, including TRVs and millets. Some of the coarse TRVs are processed into *poha*, which has a large market in central India. Additionally, the *Café Aadim* restaurant in Dantewada offers consumers an organic, farm-to-table experience that features local tribal cuisine and Chhattisgarhi delicacies made with both millets and rice, deepening consumer engagement.

Supply Chain Innovations: To ensure a steady supply of grains, farmers are incentivised through a participatory 'differential pricing mechanism' based on key commodity characteristics such as aroma, grain texture, nutritional value, and medicinal use. Bhoomgadi also circumvents costly third-party organic certifications by adopting the PGS certification by partnering with Centre for Sustainable Agriculture (CSA), Hyderabad **(PGS-India, 2025)**. In addition, Bhoomgadi identified many unique ancient grains such as *Lokti Machi*, an aromatic rice rich in micronutrients, *Chikma* millet, a short-duration, drought-resilient crop used in local tribal rituals, and *Gudma* rice, known for its medicinal properties and use in traditional healing, and promotes their registration under the

Geographical Indication (GI) framework for better market integration and mainstreaming these varieties **(TIW, 2025)**.

Improved logistics for better market access: Due to their remote location in a hilly region, Bhoomgaadi initially struggled with logistical constraints. With very few options, Bhoomgadi relied heavily on Indian Railways and private bus transporters for outward logistics, which limited the geographical reach. In addition, it was time-consuming and laborious to drop off or pick up consignments at the railway station or bus stops. It was even more inconvenient and resource-intensive for the receiver to coordinate with the arrival timings of the train or bus to pick up the consignment. Moreover, Bhoomgadi's target market, mainly organic retailers and distributors, generally order smaller quantities but with higher frequency. This was not possible with the existing options. Bhoomgadi addressed this issue by partnering with Delhivery, a national logistics provider, for pick up and door delivery of consignments. This strategic partnership significantly improved the reach and business viability by allowing faster delivery to any location for even small consignments.

4. DISCUSSION

A cross-case analysis of the marketing approaches of Dharani FaM Coop, CIKS, and Bhoomgaadi, indicates that the following thematic areas are shared across the three organisations, demonstrated through context-specific strategies.

Reframing Ancient Grains through Branding and Positioning: Each model demonstrates a distinct branding strategy. Dharani's *Timbaktu Organic* and Bhoomgaadi's *Aadim*, are developed as institutional brands aimed at product differentiation when placed on shop shelves and also for deeper penetration. In contrast, CIKS's gift boxes and curated rice collections, such as *Pride of Tamil Nadu,* are aimed at creating an image makeover of TRVs, where a premiumization strategy has been adopted by the organisation, through occasion-based gifting, wherein TRVs are marketed to elevate their health and cultural value, thereby reinforcing a premium brand position. The primary objective by adopting this strategy seems to reinforce a better recall value for each of the varieties rather than the institutional brand. These examples demonstrate how branding can transcend commodification by conveying values of locality, health, and tradition and help position ancient grains as premium, health-conscious, and culturally meaningful alternatives.

Integrating culinary heritage with product innovation: A common strategy observed across cases is reconnecting the grains to their culinary roots. There is a growing market for ethnic foods in India, and also a general interest among urban consumers for heritage foods. All three organisations have developed products using traditional recipes customised to local tastes, with specific grains prioritising consumer convenience. For instance, *Timbaktu Organic* developed many packaged ready-to-cook mixes such as Korra Payasam Mix (foxtail millet porridge/ kheer), Bhoomgadi provides a Bastar region farm-to-table experience at Café Aadim and CIKS involves reputed chefs to demonstrate recipes using TRVs. These initiatives translate traditional culinary knowledge into contemporary, user-friendly formats. These approaches preserve gastronomic heritage while responding to modern consumer needs for convenience, authenticity, and nutrition. The rediscovery and promotion of specific landraces for particular dishes strengthen both market differentiation and cultural identity.

Inclusive and Participatory Value Chain Innovations: The case models demonstrate that participatory approaches can be used for addressing certain systemic challenges. Third-party organic certification is expensive and beyond the scope of marginal farmers. Dharani and Bhoomgadi both adopted the cost-effective PGS organic certification to enhance traceability through community involvement. This allows the produce to tap into premium markets which require organic certification. The case models also show that there is a strong buy-in from the farmers when they are involved in the decision-making process. Bhoomgaadi's differential pricing, which is decided by the farmer members themselves, creates incentives for supplying higher grade products to the FPC, thereby strengthening the supply chain.

Strategic use of collaborations: The case models highlight that market asymmetries can be navigated through strategic partnerships. While PGS is cost-efficient, it is process-intensive and requires specialised knowledge of the system. Bhoomgadi's collaboration with CSA strengthens their own capacity for PGS certification. In addition, Bhoomgadi also tackled the logistics issue through its collaboration with a national logistics provider to facilitate last-mile connectivity. CIKS leverages e-marketing platforms through a private firm, Sempulam Sustainable Solutions. All three organisations build their marketing capacities by participation in international fairs such as Biofach.

Cultural Conservation as Marketing Capital: The case models illustrate that linking heritage and ecology with product identity can be a marketable asset, promoting both differentiation and agroecological awareness. CIKS's *Namma Nellu* positioned TRVs such that consumers develop a sense of custodianship and heritage pride. Bhoomgadi's supports GI tagging of lesser-known grains to build awareness of those heritage grains which have a good market potential owing to their taste, aromatic or health qualities.

Building consumer engagement through health: By showcasing the nutritional and therapeutic properties of ancient grains, these organisations blend traditional knowledge and modern wellness trends to engage with health-conscious consumers. This bipartite framing is especially effective in repositioning millets and TRVs as functional foods, or super foods, a term more popular in recent times, rather than subsistence staples.

5. CONCLUSION

This study looks at case analyses of Dharani FaM Coop, CIKS, and Bhoomgaadi. It shows that for reviving India's ancient grains, innovative and value-based marketing strategies are needed. Traditional rice varieties and millets lost prominence during the Green Revolution. However, these enterprises have successfully repositioned them through various methods. Key strategies include positioning heritage foods as premium or convenience foods. This changes these grains from "subsistence foods" to nutritious, desirable products. They also blend culinary traditions with modern convenience through ready-to-cook items and farm-to-table restaurants. Additionally, they employ inclusive value chain methods, such as the cost-effective Participatory Guarantee Scheme (PGS) and participatory differential pricing. By building collaborations with logistics providers and digital marketplaces, and by highlighting the cultural and ecological importance of these grains, these cases offer a model that others can follow. Their experiences show how India can move towards sustainable agri-food systems by connecting heritage preservation with changing market needs while balancing social, environmental, and economic goals.

6. LIMITATIONS OF THE STUDY

While secondary data provided depth, the absence of direct stakeholder interviews limits the study's ability to capture real-time, experiential insights. Future research could incorporate participatory methods to co-generate narratives with farmers, consumers, and intermediaries.

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Eco-Resilient Leadership: A New Paradigm for Sustainable Organizational Success in the 21st Century

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ABSTRACT

An innovative leadership approach is essential for organizational sustainability and addressing societal challenges, including climate change, wage inequality, and technological advancements. An eco-resilient leader demonstrates a comprehensive viewpoint, highlights adaptability, and underscores the significance of environmental conservation. This literature review consolidates definitions, antecedents, and outcomes associated with sustainable leadership by analyzing 60 peer-reviewed studies published between 2020 and 2025, obtained from Scopus and Web of Science. A TikZ map is crucial for depicting the impact of internal and external factors on an organization, encompassing strategic and planning modifications, technological innovations, and regulatory requirements. The graph illustrates the bidirectional effects present in specific sections. The persistence of human control will continue to pose challenges to the adoption of new technologies and lifestyles. Many businesses and educational institutions are poised to implement more environmentally sustainable practices. The acquisition of further information enables us to conduct additional research in leadership studies. Reports indicate the presence of AI-driven leadership programs, with individual governments conducting their own evaluations. Responsible leadership has the potential to enhance global conditions.

Keywords: Eco-Resilient Leader, Sustainable Leadership, New Technologies, Sustainable Development, Employee Well-Being

1. Introduction

In the 21st century, leaders have to cope with a number of problems in the world. For example, climate disasters are getting worse, problems in society aren't going away, and technology is changing a lot because of new technologies in Industry 4.0, such automation, distributed computing, and linked systems. Because of these difficulties, we need to stop leading in the traditional ways that put short-term profits ahead of the long-term health of people and the world. Organizations that work in VUCA (volatile, unpredictable, complex, and ambiguous) situations don't work well with traditional models that depend on economic power and decisions made from the top down. As a result, sustainable leadership has come to be seen as a way to balance economic viability, social equality, and environmental care. But there isn't a clear model in the field that combines ecological awareness and adaptive resilience in a way that works. This makes it much harder to fix things in the world today. Eco-Resilient Leadership (ERL) is a new way of thinking about leadership that includes caring about the environment, working with a number of different people, and being able to evolve in order to make the organization more successful over time and help society as a whole. In ERL, it's more important to be able to adapt to change and take care of the environment than in other kinds of sustainable leadership. We will be able to meet the United Nations' Sustainable Development Goals (SDGs) if we follow these steps. These goals include SDG 13 (Climate Action), SDG 10 (Reduced Inequalities), and SDG 8 (Decent Work and Economic Growth). ERL is different from previous models since it looks at a leader's ability to solve systemic problems while also encouraging innovation, good governance, and the development of long-term value in industry, education, and government. The Brundtland Report, released in 1987, was the first document to introduce the concept of "sustainable leadership." The main point of the article is that long-term growth needs to meet present needs while also being able

to meet future needs. Hargreaves and Fink (2004) present a contemporary paradigm of educational leadership. This shows how important it is to plan, keep learning, and work together for sustainability. In 2005, Avery came up with the business pyramid model. It stressed the need for good leadership, new ideas, and plans that put the needs of all stakeholders first. This early work did not always make it clear that people need to quickly adjust to changes in the world, society, and technology. But it did make it possible for long-term success.
We need ERL more than ever right now. For example, climate change is generating bad weather that makes supply routes less reliable. Also, more and more people want fair regulations and smart ways to use new technology. Because of these problems, we need leaders who can spot dangers and make sure everyone feels welcome. Leaders who can also make sure that their organization's plan is good for the environment all over the world.

This research investigates the question: How can Eco-Resilient Leadership help firms deal with global problems in a way that is good for the environment? There is a methodology section, a literature review section, a conceptual framework section, findings, a discussion section, practical implications, and a conclusion in the paper. The objective of this initiative is to provide an innovative theoretical framework and practical insights to support professionals in various fields.
This part talks about definitions, how theories have changed over time, what past research found, and how to measure them. It uses new studies to show that ERL is a new idea.

1.1 Definitions and Theoretical Evolution

When we lead in a way that combines social, environmental, and economic goals, you are making businesses and society healthier over time. The Brundtland Report talked about the idea of long-term growth in 1987. This hypothesis had an effect on early thoughts about how to run schools. Hargreaves and Fink's (2004) approach, for instance, was built on fairness, deep learning, and making plans for the future. Avery (2005) established the sustainable leadership pyramid, which claims that businesses should have moral leaders, listen to everyone, and come up with innovative ideas. Being able to shift with the times, whether it's with technology or the weather, is very crucial. A lot of the time, these models merely talk about a few things or don't say anything at all.
ERL has introduced two new criteria: ecological mindfulness and adaptive resilience. Being ecologically conscious means knowing how your actions influence the environment. Being adaptable resilient means being able to recognize problems coming and keep the group stable as you deal with them. A responsible leader makes the proper decisions, whereas a green leader makes choices that are good for the world. These are not the same as ERL. The distinctive thing about ERL is that it includes all stakeholders and takes action to safeguard the environment while still being flexible in how it thinks.

1.2 Antecedents of Eco-Resilient Leadership

The causes of ERL function on three levels: the person, the organization, and the situation. Being modest, emotionally intelligent, and thinking that they can make a difference in the world are just a few things that leaders may do to earn trust and get people to change their behavior for the better. We need emotional intelligence to know how other people feel. We need environmental self-efficacy to be more dedicated to your environmental goals. Companies do well when they have cultures that support them, robust corporate social responsibility (CSR) rules, and easy access to resources like green technologies. One way that organizations with good CSR strategies can help the environment is by using a circular economy. Some restrictions limit how quickly ERL can be used, the requirement for the market to survive, and new technology that affects how quickly it can be utilized. Because of tight restrictions on the environment, they have to put low-carbon measures first. People need to know how to utilize computers since technology changes all the time. The antecedents evolve, with organizational support and contextual incentives reinforcing features.

1.3 Outcomes of Eco-Resilient Leadership

ERL needs to operate on many levels to get things done. People who are pleased, engaged, and good at their professions are more likely to go to work and know why they are there. People are

more inclined to stay at their jobs and perform better job if they think they can change them. This is much more true if the people who run the firm care about the environment. With the help of ERL, certain businesses could be able to make more money, be more receptive to new ideas, and be more creative. CEOs who care about the environment typically look for new ways to save money and be ahead of the competition, such as ways to work that don't cost them anything. We can't attain the Sustainable Development Goals (SDGs) without ERL. One of the goals is to make sure that everyone has a good work. Another goal is to cut down on pollution. In the past, businesses that used sustainable supply chain practices made more money.

1.4 Measurement Approaches

ERL is hard to measure because it is made up of many parts. The 15-item sustainable leadership review by McCann and Holt (2010) is a unique way to rate things like making moral decisions and involving stakeholders. They don't talk about how bad the weather is, though. A new study says that these technologies need to get better so that they make better use of resources and hurt the world less. The easiest way to understand how ERL works is to use both numbers and words, such as talking to those who are involved. To operate with ERL's unique method of doing things, future measuring systems will need to have both environmental indicators and measures of resilience. This study examines the potential of ERL to integrate many disciplines of sustainable leadership research by providing a framework for the analysis of evolving environmental, social, and economic concerns

2. LITERATURE REVIEW

This section synthesizes the theoretical and empirical foundations of *Eco-Resilient Leadership* (ERL), a novel framework that builds on and extends sustainable leadership scholarship. By ERL solves the challenges with current models by using ecological awareness, stakeholder involvement, and adaptive resilience. It accomplishes this by addressing the challenges posed by climate calamities, social inequities, and technological upheavals. There are four components to the review: definitions and theory evolution, antecedents, results, and how to measure them. It employs 60 peer-reviewed studies from 2020 to 2025 identified on Web of Science and Scopus.

Definitions and Theoretical Evolution

Sustainable leadership involves measures that protect the long-term health of groups and society by finding a balance between equity, the environment, and economic progress. The Brundtland Report, which came out in 1987, initiated the conversation about how to develop in a way that lasts. Sustainable development involves meeting the needs of the present without making it harder for future generations to do the same. Hargreaves and Fink (2004) were the first to look into how to run schools. The conversation covered a lot of ground, such as deep learning, working with partners, and making arrangements for who will run the school if something goes wrong. Avery's 2005 sustainable leadership pyramid suggests that businesses need to put honesty, inventiveness, and customer demands first if they want to stay in business. But these models didn't always underline how crucial it is to quickly adapt to changes in technology and the environment, which is highly important in today's uncertain world.

Eco-Resilient Leadership (ERL) talks about this. It means being able to be aware of how your activities affect the world and being able to come up with new ideas and get over obstacles. There are differences between responsible leadership, green transformational leadership, and ERL. Being a responsible leader means making decisions based on moral issues. The major purpose of ERL is to help people solve problems in science, society, and the environment. When harsh weather occurs, leaders in the ERL have to deal with challenges in the supply chain that are driven by climate change. They want everyone to be able to help make decisions so that everyone gets a fair outcome**.**

Antecedents

In eco-resilient leadership (ERL), the individual, the group, and the situation are all connected. At each level, it gets easier or harder for leaders to take care of the planet. ERL enjoys things and

people. A modest leader might put the group's aims ahead of their own. After this, people are more likely to trust each other and cooperate together. Being emotionally smart means knowing how we feel and being able to estimate how other people feel. Leaders should assist individuals see things from diverse points of view and make teams that operate effectively together to get more people involved. If we want people to do things that are good for the environment, like lowering the carbon footprints of their businesses, we need to make them feel like they can make a difference. This is called environmental self-efficacy. People in power are more inclined to back programs that get firms to use renewable energy if they want to make the world a better place.

Organisational variables can assist provide the optimal environment for ERL. People who run cultures that care about the environment are more likely to make plans that are good for both people and the environment in the long term. Good CSR models can help businesses learn how to be more environmentally friendly. For example, they can adopt models of the circular economy to make less trash. People need to learn how to utilise green tools and go to training schools for ERL to work. You can use the money you saved for sustainability to develop enterprises that are good for the environment.

People use ERL in diverse ways since they can't fix the problems. The persons in control need to make sure that their plans don't infringe any environmental laws, such as those that limit how much carbon dioxide can be produced. If businesses want to stay in business, they have to obey standards that are healthy for the environment. Many individuals desire to acquire and use items and services that are good for the environment. It's easier to make choices that are beneficial for the environment and work well thanks to modern technologies like data analytics. The workplace is always changing because of environmental, organisational, and human factors. This affects how well people accomplish their jobs.

These items need to function together. A manager can learn to deal with their feelings better if they work in a supportive environment. This style of doing things can be altered because of rules from outside the corporation.

Outcomes

ERL may make a difference in many situations since it affects people, groups, and society as a whole. When people utilise ERL, they are healthier, happier, and more excited about their work. Some people run enterprises with a purpose and sincerely desire what's best for everyone and the world. This keeps individuals on track and stops them from getting too fatigued. Researchers have shown that workers are more interested in their employment and feel safer when their bosses care about the environment.

With ERL, a lot of excellent things can happen for a business. It can make more money, improve, and come up with new ideas. A leader who cares about the environment can find ways to get fresh ideas that are helpful for the environment to the people who need them. It's crucial to save money and take care of the planet at the same time. When companies like ERL manufacture goods without wasting anything away, they have an advantage over their competitors. This is good for the globe. ERL also helps businesses deal with problems in their supply chains that climate change causes.

This makes them more flexible.

ERL helps more people reach the Sustainable Development Goals (SDGs). The 13th target of the Sustainable Development Goals is to stop climate change. This aim goes along with what ERL works to help businesses cut down on their carbon emissions. Anyone may be a leader, which makes it easier to attain SDG 10 (Reduced Inequalities). It makes sure that everyone gets an equal chance. More than anything else, ERL wants enterprises to care about people's health and the growth of the globe. SDG 8 is about making sure that labour is fair and the economy is healthy. This is perfect for that. Sustainable agricultural projects that are beneficial for the environment and administered by leaders have been proven to have a substantial influence on people's health.

The results suggest that ERL can assist people and businesses in modifying how they act to be better for the environment.

Measurements

It's challenging to judge ERL because it has so many various pieces, such as biological, social, and economic ones. It is the only method to rate things like how to make moral decisions, prepare for the future, and get other people engaged. The McCann and Holt (2010) 15-item measure of sustainable leadership is employed. ERL's job is to build areas that can handle shocks. That won't work with the technologies we have presently. A recent study indicates that these gadgets need to be updated so that they show how much garbage and electricity they create and how they affect the planet. We could also learn more about how ERL alters the Earth by looking at its carbon footprint. Using a mix of strategies is a fantastic method to get through the hard sections of ERL. A quantitative survey asks the organisation and its clients questions to learn things like how busy and creative the team is. Talking to people who care about the situation and looking at case studies are two methods to learn about how society and the world alter things. A lot of the new models propose that balanced scorecards should have both common means to measure achievement and environmental markers, such how well resources are used. It may be difficult to measure things in some regions of the world, especially in countries that are not as developed. This is why it is so vital to set laws that everyone can obey and that take into account how people live in various nations. Researchers need to apply well-known testing methodologies for the environmental and resilience elements of ERL. These strategies ought to be effective in any enterprise or nation.

This evaluation shows that ERL is a powerful framework that helps leaders stay in charge for a long time by enabling them to keep an eye on things and make changes when they need to. This collection of definitions, causes, effects, and challenges with measuring might help us decide what to look at next.

3. METHODOLOGY

This study employed an integrative literature review methodology, amalgamating bibliometric and thematic analysis to synthesize current knowledge. We searched Scopus and Web of Science for articles, book chapters, and white papers that were published between 2020 and 2025 and reviewed by experts. We searched for English-language research that demonstrated a definitive link between leadership and sustainability and had been scrutinized by other experts. We talked about "eco-leadership," "sustainable leadership," and "resilient leadership." These rules choose the best 60 of the 150 discoveries depending on how good and how new they are.

The analysis of the data encompassed the subsequent components:

1. **Bibliometric Analysis**: We utilized VOS viewer to do a bibliometric analysis and uncovered research groups and well-known authors who write about things like how to become a leader in higher education and run a business.
2. **Thematic Synthesis**: NVivo's topic synthesis sorted publications into groups based on their subject matter. We spoke about what things mean, how to measure them, and why they happen.
3. **Conceptual Development**: TikZ made a frame to hold the videos together. Coming up with ERL, a new idea and framework that stops people from copying models and maintains things original.

4. CONCEPTUAL FRAMEWORK

Figure 1 depicts how the proposed framework links the causes, actions, and effects of ERL. There are several methods that leaders may get people motivated and assist them come up with new ideas. They can, for example, be humble, obey the rules and tools of the profession (such CSR policies), and operate in a certain way. A lot of things could alter because of these adjustments. Monitors keep an eye on how individuals use technology and the things around them.

5. FINDINGS AND DISCUSSION

There were about 60 research on Eco-Resilient Leadership (ERL) that were looked at. These were done from 2020 to 2025 and were looked over by other specialists in the subject. This section talks about the key results of the study and how people could apply them in their everyday life.

Figure 1 depicts what an eco-friendly boss should do..

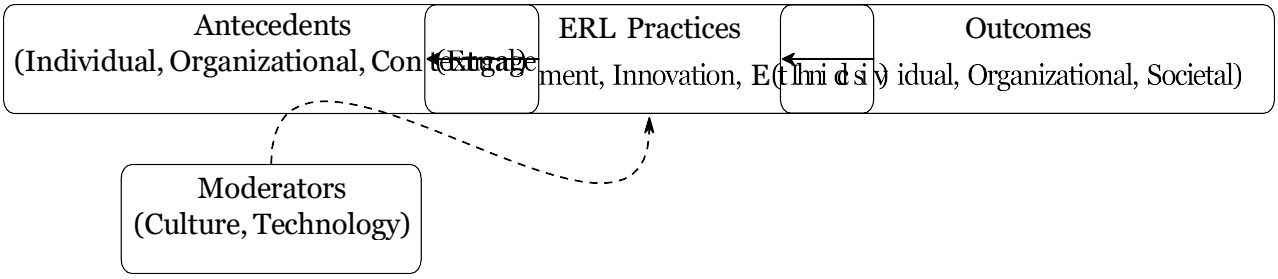

Figure 1: Conceptual Framework for Eco-Resilient Leadership

This study finds a correlation between ERL and long-term success in several domains. It emphasizes problems that need long-term fixes.

Key Findings

We can deal with things like climate change that affect the market or the supply chain this way. Many companies aspire to do good for the environment. ERL gives customers long-term solutions, such as technology that uses less electricity and rounds that keep coming back, to help them do this. CEOs who care about the environment have come up with strategies to generate money while lowering emissions by up to 20% and yet manufacturing items that don't lose value. A leader who is honest, open, and allows everyone to speak is someone people trust. This makes the company look better and stand out.

The UN's Sustainable Development Goals (SDGs) are in line with ERL. It is a better approach to learn. Schools have adjusted how they teach so that youngsters can learn how to be pleasant to other people. This is what makes kids think about and care about the world. Some schools in Europe employ ERL and discuss SDG 13, which is to stop climate change. Students learn how to make a bigger difference in their communities and get more involved in them here.. An eco-resilient leader can engage with people from diverse sections of the government to improve the system. Parks and other green spaces in cities make the place safer and fairer for everyone. We believe that ERL can improve people, groups, and society in a number of ways. It can, for instance, make people happier, more creative, and more useful to society.

Psychology is a significant aspect of ERL since it helps leaders adjust their plans so they can stay alive in the short and long run. Be ready to modify when things aren't clear, as when new rules, technology, or market needs come up. We found that companies do better when their CEOs care about the environment. This is how they can keep your trust and do the right thing. Based on these results, ERL looks like a better and more modern technique to fix things. It works now and will for a long time.

Practical Implications

It tells businesses and people who want to use ERL to remember a few crucial points. Being cognizant of the environment and including everyone who has a stake in the business are two extremely essential parts of ERL. These are things that a lot of leaders should know. We can learn how to figure out how a project might affect the world by going to school. CEOs who have been in the industry for a while and care about the environment should help new CEOs. These CEOs should show the new managers how to run a business that serves people and how to think about

how things fit together. If leaders learn about programs like these, they may opt to do things that are better for the world. They may, for instance, pick energy sources that can be used more than once. This would help them use fewer of their goods.

In the classroom, ERL can help the school run efficiently and keep everything in its place. ERL can assist government workers in thinking of innovative approaches to draft legislation. The government and businesses can work together to pay for projects that consume less energy. If businesses gain tax cuts or other financial aid, they might be more likely to use ERL. Companies can obtain money if they reach particular environmental targets that can be measured, such as hiring individuals from different backgrounds or cutting down on all of their carbon emissions. Businesses in Scandinavia have received tax benefits that are good for the environment. Because of this, emissions have gone down a lot in some regions.

People care about ERL because it helps businesses, communities, suppliers, and regulators work together to make networks. They might set up areas for people to discuss about how to be more eco-friendly to make sure that their goals are in accordance with what society wants. Companies that use ERL to plan for the long term may be better able to deal with shocks from the outside and assist the world accomplish its sustainability goals. This is a great sign that things are getting better and changing.

Challenges

When we try to use ERL, we run into a number of complications. Each one will need a different solution. It's challenging because people don't want to change. This is especially true for business owners who want to make money now instead of later. People who create items don't want to transition to eco-friendly ways because they think it will be too expensive. We need to employ change management to get people to change their beliefs. A lot of business leaders who care about the environment don't know how to use data analytics and other tools to assist them make decisions that are good for the environment. This is a worry of not being smart enough when it comes to technology. This is really essential because it's hard to get skilled workers and technology in countries that aren't doing well.

When the numbers continually changing, it's harder to use ERL. The sustainable leadership questionnaire by McCann and Holt (2010) and other instruments don't do a good job of bringing together the ecological and resilience elements of ERL. This makes it hard to understand the results. We may learn how to protect animals and cut down on carbon emissions in a number of ways. Most people can still detect when a firm is making money, though. It is hard to use ERL in countries with different economies and cultures. This research from a developing nation illustrates the necessity of modifying ERL to align with the requirements of its inhabitants. Some people think it's preferable to be a good boss with other people than to be a good boss on your own. This means that the answer will be different in each case.

Companies should pay for programs that teach their employees new skills, such how to use technology properly and learn about various cultures. Policymakers should set aside money for research on common ERL standards and get countries to work together to find the best methods to improve these programs.

6. CONCLUSION

Businesses will have to deal with a multitude of difficulties in the future, like climate change, social and economic inequality, and new technology. The study looked at 25 books that came out between 2020 and 2025. It says that ERL is a terrific idea that could make things better. These goals don't hurt anyone, not even the people who are attempting to accomplish them. It can also help people feel better and eat better. Things will get better, but there will be more to do. These are the tenth and thirteenth goals. They both said they would do everything they could to reach all three goals by 2023. It teaches you how to use business tools, get ready for the future, and get along with other people. In other domains, the market and the norms are also quite significant.

According to Rosário and Boechat, this strategy has everything we need to be a good boss for a long time.

People can use ERL to do whatever they want. Many other things have also altered. If CEOs really cared about the world, they could cut CO2 emissions by up to 20%. There are a lot of methods to use ERL, and some of them could be hard to understand. Boeske (2023) says that it's hard for people who work for a company to move to another one. They don't want to change because they want to make money fast. They've been there for a while. A supervisor needs to know how to use technologies like data analytics to make good choices. Pereira, Temouri, and Wood are all folks who have a hard time learning new things. This is quite important if you don't have a lot of money. Even with the technologies we have now, we don't know how to make ERL work in a way that improves the world and lasts. The McCann and Holt (2010) study on long-lasting leadership is one example. In 2022, Zhao and Li thought this was bad. We could be better manager if we pay attention to how our employees act and get along with each other. People from all over the world agree that schools that teach English as a foreign language (EFL) need to improve. People who think differently about what society is should actually do this. With this, we might be able to learn how they change people over time. People from all over the world agree that schools that teach English as a foreign language (EFL) need to improve. People who think differently about what society is should actually do this. With this, we might be able to learn how they change people over time. People all throughout the world utilise ERL. We can see that great ideas can transform how things are used in ways we didn't predict. One method to do this is to read what Gerard, McMillan, and D'Annunzio-Green (2017) state. Boeske remarked in 2023 that we should check ourselves often to make sure we are protecting species, using resources wisely, and not wasting too much. We could give things better scores if we had this. Pereira, Temouri, and Wood think that new data tools could be very good for the globe and the ERL. They say we should learn more about it this year. People from all across the world can chat about excellent ideas at the UN.

If we give them the right tools, difficulties can help them find new ways to do things and do them well. They see things from different angles. Rosário and Boechat's 2025 study on stakeholders and internal resiliency has changed how we think about leaders. If people in power worked collaboratively, they could reach the Sustainable Development Goals (SDGs) faster. People that work in the field utilise ERL. This will help us get things done faster. Read about ERL's goals and objectives to help the people in charge learn how to deal with issues. Nothing awful will happen.

Great idea that might make things better. These goals don't hurt anyone, not even the people who are trying to reach them. It can also make people feel better and eat better. Things will get better, but there is still work to do. These are the 10th and 13th goals. They both promised to do everything they could to meet all three goals by 2023. It shows us, how to use business tools, plan for the future, and get along with other people. The market and the rules are also very important in other areas The 2025 study by Rosário and Boechat on stakeholders and internal resilience affects how we think about leaders. If those in authority worked together, the Sustainable Development Goals (SDGs) could be accomplished faster.

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Role of Innovativeness in shaping Job Seekers Attitude and Behaviour towards Job Portals

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ABSTRACT

The digital transformation of recruitment has significantly reshaped job search processes, positioning job portals as essential platforms connecting job seekers with employers. This research investigates the effect of job seeker's innovativeness, as a multidimensional construct, encompassing innate, adoptive, and usage levels on both their attitude toward job portals and their usage behavior. A cross-sectional survey of 542 job seekers in Pune, India, was conducted using structured questionnaires and validated measurement scales. Data analysis employed exploratory factor analysis (EFA), structural equation modelling (SEM), and multivariate statistical techniques. Findings reveal that job seeker's innovativeness significantly influences job portal usage but does not impact attitudes, contradicting conventional digital adoption models. This discrepancy is attributed to habitual or necessity-driven usage, external factors shaping perceptions, and an exploratory mindset among innovative users. The study provides actionable insights for job portals to enhance engagement strategies, improve user experience, and refine recruitment processes. It also highlights implications for digital literacy, platform trust, and personalization. While limited to a specific geographic region, future research can extend across diverse job markets for broader applicability.

Keywords: Job Seeker, Job Portal, Job search, Digital literacy, Innovativeness, Consumer behaviour, Engagement strategy

INTRODUCTION

The rapid digitalization of recruitment processes has revolutionized the way job seekers connect with potential employers, making job portals indispensable in the modern hiring landscape. These platforms offer a centralized and efficient means of searching for job opportunities, enabling candidates to filter listings based on skills, experience, and preferences. Employers, in turn, benefit from advanced applicant tracking systems, candidate matching, and automated screening tools that streamline recruitment. The integration of digital features such as virtual interviews, skill assessments has further enhanced the job search experience, making it more dynamic and data-driven. As businesses continue to adopt digital-first hiring strategies, job portals play a crucial role in bridging the gap between talent supply and demand while ensuring accessibility, efficiency, and inclusivity in the recruitment process (Patwardhan, 2016).

As job seekers increasingly depend on online job search mechanisms, it becomes essential to understand the factors influencing their attitudes and behaviors toward these platforms. Elements such as ease of use, trust in digital recruitment processes, perceived effectiveness, and technological adaptability play a crucial role in shaping user engagement. Personal characteristics, including innovativeness, digital literacy, and job search experience, further determine how individuals interact with job portals. Additionally, platform-specific features like resume-building tools, employer ratings impact job seekers' perceptions and willingness to adopt digital job search methods. By analysing these factors, businesses and platform developers can enhance user experience, improve recruitment outcomes, and ensure that job portals effectively bridge the gap between candidates and employers in the digital job market (Patwardhan and Risbud 2025).

Among these factors, innovativeness, defined as an individual's willingness to adopt new technologies and approaches, plays a crucial role in determining how job seekers engage with job portals.

LITERATURE REVIEW

Consumer innovativeness refers to an individual's tendency to adopt new products, services, or ideas earlier than others, driven by various motivations and behaviours (Midgley and Dowling 1978; Rogers 2003). It can take different forms, such as functional innovativeness (focused on practical utility), hedonic innovativeness (seeking pleasure or excitement), cognitive innovativeness (satisfying intellectual curiosity), social innovativeness (seeking social recognition), experiential innovativeness (pursuing new experiences), personal innovativeness (driven by self-improvement), and technological innovativeness (Hirschman 1980; Venkatraman 1991; Goldsmith and Hofacker 1991). These variations reflect the diverse psychological and behavioural factors influencing consumers' adoption of innovations.

Innovativeness is characterized as a willingness to explore and adopt new ideas, products, services, and practices rather than sticking to familiar choices. Researchers have debated whether innovativeness is a central, enduring trait (Midgley and Dowling, 1978) or a behavioural tendency shaped by external factors (Goldsmith and Hofacker, 1991). It is influenced by personality traits such as risk tolerance, autonomy, cognitive style, and a desire for novelty. Understanding customer innovativeness enables businesses to effectively design and market new products, identify early adopters, tailor marketing strategies, enhance customer experience, and maintain competitiveness by aligning innovations with consumer expectations (Gatignon and Robertson 1985; Roehrich 2004).

Considering the levels of generality / specificity, different authors have identified innovativeness at different levels of abstraction. These conceptualizations of innovativeness are

- Social Innovativeness: Relatively early adoption of an innovation in one’s social system (Roehrich 1994).
- Behavioral Innovativeness: Degree to which an individual adopts innovation (Rogers 1995).
- Open Processing Innovativeness: General tendency (not related to specific area) to be open to new ideas.
- Hedonic Innovativeness: Drive to adopt innovation for hedonic reasons (enjoying the newness of the product (Roehrich 1994).
- Business Innovativeness: Innovativeness on behalf of an organization involving wide spectrum of original concepts, development of new ways of doing business, new business models, business application of technology and communications, new management techniques, environmental efficiency, new forms of stakeholder participation, telecommunication, transport and finance.
- Personal Innovativeness in Information Technology: refers to the willingness of an individual to try out any new information technology (Compeau and Higgins 1995; Agarwal and Karahanna 2000).
- Website Innovativeness: It is consumer’s perception of how frequently a website introduces and updates new features that are beneficial for him. It encompasses appropriateness, novelty and updating dimensions of innovativeness (Anik St-Onge and Jean-François Ouellet 2009).
- Global Innovativeness - Similarities and differences in individual’s intellectual, perceptual, and attitudinal characteristics to adopt new products across different countries of the world (Joseph and Vyas 1984; Tellis and Bell 2009).

Consumer innovativeness i.e. the tendency to buy new products, brands soon after they enter the marketplace (Steenkamp, Hofstede and Wedel, 1999) was proposed at two levels by (Lassar, Manolis, and Lassar 2005), i.e.

- Innate Innovativeness – It is a generalized unobservable trait. It is not related to specific area but rather a general tendency. It is also called as global consumer innovativeness (Leavitt and Walton 1975; Midgley and Dowling, 1978; Im, Mason, and Houston 2007). and
- Actualized Innovativeness (a behaviour) - Actualized innovativeness is further categorized into
  - ✓ Generalized actualized Innovativeness - purchase of new products in different product categories.
  - ✓ Product category specific actualized Innovativeness - purchase of new products within a single product category. It is motivated by a mix of innate innovativeness (II) and interest in product category (IPC).
  - ✓ Single product actualized Innovativeness (domain specific innovativeness) - tendency to look for, learn and adopt new products in a single product category or specific domain of interest (Goldsmith and Hofacker 1991; Citrin et al., 2000).

Innovativeness has received considerable attention among consumer researchers (Park and Jun 2003) and has been conceptualized further depending upon specific research goals, **as below**

- Cognitive Innovativeness (Hirschman 1984; Venkatraman 1991) - consumer's tendency to think, to rationalize, and to solve problems or other mental exercises.
- Sensorial Innovativeness (Hirschman 1984; Venkatraman 1991) - refers to consumers' preferences for experiences that may stimulate their senses.
- Vicarious Innovativeness - innovativeness through advertising and word of mouth - adopting the product concept without adopting the product itself (Hirschman 1980; Im, Mason and Houston 2007). It not related to specific area but rather a general tendency.
- Adoptive Innovativeness (Hirschman 1980) - refers to the actual adoption of a new product.
- Use Innovativeness - applied to products that have already been adopted by a consumer. Use innovativeness lead to User innovativeness (Rosen 2005).
- User Innovativeness - It refers to innovation by intermediate users (user firms) or consumer users (individual end-users or user communities). When individual users face problems, they develop their own modified or customized version of the existing product or service, or to look for entirely new product or service, to solve their issues (Tuomi and Ilkka 2002). It is concerned with use and configuration of existing products and technologies (Kwon, Choi, and Kim 2007).
- Service Innovativeness (Chapman, et al 2003) also known as technological innovativeness - typically leads to new products or services of some form.
- Non-Technological Innovativeness (Soft Innovativeness) – focuses on other things such as organizational issues, processes, management practices, organizational structures, customized services, enhance networking, improve distribution, and advance procurement (Howells 2001).

Differences in conceptualization of innovativeness led to a wide range of scales which have been developed to measure innovativeness at different levels of abstraction. In general, these scales range from a global or abstract level (Kirton 1976; Hurt et al 1977) to consumer specific innovativeness (Baumgartner and Steenkamp 1996) to more concrete scales which attempt to measure consumer innovativeness within a specific product domain (Goldsmith and Hofacker 1991). Different research goals and conceptualizations have also led to scales designed to measure hedonic and social innovativeness (Roehrich 1994), global consumer innovativeness (Tellis, Yin, & Bell, 2009) and even teen innovativeness (Hartman, Gehrt and Watchrevringskan, 2004). Some studies have used innovativeness scales independently, while others have used them with demographic and personality variables. In addition to comparing the direct impact of innovativeness on adoption behaviour, a large number of studies have attempted to develop more sophisticated models which incorporate other constructs (e.g., perceived risk, attitudes and cognitive style) in order to better examine what influences consumer's likelihood of new product adoption.

For successful job seeking through job portals, innovativeness on behalf of job seekers is expected at multiple levels. It is required at innate level (general tendency - internet) at adoptive level /

domain (IPC) level (product specific - job portals as internet-based service) as well as at use level (novel and creative use of internet and mobile applications to interact and transact with job portals). Hence, as prior studies came up with different innovativeness constructs based on differences and types in conceptualization, current research conceptualized more comprehensive, holistic, multidimensional innovativeness relevant to job seekers into a construct known as job seeker's innovativeness.

Marketing literature and empirical studies have consistently shown a positive correlation between innovativeness and consumer behaviour. Research indicates that higher innovativeness is linked to perceived usefulness, ease of use (Jia Jia Sim et al., 2011) and acceptance of information technology, including e-commerce (Ignacio, Bosque and Crespo 2008). It also influences attitudes and online purchase intentions (Goldsmith 2000; Limayem et al., 2000; Chiu et al. 2005; Cowart, Fox, and Wilson 2007), as well as behaviours such as information seeking (Baumgartner & Steenkamp 1996), referral opinions (Lee, Qu Kim 2007), and frequent online shopping ((Limayem et al., 2000; O'Cass and Fenech 2003).

Additionally, innovativeness shapes perceptions of social and technical characteristics (Rogers, 1995; Agrawal and Prasad 1998), future online intentions (Enrique Bigné-Alcañiz et al., 2008), and overall consumer attitudes toward digital platforms. Studies further highlight its impact on online attitudes, purchasing behaviour (Wood and Swait 2002; Hyun-Joo Lee and Patricia T. Huddleston, 2010), and engagement with digital marketplaces, reinforcing the critical role of innovativeness in shaping consumer interactions with emerging technologies.

Earlier studies have linked innovativeness to various factors, including self-efficacy (Kumar and Uzkurt, 2013), demographics (such as age, income, education, gender, and mobility), and socio-economic aspects like occupational status, urbanization, and standard of living (Frank et al., 2006; Dobre C., Dragomir and Preda 2009). Research also indicates a relationship between innovativeness and behaviours such as using the internet for information search (Ha and Stoel, 2004), online shopping frequency, word-of-mouth influence (Brengman and Geuens 2003), and future online purchasing intentions (Park and Jun, 2003).

Additionally, innovativeness is associated with individual behaviour, perceived risk, self-congruence (Cowart, Fox and Wilson 2008), cultural values (Tellis et al., 2009), social participation (Grewal, Mehta & Kardes 2000; Rogers 2003), and product involvement (Wood and Swait, 2002). These findings highlight the broad impact of innovativeness on consumer decisions, digital engagement, and adoption of new technologies across different socio-demographic groups.

Domain-specific innovativeness (DSI) refers to a consumer's tendency to adopt new products or services within a specific category, distinguishing it from general innovativeness. The construct gained prominence after the development of the DSI scale by (Goldsmith and Hofacker 1991). (Araujo et al. 2016) conducted a meta-analysis of 78 studies involving 40,641 participants, revealing strong links between DSI and factors like innovation adoption, attitude, behavioral intention, product usage, opinion leadership, and risk perception. The study also highlighted how research methods and regional differences influenced these relationships.

DSI has also been studied in the context of online shopping. (Lee and Huddleston 2010) examined its relationship with perceived risk, identifying privacy, time, performance, and financial risks as key deterrents to online purchases. Their study found that DSI directly influences online buying behavior, with perceived risk playing a mediating role. Additionally, (Kaushik, Kumar and Rahman 2014) reviewed literature on consumer innovativeness, linking DSI with innate innovativeness and innovative behavior.

While prior research has established innovativeness as a key determinant of online users' perceptions, intentions, attitudes, and behaviors, some studies have identified gaps and contradictions. Research by (Steenkamp et al. 1999) found that innovativeness varies across

countries, despite common demographic traits among innovators. (Lu, Yao, and Yu 2005) argued that innovativeness in new technology does not always influence the intention to adopt it, emphasizing the need to consider product categories in e-commerce adoption. Additionally, studies have found negative relationships between innovativeness and factors such as computer anxiety (Harris 1999), social comparison tendencies (Clark and Goldsmith 2006), age, and price sensitivity. These findings suggest that while innovativeness plays a crucial role in digital adoption, its influence can be affected by demographic, psychological, and contextual factors.

Despite extensive research, the study of consumer innovativeness remains challenged by a lack of consensus on its definition and measurement (Tellis and Griffin 2005). Researchers have debated the validity of the innovativeness construct (Hodges 2009) and the reliability of its scales, with concerns over internal consistency, scale structure, and discriminant validity (Roehrich 2004). Various measurement models, such as the Domain-Specific Innovativeness (DSI) scale, have faced criticism. Studies suggest that DSI is heavily influenced by interest in the product category (IPC), raising questions about its validity (Kee and WAN 2004). Additionally, research has found that the DSI scale becomes ineffective in predicting online purchase frequency when incorporated into models that include purchase intention, highlighting the need for more precise measurement approaches.

Hence by considering the essentiality and relevancy of innovativeness to job seekers (proposed multidimensional construct) for gainful outcomes while interacting / transacting with job portals, and inconsistencies identified through above discussed literature, it was proposed to study how job seeker's innovativeness influences job seeker's attitude towards job portals and job seeker's usage of job portals as an online job seeking avenue.

Research Objective

To study the role of job seeker's innovativeness in shaping job seeker's attitude towards job portals and job seeker's usage of job portals.

Research Hypotheses

H1- Job seeker's innovativeness influences job seeker's attitude towards job portals.
H2 - Job seeker's innovativeness influences job seeker's usage of job portals.

RESEARCH METHODOLOGY

In order to achieve the research objectives and test the proposed hypotheses, a structured and methodologically sound approach was essential to ensure a systematic and reliable examination of the relationship between job seekers' innovativeness, their attitudes toward job portals, and their usage behavior. This study adopted an empirical methodology, integrating both quantitative and qualitative methods to provide a comprehensive understanding of these dynamics. The research design, sampling strategy, data collection methods, and analytical techniques were carefully selected to uphold the validity and reliability of the findings.

This study followed a positivist research philosophy, characterized by an empirical, deductive, hypothesis-driven, and quantitative approach. The objective was to scientifically analyze how job seekers' attitudes toward job portals are shaped and how these attitudes influence portal usage. A descriptive research design was chosen to systematically outline job seekers' characteristics and identify relationships between key variables. The study adopted a cross-sectional survey design, focusing on reporting empirical findings rather than establishing causality.

The demographic scope of the study was defined using key variables such as job seekers' age, gender, profession, total work experience, highest formal education level, and gross annual personal income, categorized into class intervals. Geographically, the study was conducted in Pune, Maharashtra, India, covering Pune city, Pimpri-Chinchwad town, and 11 assembly constituencies, spanning an area of 9,220 km².

A total of 542 job seekers were surveyed using a simple random probability sampling technique. A structured questionnaire served as the primary research instrument, incorporating 7-point Likert scales to measure job seekers' innovativeness as psychological construct. The scale underwent rigorous validation through unstructured interviews with job portal executives and discussions with experienced job seekers to refine wording and ensure content validity.

Additionally, a pilot study was conducted to enhance the questionnaire's internal validity through descriptive analysis, and Cronbach's alpha was calculated to establish reliability, with a threshold value of 0.70. The adequacy of the data for factor analysis was further confirmed through the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity.

Data analysis was conducted at multiple levels. Initially, univariate analysis was performed using frequency tables and measures of central tendency. Bivariate analysis followed, utilizing techniques such as cross-tabulation and correlation coefficients to explore relationships between key variables. To generalize the findings, inferential statistics were employed, and multivariate analysis was conducted using factor analysis. Exploratory factor analysis (EFA) was performed to identify underlying data constructs and validate item relationships, employing varimax rotation for clear factor separation and data reduction. This approach facilitated hypothesis testing and pattern identification. Finally, structural equation modeling (SEM) was utilized to test the proposed hypotheses, ensuring a robust analytical framework for evaluating the research model.

CONCEPTUAL SCOPE

Concepts of social science being often abstract and unclear, for the study the same were operationalized as below.

1. Job Portal: It is a third-party specialized recruitment website (an online destination operated by a legal entity) where job opportunities are listed with the aim to connect jobseekers to those who seek them (recruiters).
2. Consumer (Job Seeker): A **person** who is looking for a job or who wants to change his / her current job. The study included all those individuals who are currently registered with any job portal/s and all those who in the past have interacted / transacted with job portal/s as registered job seeker.
3. Job Seeker's Innovativeness: This refers to a job seeker's willingness, receptiveness, or tendency to explore, experience, and adopt new ideas, products, services, brands, and practices instead of adhering to previous choices, systems, and usage patterns. It encompasses creativity (lateral or out-of-the-box thinking), responsiveness, flexibility, cognitive abilities, diverse experiences, and open-mindedness (a willingness to challenge assumptions) in utilizing job portals as an online job-seeking platform. Additionally, it includes a job seeker's ability to manage risk, demonstrate self-reliance, engage in active problem-solving, and leverage material resources and personal attributes while interacting with job portals. The study conceptualized job seekers' innovativeness at three levels: the innate level (general tendency - innovativeness regarding the internet as a channel), the adoptive/domain level (interest in a specific product category, i.e., job portals as an internet-based service), and the usage level (novel and creative applications of the internet and mobile technology for interacting and transacting with job portals).

Demographic Characteristics of Respondents

- Out of studied 542 respondents (job seekers), 461 (85.1%) respondents were found presently registered with the any job portal/s whereas 81 (14.9%) respondents were found previously registered – presently unregistered with any job portal/s.
- The studied job seekers were representing alike different primary professions including IT / ITES, education, service, consultancy, marketing / retail, insurance / banking / finance, auto / manufacturing / engineering etc.

- 192 (35.4%) respondents were representing age group 18 Years to 25 Years, 199 (36.8%) respondents were representing age group 26 Years to 30 Years and 109 (20.1%) respondents were representing age group 31 Years to 35 Years.
- 340 (62.7%) respondents were male whereas 202 (37.3%) were female respondents.
- Majority of the respondents (97%) were possessing up to 15 years of total work experience in full time employment.
- 54.8% respondents were post graduate, whereas 40.7% respondents were graduate.
- 13.7% respondents were having their gross annual personal income more than 10 Lakh rupees. Whereas rest 86.3% respondents were having their gross annual personal income less than 10 Lakh rupees.

Instrument Validation and Reliability Analysis

Table 1: Scale Description and Reliability of Scale

Construct	**Job Seeker's Innovativeness**
Name of the scale	Job Seeker's Innovativeness Scale (JSIS)
No. of Items	08
Total Cases (N)	542
Valid Cases	539
Valid cases %	99.4
Scale Mean	39.77
Scale Variance	124.37
Scale SD	11.15
Cronbach's Alpha	0.893

Table 2: Result of KMO & BTS Test (For sampling adequacy and sampling confidence supporting factor analysis)

Name of the scale	**KMO Measure of Sampling Adequacy**	**Bartlett's Test of Sphericity**		
		Approx. Chi-Square	**Difference (df)**	**Significance**
Job Seeker's Innovativeness Scale (JSIS)	0.730	2922.74	28	.000

Exploratory Factor Analysis

Table 3: Construct – Job Seeker's Innovativeness

Code	**Statement**
I1	I prefer using online job-seeking platforms over traditional job search methods.
I2	I am willing to try new job portals even if I am unfamiliar with them.
I3	I am eager to explore new technologies and digital platforms for job searching.
I4	I experiment with different ways of networking and applying for jobs through online platforms.
I5	I use multiple online channels (e.g., social media, professional networks, niche job portals) for job searches.
I6	I actively seek information about new trends in online job searching.
I7	I create and optimize my online professional presence (e.g., LinkedIn, personal websites) to improve job prospects.
I8	I integrate mobile apps, AI chatbots, and other digital tools into my job search process.

1 = Extremely Unlikely, 2 = Moderately Unlikely, 3 = Somewhat Unlikely, 4 = Not Sure, 5 = Somewhat Likely, 6 = Moderately Likely, 7 = Extremely Likely

The scree plot indicated three dimensions resulted out of the factor analysis. The three factors in combination explained 85.829% of the total variance of which 39.056% was explained by one component and 26.563% was explained by another component (dimension) and 20.210% was explained by 3rd component. Further cross loadings were verified through rotated component matrix and items with cross loading more than .5 were put for elimination. No item exhibited cross loading. Hence all 8 items were retained. Those were segregated in three dimensions as below (Table 4).

Table 4: Identification of dimensions and factor loadings

Dimension	Item No.	Mean	S.D.	Loading	α #	AVE	N. Items
D1 Innate Innovativeness	I1	5.28	1.238	0.724	0.864	39.056	3
	I2	5.74	1.351	0.787			
	I3	5.59	1.294	0.753			
D2 Adoptive Innovativeness	I4	5.02	1.183	0.689	0.849	26.563	3
	I5	5.23	1.237	0.717			
	I6	5.14	1.215	0.705			
D3 Use Innovativeness	I7	5.44	1.283	0.746	0.837	20.210	2
	I8	5.78	1.357	0.792			

FINDINGS

Table 5: Corelations of Job Seekers' Innovativeness with identified aspects / variables.

Aspect / Variable	Job Seekers' Innovativeness (Association & Test)
Job Seeker's Primary Profession	Extremely Good Relation Cramer's *V* value = .461
Job Seeker's Age	No Relation Spearman's rho (p) = -.035, Sig. (2-tailed) = .421
Job Seeker's Gender	Extremely Good Relation Cramer's *V* value = .432
Job Seeker's Total Work Experience	Significant but Weak Relation Spearman's rho (p) = -.115, Sig. (2-tailed) = .007
Job Seeker's Work Experience (Abroad)	Extremely Good Relation Cramer's *V* value = .545
Job Seeker's Work Experience (working in different city/s)	Strong Relation Cramer's *V* value = .412
Job Seeker's Formal Education	Extremely Good Relation Cramer's *V* value = .470
Job Seeker's Possessing Professional Certification	Extremely Good Relation Cramer's *V* value = .430
Job Seeker's Gross Annual Personal Income	No Relation Spearman's rho (p) = .052, Sig. (2-tailed) = .229
Type of Job Seeker	Extremely Good Relation Cramer's *V* value = .445
Job Seekers Seeking Change in Industry / Sector	Extremely Good Relation Cramer's *V* value = .474

Aspect / Variable	Job Seekers' Innovativeness (Association & Test)
Job Seekers Seeking Different Profession/S	Extremely Good Relation Cramer's *V* value = .417
Job Seekers Looking to Change Job Location	Extremely Good Relation Cramer's *V* value = .479
Job Seeker's Tenure of Registration	Significant but Weak Relation Spearman's rho (p) = -.134, Sig. (2-tailed) = .002
Job Seekers Getting Job Through Job Portals	Extremely Good Relation Cramer's *V* value = .413
Frequency with Which Job Seekers Update their Job Profile	Very Strong Relation Cramer's *V* value = .385
Expecting Different Identified Benefits from Job Portals	Extremely Good Relation Cramer's *V* value = .432
Job Seekers Actively / Passively Seeking New Job	Significant but Weak Relation Spearman's rho (p) = -.262, Sig. (2-tailed) = .000
Job Seekers Subscribing to Different Types of Services	Strong to Extremely Good Relation Cramer's *V* value = .439
Job Seekers Exploring Different Avenues to Know About Job Portals	Strong to Extremely Good Relation Cramer's *V* value = .416
Job Seekers Posting Comment about Job Portals by Using Various Modes of EWoM	Very Strong to Extremely Good Relation Cramer's *V* value = .427
Job Seekers Seeking Feedback About Job Portals	Extremely Good Relation Cramer's *V* value = .429
Job Seekers Actively Using Various Online Applications	Extremely Good Relation Cramer's *V* value = .456
Rating Job Portals as an Online Job Seeking Avenue	Not Helpful Pearson's Correlation = -.052, Sig. = .225

Table 6: Hypothesis Testing Result & Interpretation

	Hypothesis	Structural Path	SRW	SE	CR	p	Result
H1	Job seeker's Innovativeness influences job seeker's attitude towards job portals.	Innovativeness → Attitude	0.05	.045	0.703	.224	Not Supported
H2	Job seeker's Innovativeness influences job seeker's usage of job portals	Innovativeness →Usage	.048	.046	8.886	.001	Supported

SRW = Standardized regression weight SE = Standard Error
CR = Critical Ratio P - Value < 0.001

DISCUSSION

Innovativeness is characterized by an individual's willingness, openness, or inclination to explore, experience, and embrace new ideas, products, services, brands, and practices instead of sticking to previous choices, systems, and consumer habits. Prior research has conceptualized innovativeness in various ways. Recognizing the need highlighted by (Lu, Yao, and Yu 2005) to assess

innovativeness within specific product categories during e-commerce adoption, this study introduces job seeker's innovativeness as construct.

By identifying the requirement of innovativeness of the job seeker at multiple levels, this study constructed job seeker's innovativeness scale by adopting innovativeness aspects at innate level, at adoptive level, as well as at use level. By methodically constructing the suggested scale, by validating it further for appropriateness and clarity through unstructured interviews with experts (executives from popular job portals) and through factor analysis, this study addressed the issues raised during prior research regarding structure, validity and internal consistency of various adoptive innovativeness scales (Roehrich 1994; Kee and Wan, 2004; Hodges 2009). Suggested job seeker's innovativeness scale was found reliable and the scale items were found internally consistent. By extracting three dimensions through exploratory factor analysis, the study validated job seeker's innovativeness construct.

Researchers have previously claimed that consumers' innovativeness influences their online intention and attitude towards e-commerce. Contradictory to these results, it was found that job seeker's innovativeness does not influence job seeker's attitude towards job portals. To satisfy the need suggested by (Lin 2010) to investigate the influence of innovativeness on job seeker intentions to use job-search websites, when structural equation modelling was implemented, corelation was found between job seeker's innovativeness and job seeker's usage of job portals. These findings supported the findings of (Hodges 2009), however, contradicted the results of prior studies (Fenech and O'Cass, 2001; Wood and Swait, 2002; Park and Jun, 2003; Lee and Huddleston 2010) which stated that consumer's innovativeness is associated with individual's internet use, online purchasing / shopping, online frequency and online behaviour.

The contradictory findings, where job seeker's innovativeness influences job portal usage but not attitude, can be attributed to several factors

- Lack of Emotional or Cognitive Association: Innovativeness reflects a behavioural trait, openness to new technologies, while attitude is a cognitive-affective construct shaped by beliefs and perceptions. Thus, experimenting with job portals does not necessarily lead to a positive attitude, as job seekers may try various platforms without forming strong opinions about them.
- Habitual or Necessity-Driven Usage: Many job seekers use job portals out of necessity rather than preference. Even if they frequently explore new platforms due to their innovativeness, their engagement may be driven by efficiency, convenience, or job availability, rather than a strong preference for online job searching.
- External Factors Shaping Attitude: Job seekers' attitudes are influenced more by usability, effectiveness, trust, and reliability rather than their innovativeness. If a job portal fails to deliver relevant job matches or lacks credibility, even highly innovative job seekers may remain sceptical or indifferent toward it.
- Functionality Over Preference: Innovative individuals tend to experiment with multiple technologies rather than commit to a specific platform. For them, job portals are tools, not preferences, leading to neutral attitudes despite high usage.
- Risk-Taking and Exploration: Innovators are naturally inclined to test new platforms, not necessarily because they perceive them positively but due to an exploratory mindset. This risk-taking behavior drives usage but does not significantly impact their overall attitude toward job portals.

The present study found no relation between job seeker's innovativeness and job seeker's perceived risk. These findings challenged the earlier results by (Cowart, Fox and Wilson 2007) where innovativeness was found related with perceived risk. The study also challenged prior research by (Goldsmith et al. 2003) who identified a negative relation between innovativeness and price sensitivity. The study found significant relation between job seeker's innovativeness and job seeker's price sensitivity.

Researcher found significant but weak relation between job seeker's innovativeness and electronic word of mouth. These findings supported the results of (Brengman and Geuens 2002) and (Lee, Qu and Kim 2007). Further it was found that job seeker's innovativeness is strongly related with job seeker's gender, job seeker's education and job seeker's occupation. These findings supported the results of (Venkatraman 1991), (Tellis et al. 2005) and (Frank et al. 2006). However, by not finding any relation between job seeker's innovativeness and job seeker's gross annual income, this study opposed the results of (Tellis et al. 2005) and (Im et al. 2007). Similar to majority of the earlier research, present study also found no relation between job seeker's innovativeness and job seeker's age.

Apart from above discussed findings, present study found that job seeker's innovativeness is strongly related with job seeker's total work experience, type of job seeker, job seeker seeking change in industry / sector / function, job seeker seeking different profession/s, job seeker looking to change job location, job seeker interacting / transacting with different job portals, job seeker getting job through job portal/s, job seeker's frequency of job profile updating, job seeker expecting different benefits from job portals, job seeker actively seeking new job through job portals, job seeker subscribing for different types of services, job seeker believing in price fairness, job seeker exploring different avenues for job portal seeking, job seeker posting comment about job portals using various modes of EWoM, job seeker seeking feedback about job portals, job seeker actively using various online applications and job seeker's perceived value. Job seeker's was found possessing no relation with job seeker's tenure of registration with job portal/s.

CONCLUSION

This study contributes to the field of online consumer behaviour by extending its scope to job portals. It identifies and validates job seeker's innovativeness as a key determinant of job portal usage but finds no significant influence on job seekers' attitudes. The research conceptualizes and operationalizes job seeker's innovativeness, offering a reliable and validated measurement scale. Additionally, by examining its relationship with other factors, the study provides a scientific understanding of the utility and motivations driving job seekers to use job portals. It also establishes significant correlations between job seekers' innovativeness and various demographic and behavioural variables.

This study offers practical implications for job portals to refine their market strategies by addressing job seekers' perceptions, attitudes, and engagement behaviours. It provides insights into job seekers' continuance behaviour, how they acquire and evaluate job search information, and their psychological engagement with job portals. By identifying pain points and aligning emerging technologies with user needs, job portals can enhance user experience and service offerings. Furthermore, the findings help platforms differentiate value propositions, drive organic growth in a competitive market, improve web presence, and strengthen communication strategies with job seekers.

LIMITATIONS OF THE STUDY

This study is geographically confined to Pune, Maharashtra, India (a Tier 1 city), which may limit the generalizability of the findings to other job markets. The reliance on self-reported data poses a risk of response bias. Additionally, since job portals have been relatively recently adopted in India, the sample primarily consists of younger job seekers (18–35 years), restricting its applicability across different age groups. Future research should incorporate longitudinal methods with a more diverse respondent base, considering variations in work experience and registration duration. Furthermore, examining job seekers' expectations at different career stages and extending the study to other job portals or online job-seeking platforms could provide deeper insights.

Data Availability:

Data will be made available on the reasonable request.

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Conflict of Interest Disclosure Statement
We, the authors, hereby declare that there are **no conflicts of interest related to this work**. No financial, personal, or professional affiliations exist that could be perceived as influencing the content or conclusions presented in this manuscript. **All authors confirm that they have no competing interests to disclose.**

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Assessing the Performance of a Hybrid Healthcare System: Smart Health Solutions

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ABSTRACT

Smart Health Solutions (SHS) are essential to improving patient care, streamlining operations, and optimizing resource use in the changing healthcare sector. This study evaluates a hybrid healthcare system that seamlessly integrates *Smart Health Technologies* (SHT) with traditional healthcare methods. The study will evaluate this integration's performance, efficiency, and effects on patient outcomes, healthcare processes, and system sustainability. Patient records, system logs, and healthcare professionals input are analyzed for the research. To assess hybrid system benefits, therapeutic efficacy, patient satisfaction, and resource allocation will be carefully examined. The report also examines how integration affects healthcare workers' workloads, identifying best practices and areas for improvement. Technology is also examined, including *Smart Health Solutions'* (SHS) reliability, security, and interoperability in the hybrid system. To comply with ethics and regulations, privacy and data protection will be extensively assessed. This research should inform healthcare policymakers, practitioners, and technology developers. In a digital age, stakeholders may make educated decisions to improve healthcare quality and efficiency by evaluating the strengths and weaknesses of a hybrid healthcare system with smart health technologies. This project aims to connect technological innovation and healthcare implementation to create a more robust and responsive healthcare ecosystem. Using an AI tool, algorithms, program structure to implement the proposed techniques for streamlining operations, etc. A survey result with the examples also supports this technology being implemented.

Keywords: Streamlining operations, Hybrid healthcare, Smart Health Technologies, Emergency Effective Healthcare Solutions, Emergency Medical Services

INTRODUCTION

We urgently require creative solutions and strong infrastructures to successfully handle emerging difficulties, as the COVID-19 pandemic has shown the major weaknesses in healthcare systems around the world. Despite the many challenges caused by the pandemic, *Smart Health Solutions* (SHS) & *Emergency Effective Healthcare Solutions* (EEHS) have shown great promise in improving patient care, streamlining operational processes, and making the most efficient use of available resources. *Smart health technologies* (SHT) are the key factor and backbone of smart health solutions (SHS). They offer many benefits to healthcare, but they also introduce new challenges when integrated into pre-existing systems. Thorough evaluation and proactive

intervention are necessary to address challenges such as data protection, the major challenge of SHS, system dependability, and healthcare professionals' task management. Therefore, a promising approach to rethinking healthcare delivery in the aftermath of a pandemic is the integration of conventional medical practices with cutting-edge smart health technology. Evidence-based insights help healthcare stakeholders use smart health technologies effectively in these difficult situations. A *hybrid healthcare* system that combines traditional procedures with cutting-edge technology may solve these problems. This technique uses patient data, system logs, and healthcare professional comments to objectively evaluate performance indicators, efficiencies, and practical advantages to demonstrate technology-enabled healthcare delivery's transformative potential. Technology dependability, security, and interoperability are crucial to data protection and system resilience. This study synthesizes these lessons to bridge innovation and implementation and provide a roadmap for building a resilient, responsive, and patient-centric healthcare ecosystem after global health crises. Demographic trends and rising disease rates have fueled healthcare sector growth in recent years. Clinical resources and healthcare staff are in high demand because of this spike. Traditional healthcare systems are essential, but pricing and accessibility limit their ability to meet various populations' needs.

This dramatic shift began in the early 1990s with a paradigm shift toward more advanced medical care. Agile treatment methods, fast patient care, remote health monitoring, and quick emergency response are examples of this progress. The need for cutting-edge technology to provide high-quality healthcare has been a major obstacle.

To meet the ever-changing demands of healthcare delivery, India is only one of many countries around the world using Smart Health Solutions (SHS). Famous examples include:

1. **Ayushman Bharat Health Account (ABHA)**: This initiative, spearheaded by the Indian government, seeks to guarantee healthcare coverage for all citizens and shield them from financially devastating medical bills. It uses technology and politics to improve healthcare for all.
2. **Unified Health Interface (UHI)**: UHI integrates healthcare systems and allows stakeholders to share data to streamline services. It enhances healthcare information access and interoperability for better decision-making.
3. **Deep Learning and Machine Learning Applications**: SHS efforts use deep learning and machine learning to improve healthcare. This includes predictive analytics for disease diagnosis, individualized therapy suggestions, and healthcare resource optimization.
4. **Telemedicine Platforms:** Telemedicine platforms allow patients and doctors to consult remotely, removing geographical boundaries and improving healthcare access. Advanced technologies enable virtual appointments, remote monitoring, and real-time communication on these platforms.
5. **Health Information communicate (HIC):** HIC platforms allow healthcare providers to securely communicate electronic health records and medical information, improving patient care coordination and clinical decision-making.
6. **Wearable Health Monitoring Devices:** Sensors and IoT technologies provide continuous monitoring of vital signs and health metrics, empowering people to control their health and detect potential health issues.
7. **Digital Health Records Systems:** These systems digitize patient medical records for secure storage, retrieval, and sharing among healthcare facilities. These technologies improve healthcare coordination and efficiency by improving data accuracy, accessibility, and interoperability.
8. **AI-Powered Diagnostic Tools:** Machine learning algorithms analyse medical imaging, test results, and clinical data to diagnose and treat diseases. These tools improve diagnostic accuracy, turnaround speed, and evidence-based clinical decision-making.

Healthcare is becoming more accessible, efficient, and patient-centric as Smart health solutions and innovative technologies are adopted. These projects are important steps toward global healthcare coverage and health outcomes.

Background Status of ambulance services in India

Under the National Ambulance Code (NAC), road ambulances are classified based on their functionality and capabilities to cater to different medical needs and emergencies. These classifications ensure that ambulances are equipped with the necessary resources to provide appropriate medical care during transportation. The NAC, developed by the Ministry of Road Transport and Highways (MoRTH), aims to standardize ambulance services across the country and improve the quality of emergency medical response.

The classifications of road ambulances under the NAC are as follows:

Table 1: Types of Ambulances Classified Under the National Ambulance Code and Their Minimum Requirements

Ambulance Type	Functionality	Requirements as per NAC
Type A	Ambulance, Medical First Responder	When patients are unable to be transported in a supine position or get medical treatment inside the vehicle, it is necessary to give them access to emergency out-of-hospital care. Indoor medical treatment is only required for transport patients.
Type B	Ambulance, Patient Transport Vehicle	Used for patients who are not considered to be in immediate danger of becoming an emergency and for transportation between treatment locations. Need basic first aid and nursing equipment.
Type C	Ambulance: Basic Life Support (BLS) Ambulance Vehicle	Patients requiring basic monitoring or non-invasive airway care can be transported and treated in this manner. The provision of pre-hospital care necessitates the availability of medical equipment capable of performing basic treatments and monitoring patients.
Type D	Ambulance, Advanced Life Support (ALS) Ambulance Vehicle	For the transportation and care of patients in critical need of invasive airway control or extensive monitoring. Pre-hospital critical care requires modern treatment and monitoring technology.
Type E	First Responder Ambulance	A **First Responder Ambulance** is an essential unit in the emergency medical services (EMS) system, primarily designed for rapid response in life-threatening situations. This vehicle is typically staffed by highly trained paramedics or emergency medical technicians (EMTs) who are equipped to provide initial care at the scene of an emergency before the arrival of advanced transport units. First responders are tasked with stabilizing patients in the critical moments following an emergency, delivering life-saving interventions, and preparing the patient for transport to a medical facility.
Type F	Mortality Transport System (MTS) Ambulance	The **Mortality Transport System (MTS) Ambulance** is specifically designed for the transportation of deceased individuals, typically from the place of death to the mortuary or other designated facilities. These vehicles are often used by hospitals, police services, and funeral homes to ensure the dignified and safe transport of bodies.

Summary of Ambulance Types:

1. **Type A: Ambulance, Medical First Responder** – Provides emergency out-of-hospital care when patients cannot be transported in a supine position, or when immediate medical attention is required in the field.

2. **Type B: Ambulance, Patient Transport Vehicle** – Transports non-critical patients between treatment locations, equipped with basic first aid and nursing equipment for patients who do not require immediate emergency care.
3. **Type C: Ambulance, Basic Life Support (BLS) Vehicle** – Transports patients who require basic monitoring or non-invasive airway care, with the necessary equipment for basic medical treatments and monitoring.
4. **Type D: Ambulance, Advanced Life Support (ALS) Vehicle** – Used for transporting patients in critical condition who need invasive airway control, extensive monitoring, and advanced medical care, equipped with modern treatment and monitoring technology.
5. **Type E: First Responder Ambulance** – Provides rapid response to emergencies, offering life-saving interventions and stabilizing patients before they are transported to a medical facility, typically equipped with basic life-saving equipment.
6. **Type F: Mortality Transport System (MTS) Ambulance** – Used exclusively for the transportation of deceased individuals, equipped with features to ensure safe and dignified transport, including climate control and secure compartments for the deceased.

These different types of ambulances each play a vital role in the overall emergency care system, with distinct functions to address the varying needs of patients and situations, from initial medical response to critical care and post-mortem transport. Understanding the scope and purpose of each ambulance type is essential for optimizing emergency services and improving patient outcomes.

Ambulance services in India are provided by a wide range of organizations, including public and commercial hospitals, philanthropic organizations, and humanitarian organizations. The majority of states and territories have *National Ambulance Services* (NAS) run by the government's *National Health Mission* (NHM). The Emergency Response System (Dial-108) provides free ambulance service for every 1,000,000 people. Dial-102 (Patient Transport Services) serves pregnant mothers and newborns. In several states, empaneled vehicles transport pregnant women and children. Janani Express, Mamta Vahan, and Nishchay Yan Prakalpa serve Madhya Pradesh, Odisha, Jharkhand, and West Bengal. Political parties offer ambulance services, but they often use them for publicity. These ambulances may prominently display the party's emblem and leaders' images, despite regulatory requirements for ambulance-only signs.

Digital-led healthcare has created the "uberfication" of Indian ambulance services. Online ambulance bookings are available in Delhi, Hyderabad, and Bengaluru.

Five “A's” of Healthcare Challenges in India

1. Awareness: A significant gap exists in health awareness across all age groups in India. For instance, only one-third of antenatal mothers had adequate knowledge about breastfeeding, and merely 11.3% of adolescent girls in urban Haryana were aware of key reproductive health issues. Among the elderly, only 20.3% were aware of common illnesses and their prevention. These gaps arise from low literacy, limited focus on health education, and poor prioritization of health. Encouragingly, behavioral interventions have shown promise in raising awareness, emphasizing the importance of education for positive behavior change.

2. Access: Healthcare access is hindered by geographic, financial, and systemic barriers. In rural India, only 37% of people have access to inpatient facilities within 5 km, and primary health centers (PHCs) often lack basic infrastructure like beds, clean labor rooms, and electricity. While the National Rural Health Mission has improved healthcare infrastructure, disparities in access persist, especially for rural and marginalized populations. Addressing these challenges requires identifying barriers and improving healthcare availability, quality, and reach.

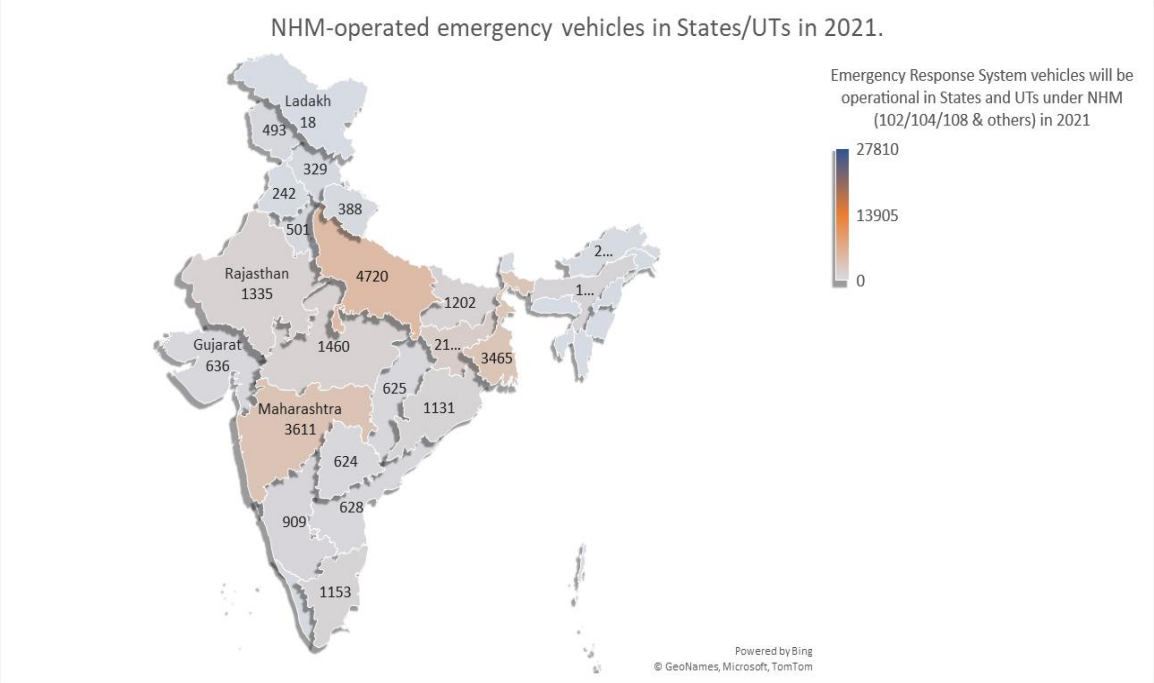
3. Absence of Workforce: India faces a shortage and unequal distribution of healthcare professionals. With only 20 health workers per 10,000 population, rural areas experience

significant deficits. Vacancies in government positions, such as 27% of doctor posts in PHCs, exacerbate the problem. While private providers contribute to healthcare delivery, gaps in the public health system remain a concern. Policymakers need to address workforce shortages, training, and equitable deployment to ensure accessible and quality care for all.

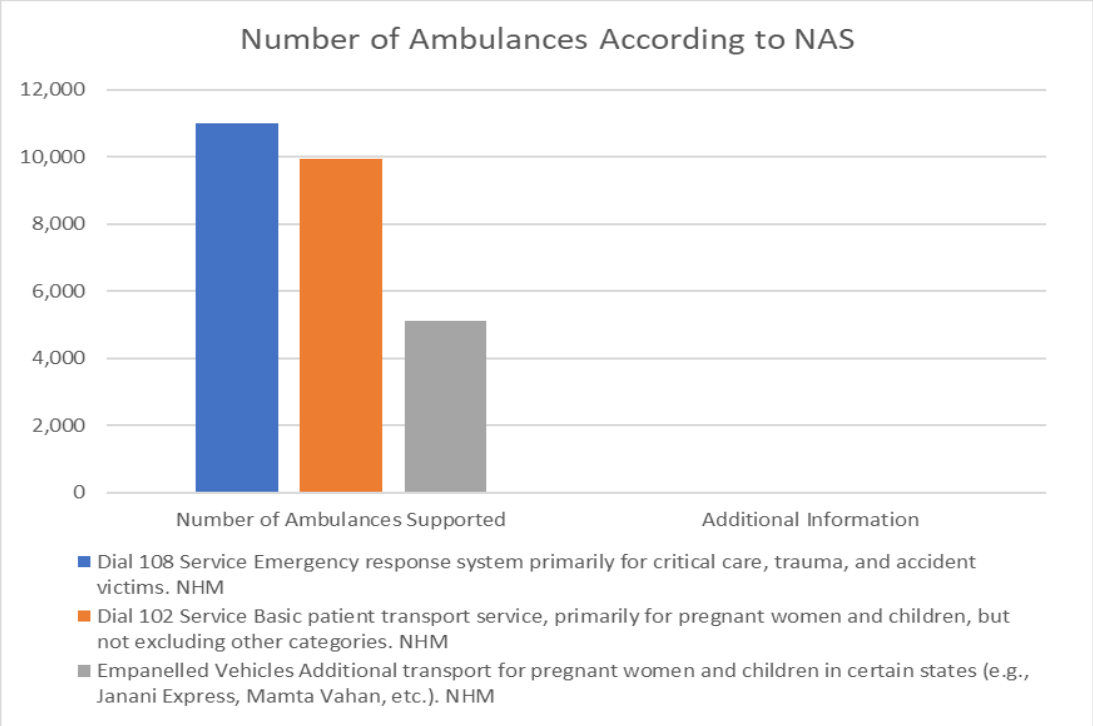
4.Affordability: Healthcare costs in India are a significant burden, with 75% of expenditures borne by households. Private healthcare dominates but is often expensive and unregulated, leading to financial distress for many families. Public healthcare, though low-cost, is often underutilized due to perceptions of poor quality. To improve affordability, government health spending must increase to 5–6% of GDP, and wasteful practices must be minimized. Educating healthcare professionals about cost-effective practices can also contribute to reducing expenses.

5.Accountability: Healthcare accountability involves fulfilling responsibilities to clients, employers, peers, and society. It requires adherence to ethical standards, transparency, and a commitment to improving health outcomes. Strengthening accountability mechanisms can help ensure that healthcare professionals and institutions deliver equitable and reliable services.

State-wise Availability of Ambulances in India



The map illustrates the distribution of NHM-operated emergency vehicles across various States and Union Territories in India for the year 2021. States like Uttar Pradesh (4720), Madhya Pradesh (3465), and Maharashtra (3611) recorded the highest number of emergency vehicles, showcasing significant efforts toward strengthening emergency response systems. Conversely, smaller states and union territories, such as Ladakh (18) and Sikkim (21), had fewer vehicles, reflecting their population size and geographical constraints. The color gradient on the map indicates the density of operational emergency vehicles, with darker shades representing higher concentrations. This data highlights the disparity in healthcare infrastructure across regions, emphasizing the need for equitable resource distribution to enhance emergency medical assistance nationwide.

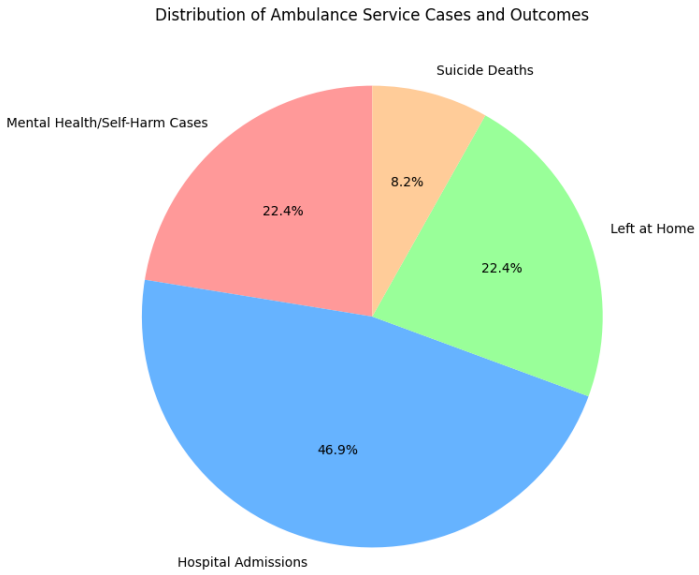


Statistics

India faces a critical public health challenge due to its high road traffic fatality rates, which stand at approximately 18.9 deaths per 1,00,000 population. This is alarmingly higher compared to 8.7 in high-income countries, highlighting significant disparities in road safety and emergency care systems. In 2019 alone, India witnessed 1,51,113 deaths and 4,51,361 injuries caused by road accidents. Despite these alarming figures, emergency medical services (EMS) remain grossly underdeveloped and inefficient. The National Institution for Transforming India (NITI Aayog), a premier policy think tank of the Government of India, revealed that over 98.5% of ambulances in the country are used for transporting deceased individuals rather than providing critical emergency care. Additionally, 90% of ambulances lack basic medical equipment, and 95% are staffed with untrained personnel. Compounding the issue, many doctors working in emergency departments across district hospitals lack formal training in EMS, leading to severe delays in providing lifesaving care. These delays contribute to nearly 30% of preventable deaths, underscoring the urgent need for strengthening the emergency care system.

- A study conducted by the All India Institute of Medical Sciences (AIIMS) further reinforces the gaps in ambulance services, reporting that only 11% of patients reach hospitals via ambulances. Ambulance services are often unaffordable for many families due to their opaque pricing structures, which combine time-based charges, emotional distress, and opportunity costs. The irregularity and inconsistency in costs make it difficult for patients to budget for this essential service. Moreover, hospital-based ambulances are underutilized and frequently lack advanced medical technology and trained personnel, rendering them ineffective during critical emergencies.
- Mental health and self-harm cases also place a significant burden on ambulance services. For instance, ambulance teams attended 6,802 patients with mental health or self-harm incidents on 9,014 occasions, accounting for 11% of all calls attended during the year. Of these cases, the most common pathway was transportation to an emergency department followed by discharge, representing 51% (4,566 out of 9,014) of the calls. Meanwhile, 11% of patients (1,003) were left at home, while 23% (2,043) required hospital admission. Tragically, within 12 months of the initial ambulance attendance, 279 patients (4%) had died, with 97 of these cases attributed to suicide.

- A recent survey with a 42% response rate involving 2,906 participants revealed that 11% (319 out of 2,716) of respondents contacted ambulance services, while 43% sought emergency department (ED) care. Interestingly, minor issues such as fever in children or sore ribs were primary reasons for emergency service use, particularly among males, older individuals, and members of ethnic minority groups. These trends suggest a need for better public awareness on appropriate use of emergency services and improved access to primary healthcare.
- In analyzing the demographics of injured individuals, data indicates that men are disproportionately affected, constituting nearly 60% of all reported injuries, while women account for 23%. The gender of the remaining 17% was not recorded. The mean age of injured individuals was approximately 29.8 years, with a standard deviation of 15.9, suggesting that younger adults are particularly vulnerable. Notably, 30% of the injured fell within the 16 to 25 age group, a demographic often engaged in high-risk activities such as commuting or driving.
- The average response time for ambulances was reported as 9 minutes and 1 second, with a standard deviation of 2 minutes and 46 seconds. The response delays are often attributed to operational inefficiencies, poor infrastructure, and geographical challenges. Among the various reasons for emergency missions, incidents occurring outside operational zones accounted for the highest proportion (29.3%), followed by traffic-related incidents, which constituted 24.2% of calls. This data highlights the pressing need to optimize ambulance response times, ensure equitable distribution of resources, and improve communication systems to provide timely emergency care.
- Given these findings, it is evident that India requires a comprehensive overhaul of its EMS infrastructure. Investments must focus on equipping ambulances with advanced life-support technology, training personnel in emergency care, and reducing response times. Additionally, there is a need for public health initiatives to address mental health crises, promote road safety, and enhance access to affordable ambulance services. A holistic approach that combines policy reforms, technological innovation, and public education is imperative to reduce fatalities and improve patient outcomes in emergency situations.



The graph above illustrates the distribution of ambulance service cases and outcomes related to mental health and self-harm incidents:

- **Mental Health/Self-Harm Cases**: 22.4% of calls involved mental health or self-harm cases.
- **Hospital Admissions**: 46.9% of these cases resulted in hospital admission.
- **Left at Home**: 22.4% of patients were left at home after the ambulance service.
- **Suicide Deaths**: 8.2% of cases unfortunately led to suicide deaths.

This highlights the burden of mental health issues on ambulance services and the need for a comprehensive approach to mental health crises in emergency response systems.

Conclusion and Benefits of Assessing the Performance of a Hybrid Healthcare System: Smart Health Solutions:

In conclusion, assessing the performance of a hybrid healthcare system that integrates traditional healthcare practices with advanced smart health solutions is critical for improving the efficiency, accessibility, and overall quality of healthcare services. A hybrid healthcare system leverages the strengths of both conventional healthcare infrastructure and modern technologies such as telemedicine, AI-driven diagnostics, wearable devices, and cloud-based data management. This fusion not only addresses the limitations of traditional systems but also optimizes the healthcare experience for patients, providers, and administrators alike.

One of the primary benefits of assessing the performance of a hybrid healthcare system is its potential to enhance patient care. Smart health solutions, such as real-time health monitoring, predictive analytics, and personalized treatment plans, can significantly reduce the time required for diagnosis and treatment. By using data-driven insights, healthcare providers can make more accurate decisions, minimizing human error and ensuring timely interventions. These advancements are especially crucial in critical care settings, where fast decision-making can save lives. Moreover, the integration of telemedicine ensures that individuals in remote or underserved areas can access high-quality healthcare without the need for long-distance travel.

Another key advantage of hybrid healthcare systems is their ability to improve operational efficiency. Through the use of cloud-based platforms, digital health records, and automated systems, healthcare facilities can streamline administrative tasks, reduce overhead costs, and eliminate redundancies. Data sharing between hospitals, clinics, and other healthcare providers facilitates better coordination, ensuring that patients receive continuous and comprehensive care, regardless of where they are treated. This interconnectedness also supports timely access to medical histories, test results, and ongoing treatment plans, enhancing the continuity of care.

Smart health technologies also offer significant benefits in preventive care. Wearable devices, for example, can continuously monitor vital signs such as heart rate, blood pressure, and oxygen levels, alerting both patients and healthcare providers to any anomalies. This continuous monitoring can help identify potential health issues early, reducing the risk of serious medical conditions and improving long-term outcomes. Additionally, predictive models that assess a patient's risk factors can enable healthcare professionals to intervene proactively, preventing the progression of chronic diseases such as diabetes, hypertension, and cardiovascular conditions.

From an administrative and financial standpoint, assessing hybrid healthcare systems can lead to significant cost savings. By incorporating telemedicine and remote monitoring, hospitals can reduce the strain on emergency departments and inpatient services, allowing healthcare providers to focus resources on those who require immediate or intensive care. The use of AI in administrative tasks, such as scheduling and billing, further reduces operational inefficiencies. Furthermore, the hybrid approach helps reduce the costs associated with unnecessary tests, long hospital stays, and readmissions, making healthcare more affordable for both patients and providers.

In terms of accessibility, hybrid healthcare systems break down geographical and financial barriers to care. Telemedicine platforms enable consultations with specialists, reducing waiting times and allowing patients to access healthcare professionals they might otherwise be unable to reach. This is particularly important in rural or remote areas where healthcare infrastructure is often limited, ensuring that everyone, regardless of location, can receive timely and appropriate care. By offering a range of services at various price points, hybrid systems also cater to different socioeconomic groups, promoting inclusivity and health equity.

Finally, the performance assessment of a hybrid healthcare system is pivotal for continuous improvement. Monitoring key performance indicators (KPIs) such as patient satisfaction, treatment outcomes, response times, and cost-effectiveness helps identify areas of weakness or inefficiency. Through periodic evaluations and feedback loops, healthcare systems can implement targeted interventions, adopt new technologies, and refine existing processes to maintain high standards of care. This culture of continuous improvement ensures that hybrid healthcare systems remain adaptive to changing healthcare needs, technological advancements, and evolving patient expectations.

In conclusion, the hybrid healthcare system's ability to combine the best of traditional care with innovative smart health solutions offers numerous benefits, including improved patient care, operational efficiency, preventive healthcare, cost savings, and enhanced accessibility. Through the ongoing assessment of system performance, healthcare providers can ensure that these systems evolve to meet the demands of modern healthcare, ultimately leading to better health outcomes and a more sustainable healthcare model.

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Advancements in Artificial Intelligence and Big Data in Healthcare
Highlights the integration of AI and Big Data in healthcare systems, which forms the backbone of many smart health solutions.

Digital Health Technologies in Healthcare Systems
Reviews the evolution of digital health technologies and their transformative role in modern healthcare systems.

Wearable Health Technologies: A Review of Current Applications and Future Directions
Focuses on the impact of wearable health devices, contributing to real-time patient monitoring in hybrid healthcare systems.

Impact of Telemedicine on Healthcare Delivery
Examines how telemedicine impacts healthcare delivery, particularly in improving patient care and access to medical services.

Healthcare 4.0: A New Paradigm for Healthcare
Introduces the concept of Healthcare 4.0, exploring the digital transformation of healthcare through IoT, AI, and telemedicine.

Artificial Intelligence in Healthcare: Past, Present and Future
Provides a comprehensive review of AI's evolution in healthcare and its potential for future advancements.

Big Data in Healthcare: Opportunities and Challenges
Discusses how big data can improve healthcare decision-making and patient care, essential for hybrid healthcare systems.

Smart Health: The Intersection of Technology and Healthcare
Explores how smart health technologies, such as IoT and AI, create more efficient and effective healthcare solutions.

Smart Healthcare System: A Vision to Overcome Healthcare Challenges
Presents a vision for overcoming healthcare challenges through smart healthcare systems powered by digital technologies.

The Role of Telemedicine in Improving Health Outcomes in Rural Areas
Discusses the role of telemedicine in improving health outcomes, particularly in rural areas, where healthcare access is limited.

The Effectiveness of Remote Monitoring in Chronic Disease Management
Reviews how remote monitoring can improve chronic disease management, an important aspect of hybrid healthcare systems.

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Telemedicine for Healthcare: Opportunities and Challenges
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Discusses the integration of smart health technologies, including AI and IoT, in healthcare systems to improve efficiency.

Future Trends in Healthcare and the Role of IoT
Explores how the Internet of Things (IoT) is shaping the future of healthcare, contributing to patient monitoring and management.

Artificial Intelligence in Healthcare: Future Perspectives and Ethical Considerations
Provides a forward-looking perspective on AI in healthcare, discussing both the potential benefits and ethical concerns.

Telehealth and Telemedicine: The Future of Healthcare Delivery
Outlines the growing role of telehealth and telemedicine in transforming healthcare delivery, especially in rural and underserved areas.

E-Health: The Role of Technology in Healthcare Delivery
Discusses the role of e-health technologies in facilitating efficient healthcare delivery, especially in a digital era.

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Discusses the transformative impact digital health solutions are having on healthcare systems worldwide.

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Explores the integration of smart healthcare systems with IoT technologies to create efficient and scalable healthcare solutions.

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Highlights the applications and benefits of telemedicine in improving healthcare delivery, especially for remote patients.

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Discusses the integration of IoT with smart health solutions, enhancing healthcare delivery and patient outcomes.

Artificial Intelligence in Medical Diagnosis: A Review
Reviews the role of AI in medical diagnostics, which is a crucial component of smart healthcare systems.

Healthcare Data Analytics: Applications and Challenges
Explores the role of healthcare data analytics in improving decision-making and patient care in hybrid healthcare systems.

Smart Healthcare for All: The Future of Medicine
Focuses on the future of smart healthcare and how it will make healthcare services more accessible and efficient.

AI in Healthcare: Impact, Challenges, and Opportunities
Discusses AI's impact on healthcare, the challenges faced, and the opportunities for further development in healthcare systems.

Smart Health Systems: Designing for Healthcare Efficiency and Quality
Examines how smart health systems can improve healthcare efficiency and quality through better data utilization and technology.

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Perceived Authenticity and Trust in Green Digital Marketing: Drivers of Gen Z Consumers' Purchase Intentions

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ABSTRACT

As sustainability takes centre stage in today's marketplace, green digital marketing has become an important way for brands to connect with environmentally aware consumers. Yet the rise of greenwashing has made audiences more skeptical, putting authenticity and trust at the heart of how green campaigns are received. This study explores how these two factors-perceived authenticity and trust-shape Gen Z consumers' intentions to buy from brands that position themselves as sustainable. Gen Z is especially relevant here: while they are known for valuing sustainability, they are equally quick to challenge messages that feel inauthentic.

Guided by the Stimulus-Organism-Response (S-O-R) framework, this research adopts a quantitative approach, drawing on survey data collected from 157 Gen Z respondents. Factor analysis was used to uncover the main dimensions of authenticity, trust, and purchase intention, while cluster analysis segmented Gen Z into distinct groups based on their attitudes toward green marketing. The results show that when campaigns are perceived as authentic, they significantly strengthen consumer trust, which in turn is a strong driver of purchase intentions. The clustering also reveals clear differences within Gen Z, from highly engaged "conscious buyers" to more skeptical "doubtful adopters," reflecting the generation's diverse responses to green initiatives.

This study adds depth to our understanding of green digital marketing by showing how psychological perceptions translate into consumer behaviour. For practitioners, the message is clear: transparency, consistency, and genuine value alignment are crucial to building trust and long-term loyalty. In an age of heightened consumer scrutiny, authenticity and trust are not optional-they are the foundation for meaningful engagement with Gen Z.

Keywords: Perceived authenticity, Trust, Green digital marketing, Gen Z, Purchase intentions, Sustainability, Consumer behaviour

Introduction

In recent years, environmental sustainability has moved from a peripheral concern to a core dimension of marketplace competition. Consumers increasingly demand that brands behave in an environmentally responsible way, and digital marketing has emerged as a key channel through which firms communicate their "green" credentials. At the same time, the rise of greenwashing - whereby firms exaggerate or misrepresent their ecological claims - has heightened consumer scepticism. In this context, for consumers, particularly younger generations, dimensions such as authenticity and trust become central to how they perceive green marketing communications.

Among the younger cohorts, Generation Z (typically born mid-1990s to early-2010s) stand out. They have grown up digitally, are highly socially connected, and are more aware of sustainability issues than many previous generations. They not only expect brands to reflect meaningful values, but they also hold them to account when claims appear superficial or inauthentic.

Against this backdrop, the current study examines how perceived authenticity of green digital marketing campaigns and trust in the brand mediate Gen Z's purchase intentions toward brands advertising as sustainable. Grounded in the stimulus-organism-response (S-O-R) framework, it explores how the stimulus of green digital marketing (with authenticity perceptions) affects the

organism (trust) and then the response (purchase intention). It also segments Gen Z consumers into different attitudinal clusters (e.g., highly engaged "conscious buyers" vs more sceptical "doubtful adopters") to uncover heterogeneity in responses.

The contributions of this research are both theoretical and managerial: theoretically it advances green marketing and digital marketing literatures by clarifying the mechanisms of authenticity → trust → purchase intention in a Gen Z context; managerially it offers actionable insights for marketers aiming to build credible sustainable brand communications rather than mere surface-level claims.

REVIEW OF LITERATURE

Theocharis&Tsekouropoulos (2025) "Sustainable Consumption and Branding for Gen Z: How Brand Dimensions Influence Consumer Behaviour and Adoption of Newly Launched Technological Products" (Sustainability) 17(9): 4124. The authors examine how various brand-dimensions - online brand experience, brand image, brand trust, brand loyalty, awareness, knowledge - influence Gen Z consumers' purchase intentions in the context of new technological products marketed as sustainable. They used a Gen Z sample and regression analysis.

Ridwan, Musa &MaulanaHaeruddin (2025) "Decision-making behaviour of Generation Z in online purchases: A systematic literature review" (Multidisciplinary Reviews) 8(12): 2025384. This systematic review focuses on Gen Z's online purchase behaviour, highlighting digital engagement, social media, influencer marketing, and sustainability as important influences.

Silva &Krikheli (2024) "The Influence of Digital Marketing on Gen Z Consumer Behaviour and Decision-Making Process" (Master's Thesis, Umeå University). This empirical study with a Gen Z sample (n = 144) examined how digital marketing channels (social media, search engine, email) influence Gen Z's decision-making. It notes that Gen Z expects authenticity and engagement from digital experiences.

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Objectives of the study

1. To understand the composition of the sample and their general attitudes toward green digital marketing.
2. To examine the association between consumer demographic variables and their attitudes toward green digital marketing.
3. To ensure construct validity and reliability of the measurement items representing the key variables (authenticity, trust, and purchase intention) using exploratory factor analysis (EFA).
4. To segment Gen Z consumers into distinct clusters based on their attitudes and perceptions toward green digital marketing.

RESEARCH METHODOLOGY

The present study adopts a quantitative research approach, as it seeks to measure and analyse relationships between key variables-perceived authenticity, trust, and purchase intention-in the context of green digital marketing among Generation Z consumers. This study employs a quantitative, descriptive–exploratory research design based on primary survey data from 168 Gen Z respondents selected through convenience sampling. The design allows for both the measurement of relationships among key constructs (authenticity, trust, purchase intention) and the identification of distinct consumer clusters, thereby achieving a comprehensive understanding of Gen Z's responses to green digital marketing.

DATA ANALYSIS AND INTERPRETATION

a. Percentage Analysis

Table 1: Demographic and socio-economic details of the respondents

		Frequency	%
Age	Below 20 years	134	85.4
	21–30 years	23	14.6
Gender	Male	48	30.6
	Female	102	65.0
	Prefer not to say	7	4.5
Education Level	School Level	9	5.7
	Undergraduate	130	82.8
	Postgraduate	10	6.4
	Professional Qualification	8	5.1
Occupation	Student	140	89.2
	Private Employee	7	4.5
	Government Employee	2	1.3
	Business	8	5.1
Monthly Family Income	Less than ₹20,000	63	40.1
	₹20,001 – ₹40,000	35	22.3
	₹40,001 – ₹60,000	14	8.9
	₹60,001 – ₹80,000	21	13.4
	Above ₹80,000	24	15.3
Frequent exposure to sustainability content	Very frequently	73	46.5
	Frequently	60	38.2
	Occasionally	12	7.6
	Rarely	12	7.6
Social Media Platform used frequently	Insta gram	69	43.9
	YouTube	46	29.2
	X	10	6.36
	Facebook	15	9.5
	Pinterest	17	10.8

Age

The majority of respondents are very young - mostly below 20 years (85.4%) and only few respondents (14.6%) belong to the category "21-30". This indicates that the students have the more awareness about Green Digital marketing.

Gender
The sample is predominantly female, making up nearly two-thirds of respondents (65%). Males form about one-third (4.5%), while a small portion chose not to disclose gender. This could mean that female respondents are actively engaged in purchasing the products related to sustainability.

Education
The majority of respondents are undergraduates, indicating the sample largely consists of college students or young adults pursuing tertiary education. This shows that the trend is arising from young adults who are comfortable in using social media.

Occupation
Nearly nine out of ten respondents are students, confirming that the study says that the academic population are more interested in sustainability contents in social media.

Income
The largest income group falls between ₹20,000 and ₹40,000 monthly. This suggests most respondents come from middle-income families. However, there's still a fair mix across other income brackets, including higher earners. This indicates that since most of the respondents belongs to middle – income families will have less purchase intention to buy the products with sustainability.

Frequent exposure to sustainability content
Most participants are highly engaged with sustainability-related content, with over 84% reporting frequent or very frequent exposure. This indicates strong awareness or interest in sustainability topics among the surveyed group.

Social Media platforms frequently used
The results show that Instagram is the most popular social media platform among respondents, with 43.9% (69 people) saying they use it frequently. This highlights Instagram's strong appeal, likely because of its highly visual and interactive nature that keeps users engaged.

Next in popularity is YouTube, used frequently by 29.2% (46 respondents). This suggests that video content continues to play a big role in people's online habits and entertainment choices.

On the other hand, Pinterest (10.8%), Facebook (9.5%), and X (formerly Twitter) (6.36%) are used much less often. These platforms seem to have a smaller but still active user base, possibly reflecting shifts in social media trends and preferences toward more visual and dynamic platforms.

Overall, it's clear that people in this group prefer visual and multimedia platforms like Instagram and YouTube, while more traditional or text-focused platforms such as X and Facebook are less commonly used.

b. Chi-Square Test

Relationship between the family income and frequent exposure to sustainability content:

HO: There is no significant relationship between the age and Frequent exposure to sustainability content

H1: There is a significant relationship between the age and Frequent exposure to sustainability content

Table:2 Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.879[a]	3	.118
Likelihood Ratio	5.348	3	.148
Linear-by-Linear Association	1.249	1	.264
N of Valid Cases	157		

INTERPRETATION:
Since the asymptotic value (.118) is greater than the significant value (0.05), so we accept the null hypothesis (H0). Therefore, there is no significant relationship between the age and Frequent exposure to sustainability content.

Relationship between the gender and engagement likelihood towards brand promotion

HO: There is no significant relationship between the gender and engagement likelihood towards brand promotion.

H1: There is significant relationship between the gender and engagement likelihood towards brand promotion

Table:3

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.470[a]	2	.039
Likelihood Ratio	4.214	2	.122
Linear-by-Linear Association	2.119	1	.145
N of Valid Cases	157		

Interpretation:
Since the asymptotic value (.039) is lesser than the significant value (0.05), so we reject the null hypothesis (H0). Therefore, there is significant relationship between the gender and engagement likelihood towards brand promotion

Factor Analysis

Table 4: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**.639**
Bartlett's Test of Sphericity	Approx. Chi-Square	**2937.954**
	df	**190**
	Sig	**0.000**

From the above table it is found that the KMO measure of sampling adequacy is .**639**, and chi-square is **2937.954** for degree of freedom 190. These statistical values are highly significant at 5% level. This forces us to conclude that factor analysis applied on 20 variables of nature for 157 respondents is perfectly justified. This indicates the factor segregated with the help of variables perfectly fits the normal distribution and reflects the characteristics factors of the population.

Table:5 Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.966	24.830	24.830	4.966	24.830	24.830	4.644	23.222	23.222
2	3.657	18.283	43.113	3.657	18.283	43.113	3.138	15.691	38.913
3	2.825	14.126	57.239	2.825	14.126	57.239	2.934	14.672	53.585
4	1.803	9.013	66.252	1.803	9.013	66.252	1.997	9.987	63.572
5	1.468	7.341	73.593	1.468	7.341	73.593	1.658	8.290	71.862
6	1.158	5.788	79.381	1.158	5.788	79.381	1.504	7.519	79.381
7	.866	4.331	83.712						
8	.655	3.274	86.987						
9	.552	2.759	89.745						
10	.490	2.449	92.195						
11	.399	1.993	94.187						
12	.317	1.586	95.773						
13	.233	1.166	96.939						
14	.192	.962	97.901						
15	.140	.700	98.601						
16	.104	.520	99.122						
17	.092	.462	99.584						
18	.045	.224	99.808						
19	.027	.134	99.942						
20	.012	.058	100.000						

Interpretation

The total variance Table explains that the 20 variables exhibit 79.381% of total variance with 6 Eigen values i.e. 4.644, 3.138, 2.934, 1.997, 1.658, 1.504. All these values are strictly greater than one. This shows the existence of three major factors. Individually these factors possess the Variances i.e. 23.222, 15.691, 14.672, 9.987, 8.290 and 7.519. Among these values the first factor possesses the highest variance and the last factor has the smallest variance. This leads to the conclusion that the factor segregation is perfect and that they can be named with respect to the variables within them.

Rotated Component Matrix	Component					
	1	**2**	**3**	**4**	**5**	**6**
Sustainability campaign seems genuine	.912					
Truly care about the environment	.910					
Languages and visuals shown are sincere	.905					
Able to distinguish between authenticity & publicity	.734					
Being Transparent	.564					
Consistency	.506					
Provide verifiable information on sustainability		.921				
Deliver Environmental Promises		.916				
Eco – friendly		.616				
Good reputation			.839			
Accused of Green washing			.789			
Likely to purchase			.640			
Willing to pay higher			.612			
Socially Responsible				.796		
Likely to buy from them				.690		
Recommendation				.538		
Effective platform for promotion					.839	
Increased Awareness on environmental issues						.872
Positively Influence						.529
Feel skeptical						.507
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.						
a. Rotation converged in 8 iterations.						

Interpretation
The table shows the extraction of all the 20 variables and how these are loaded on "Six Factors". These Six factors are named and variables included in each factor are explained below:

Factor 1
The first factor consists of **Six** variables which are given below:

Table: 7

S.NO	Statements	Factor loading
1	Sustainability campaign seems genuine	.912
2	Truly care about the environment	.910
3	Languages and visuals shown are sincere	.905
4	Able to distinguish between authenticity & publicity	.734
5	Being Transparent	.564
6	Consistency	.506

The first factor can be called **"ECO SINCERITY SEEKERS"**

Table: 8: FACTOR 2

S.NO	Statements	Factor loading
1	Provide verifiable information on sustainability	.921
2	Deliver Environmental Promises	.916
3	Eco – friendly	.616

The second factor can be called **"TRUST CONSCIOUS COMSUMERS"**

Table: 9 FACTOR 3

S.NO	Statements	Factor loading
1	Good reputation	.839
2	Accused of Green washing	.789
3	**Likely to purchase**	.640
4	**Willing to pay higher**	.612

The third factor can be called **"SUSTAINBILITY TRUST GREEN PURCHASERS"**

Table: 10: FACTOR 4

S.NO	Statements	Factor loading
1	Socially Responsible	.796
2	Likely to buy from them	.690
3	Recommendation	.538

The fourth factor can be called **"RESPONSIBILITY DRIVEN BUYERS"**

Table: 11 FACTOR 5

S.NO	Statements	Factor loading
1	Social media -Effective platform for promotion	.839

The fifth factor can be called **"SOCIAL MEDIA INFLUENCED CONSUMERS"**

TABLE 12: FACTOR 6

S.NO	Statements	Factor loading
1	Increased Awareness on environmental issues	.872
2	Positively Influence	.529
3	Feel skeptical	.507

The sixth factor can be called **"ECO MINDFUL CONSUMERS"**

Naming Factors
Overall sample – (N = 157)

Factor 1	**ECO SINCERITY SEEKERS**
Factor 2	**TRUST CONSCIOUS COMSUMERS**
Factor 3	**SUSTAINBILITY TRUST GREEN PURCHASERS**
Factor 4	**RESPONSIBILITY DRIVEN BUYERS**
Factor 5	**SOCIAL MEDIA INFLUENCED CONSUMERS**
Factor 6	**ECO MINDFUL CONSUMERS**
% of total variance	**79.381%**

Factor 1 is called as **Eco sincerity seekers** since the variables is related to the perceived Authenticity among green digital consumers

Factor 2 is named as a **Trust conscious consumers** because the information is linked to the brand trust of the consumers on sustainability

Factor 3 is labelled as **Sustainability trust green purchasers** as the responses are related to the brand trust and the purchase intentions of consumers

Factor 4 is labelled as **Responsibility driven buyers** as the responses are related to preference to purchase when the brand maintains sustainability on various aspects.

Factor 5 is labelled as **social media influenced consumers** as the responses are related that social media can act as platform to promote sustainability.

Factor 6 is labelled as **Eco mindful consumers** as the responses are related to the attitudes of consumers regarding green digital marketing

CLUSTER ANALYSIS

Cluster analysis is a method used to group people or items based on how similar they are in certain ways. In marketing and consumer research, it helps uncover natural groupings of consumers who think, feel, or act alike. For example, people might be clustered according to their environmental awareness, level of trust in brands, or buying intentions. By finding these patterns, businesses and researchers can better understand different types of consumers and design messages, products, or strategies that truly connect with each group.

TABLE 13: Final Cluster Centres

Variables	**CLUSTERS**		
	Real Deal Consumers	**Credibility focused consumers**	**Trust Driven consumers**
Eco Sincerity Seekers	7.67736	2.61981	3.11811
Trust Conscious Comsumers	3.09201	1.23687	2.00749
Sustainbility Trust Green Purchasers	3.37559	2.71749	3.02398
Responsibility Driven Buyers	2.43626	3.35658	3.01522
Social media Influenced Consumers	1.26814	4.69398	3.10755
Eco Mindful Consumers	1.86055	2.36446	4.01499

Cluster analysis was conducted in SPSS using the Hierarchical Clustering technique. The dendrogram from this analysis suggested the presence of five distinct clusters within the data. To validate these results, a K-Means Clustering analysis was also performed. The SPSS output table from this step presents the final cluster centers, highlighting the dominant factors within each cluster after all iterations were completed and cases were reassigned.

Each statement in the study was measured on a five-point scale, where 1 represents strongly disagree and 5 represents strongly agree. Therefore, any score above 2.5 indicates agreement with the statement, while a score below 2.5 indicates disagreement. Based on the final results, three meaningful clusters were identified. These clusters reflect distinct consumer profiles, each characterized by different dominant factors as shown in the table, allowing for a clearer understanding of the patterns and tendencies within the data.

Real-Deal Consumers

Real-deal consumers care deeply about authenticity and genuineness. They can easily tell the difference between brands that truly care about ethical and environmental values and those that only pretend to. They admire brands that "walk the talk" - the ones whose actions match their words. The above table shows that the consumers are most attracted by eco seekers a variable related to authenticity and least influenced by social media platform. Meanwhile, the moderate variable here is the trust conscious variable. Thereby when a brand is fulfilling consumers authenticity, they are ready to purchase the product.

Credibility-Focused Consumers

Credibility-focused consumers are those who choose brands they see as honest, reliable, and transparent. They like brands that back up their claims with real evidence and stay consistent in what they say and do. For these consumers, credibility is the key to building lasting trust and loyalty. The above table shows that the consumers are most attracted by social media platform a where the consumers are able to know more about the brand & its sustainability and least influenced by trust conscious variable. Meanwhile, the moderate variable here is the sustainability trust green purchasers. Thereby consumers when they really trust a brand based on their sustainability actions, environmental promises, the reputation that the brand earned for social responsibility and have been acused of green washing consumers ready to purchase as well make recommendation to their friends about the sustainability product.

Trust-Driven Consumers

Trust-driven consumers base their buying decisions on how much they trust a brand. When they believe in a company's reliability and consistency, they're more confident in purchasing - often willing to spend more for brands that deliver on their promises. The above table shows that the consumers are most attracted by eco mindful consumers a where the consumers are able to know more about the brand & its sustainability and least influenced by trust conscious variable. Meanwhile, the moderate variable here is the social media platform. Thereby the consumers feel that their awareness towards green digital marketing is increased also they feel skeptical when the brands simply claim eco-friendly without sustainability. Authentic green campaigns play avital role in influencing consumers, also this might be based on the brand perception of the consumers.

Although credibility-focused, real-deal, and trust-driven consumers have different motivations, they share a common belief in the importance of trust and sustainability. Credibility-focused consumers want honesty backed by proof - they trust brands that are open and transparent about their actions. Real-deal consumers care most about authenticity, supporting brands that genuinely live by their ethical and environmental values rather than just talking about them. Trust-driven consumers show their confidence through loyalty, staying committed to brands that consistently keep their promises. Together, these groups show that in today's conscious marketplace, trust, authenticity, and credibility go hand in hand - forming the foundation of strong, lasting relationships between consumers and brands.

IMPLICATIONS OF THE STUDY

Managerial Implications

The findings of this study offer several meaningful takeaways for marketing professionals and brand strategists aiming to build stronger relationships with Generation Z consumers.

Authenticity as a Strategic Imperative.

Generation Z consumers possess a high level of discernment and can easily identify exaggerated or inauthentic sustainability claims. Brands must ensure their sustainability messaging is grounded in genuine, verifiable environmental practices to maintain credibility and long-term trust (Theocharis & Tsekouropoulos, 2025; Urme et al., 2025). Authenticity is not only desirable-it is essential for brand survival in an increasingly eco-conscious marketplace.

Building Trust Through Transparency.

Trust is built when brands are transparent about their environmental actions and provide verifiable proof of their claims. Sharing third-party certifications, data-driven evidence, and consistent sustainability reports strengthens consumer confidence. This approach supports the perception that the brand is both honest and accountable (Amir, 2024).

Leveraging Social Media Effectively.

Social media platforms such as Instagram and YouTube play a crucial role in shaping Gen Z's perceptions of sustainability. These platforms allow brands to share authentic sustainability stories, showcase real actions, and engage audiences through creative visual content. Meaningful, educational, and emotionally engaging content generates higher levels of trust and brand connection than purely promotional campaigns (Silva & Krikheli, 2024).

Targeted Consumer Segmentation.

Recognizing the heterogeneity within Gen Z allows marketers to tailor their strategies effectively:
Real-Deal Consumers respond to authentic, story-driven campaigns that emphasize genuine sustainability actions.
Credibility-Focused Consumers value evidence-based and transparent communication, often reinforced by credible endorsements.

Trust-Driven Consumers are drawn to brands that demonstrate consistency and reliability in delivering on sustainability commitments.
By aligning communication strategies with these segments, brands can foster deeper engagement and develop enduring trust-based relationships.

Theoretical Implications

The results of this research reinforce the Stimulus–Organism–Response (S–O–R) framework, confirming that perceived authenticity (stimulus) influences consumer trust (organism), which then drives purchase intention (response). This process highlights the psychological pathway through which green digital marketing influences Gen Z consumers.

The study contributes to theoretical understanding by extending the literature on authenticity and trust in the context of digital sustainability communication. It provides empirical evidence supporting the mediating role of trust in green marketing effectiveness, aligning with previous research on authenticity-driven purchase intentions.

Policy and Educational Implications

Policy Implications.
Regulatory authorities should promote clear sustainability communication standards and certification systems. Such measures will help combat greenwashing, enhance consumer protection, and motivate brands to engage in authentic and verifiable sustainability practices.

Educational Implications.
Educational institutions play a crucial role in cultivating digital and environmental literacy among young consumers. By incorporating sustainability awareness and critical media evaluation skills into academic curricula, students can become more discerning consumers, capable of distinguishing between authentic green marketing and superficial eco-claims. This will empower the next generation to make more informed, ethical consumption choices.

CONCLUSION

This study concludes that Generation Z's engagement with green digital marketing is driven primarily by authenticity, trust, and social media influence. Gen Z consumers expect brands to act consistently with their stated environmental commitments, communicate transparently, and demonstrate tangible social responsibility.

For marketers, authenticity and credibility are not optional strategies-they are the foundation of meaningful consumer relationships. Brands that align their communication with genuine sustainability practices and maintain long-term transparency are more likely to earn the loyalty and advocacy of Gen Z consumers.

In essence, authenticity has become the new currency of credibility in the green digital marketplace. Sustainable success will depend not only on what brands claim but on how consistently they live those values through real actions and honest communication.

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A Study on ChatGPT as a Virtual Instructor: Improving Academic Assistance for Students

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ABSTRACT

ChatGPT is an OpenAI chatbot used to generate content, to get answers for questions, to engage in conversations and to have explanations. This research presents the results of an empirical examination into how well ChatGPT, as a virtual instructor, may help students with academic support. The use of chatbots in educational settings has attracted a lot of attention as artificial intelligence develops. The purpose of this study is to evaluate ChatGPT's capacity to offer individualized academic support for a range of subjects and educational levels.

The insights gathered for this research is to assess ChatGPT's effectiveness in providing instructional support, analyzing this with a wide range of participants, from different age groups. Participants were able to participate in suggesting ways on how ChatGPT can be improved to better assist with academic-related queries.

According to the research, ChatGPT demonstrates promising potential as a virtual instructor, significantly enhancing academic assistance in terms of accessibility, responsiveness, and adaptability. Participants reported high levels of satisfaction with the quality of support provided by ChatGPT, highlighting its ability to address individual learning needs effectively.

Whereas participant feedback also sheds light on the limitations of ChatGPT as a virtual instructor, informing recommendations for future enhancements and integration into educational settings. Overall, the study contributes to the growing body of research on AI-driven educational technologies and underscores the transformative role of ChatGPT in enhancing the learning experience.

Keywords: ChatGPT, Virtual Instructor, Academic Assistance, Educational Technology, User-friendliness, Personalized Learning, Instructional Support.

1. INTRODUCTION

ChatGPT

ChatGPT is a state-of-the-art chatbot developed by OpenAI and released in November 2022. This chatbot is based on a large language model, enabling users to control the direction, length, style, level of detail, and language of a conversation. Prompt engineering is used to consider the context of each conversation stage, where successive prompts and responses are utilized. The model is designed to provide advanced conversational capabilities, making it suitable for various language-related tasks.

ChatGPT is a conversational AI application developed using OpenAI's proprietary series of generative pre-trained transformer (GPT) models, which are based on Google's transformer architecture. It is trained using a combination of supervised and reinforcement learning techniques for fine-tuning its conversational capabilities. Initially released as a research preview, ChatGPT is now available as a freemium service. The free version uses the GPT-3.5 model, while the advanced version, named "ChatGPT Plus," is based on GPT-4 and is available to paid subscribers. The paid version also provides priority access to newer features.

With its groundbreaking innovations and cutting-edge technologies, ChatGPT has been widely acknowledged as the trailblazer that set off the AI boom, paving the way for a rapid and unprecedented development in the field of artificial intelligence. Its pioneering contributions have been instrumental in shaping the present-day AI landscape and driving the ongoing revolution that has transformed the way we interact with technology.

2. PROBLEM STATEMENT

In the digital era, students are relying on various AI based chatbots to get assistance in their academic tasks. ChatGPT as an OpenAI provides a variety of options and required data to thestudents for the academic projects, assignments, articles, or any other written content. With the help of the chatbots, information can be viewed and presented in different ways which can improve the critical thinking of users. Some people worry that these programs might make people less intelligent, encourage cheating and copying, or spread false information.

3. OBJECTIVES

i. Discover the potential of incorporating ChatGPT into online educational platforms for enhanced and interactive learning experiences.
ii. Evaluate ChatGPT's adaptability to different subjects and academics in online education.
iii. Discuss the pros and cons of using conversational AI in various educational environments.
iv. Study student attitudes and participation in ChatGPT-facilitated interactive learning.
v. Discuss the ethical and privacy issues related to the use of AI-powered chat interactions in education.

4. LITERATURE REVIEW

Exploring the Integration of ChatGPT in Education: Adapting for the Future
Author: Elbanna, S. and Armstrong, L.
Publisher: Emerald Publishing Limited
Link: www.emerald.com
Introduction: This article aims to explore the advantages of integrating a new generative artificial intelligence (AI) technology in education. It investigates the use of ChatGPT in personalised learning, assessment and content creation and examines ways to manage its limitations and some ethical considerations. The purpose is to stimulate discussion on the effective application of ChatGPT as a tool for learning and skill development while remaining mindful of the ethical issues involved.

Conclusion: The study concludes that ChatGPT can be effectively integrated into education to automate routine tasks and enhance the learning experience for students, ultimately increasing productivity and efficiency and fostering adaptive learning. However, the limitations of ChatGPT, even when updated, must be borne in mind,

including factual inconsistencies, potential bias promotion, lack of in-depth understanding and safety concerns. The study nevertheless highlights the benefits of responsibly integrating ChatGPT within the field of education.

Chatting and cheating: Ensuring academic integrity in the era of ChatGPT
Author: Debby R.E. Cotton, Peter A. Cotton & J. Reuben Shipway
Publisher: Taylor & Francis Online
Link: www.tandfonline.com

Introduction: ChatGPT is a variant of the GPT-3 (2020) artificial intelligence language model developed by OpenAI. It is specifically designed to generate human-like text in a conversational style, and was introduced in 2021. It has received significant attention in the media and tech

industry. GPT-3 is based on the Transformer architecture, which was introduced in a paper by Vaswani and has since become widely used in natural language processing tasks.

Conclusion: In conclusion, chatAPIs and GPT-3 have the potential to offer a range of benefits for higher education, including increased student engagement, collaboration, and accessibility. ChatAPIs can facilitate asynchronous communication, provide timely feedback, enable student groups, and support remote learning, while GPT-3 can be used for language translation, summarisation, question answering, text generation, and personalised assessments, among other applications. However, these tools also raise a number of challenges and concerns, particularly in relation to academic honesty and plagiarism. ChatAPIs and GPT-3 can be used to facilitate cheating, and it can be difficult to distinguish between human and machine-generated writing. Universities must carefully consider the potential risks and rewards of using these tools and take steps to ensure that they are used ethically and responsibly.

What is the Impact of ChatGPT on Education
Author: Chung Kwan Lo
Publisher: MDPI Books
Link: www.mdpi.com

Introduction: ChatGPT has introduced new challenges and threats to education. With its ability to provide specific answers to user questions, it can be used to complete written assignments and examinations on behalf of students, leading to concerns about AI-assisted cheating. In response, some schools have banned access to ChatGPT on campus [**12**]. The implications of GhatGPT in the field of education were explored in a review by Mhlanga [**13**]. He analysed eight articles on ChatGPT and revealed that educators had concerns regarding the use of ChatGPT in education. They expressed worries that students may outsource their work to ChatGPT because of its ability to rapidly generate acceptable texts.

Conclusion: This rapid review of 50 articles highlighted ChatGPT's varied performance across different subject domains and its potential benefits when serving as an assistant for instructors and as a virtual tutor for students. However, its use raises various concerns, such as its generation of incorrect or fake information and the threat it poses to academic integrity. The findings of this review call for immediate action by schools and universities to update their guidelines and policies for academic integrity and plagiarism prevention. Furthermore, instructors should be trained on how to use ChatGPT effectively and detect student plagiarism. Students should also be educated on the use and limitations of ChatGPT and its potential impact on academic integrity.

Impact of Implementation of ChatGPT in Education: A Systematic Review
Author: Marta Montenegro-Rueda, Jose Fernandez-Cerero, Jose Maria Fernandez-Batanero, Eloy Lopez-Meneses
Publisher: MDPI Books
Link: www.mdpi.com

Introduction: The aim of this study is to present, based on a systematic review of the literature, an analysis of the impact of the application of the ChatGPT tool in education. The data were obtained by reviewing the results of studies published since the launch of this application (November 2022) in three leading scientific databases in the world of education (Web of Science, Scopus and Google Scholar). The sample consisted of 12 studies. Using a descriptive and quantitative methodology, the most significant data are presented. The results show that the implementation of ChatGPT in the educational environment has a positive impact on the teaching–learning process, however, the results also highlight the importance of teachers being trained to use the tool properly. Although ChatGPT can enhance the educational experience, its successful implementation requires teachers to be familiar with its operation. These findings provide a solid basis for future research and decision-making regarding the use of ChatGPT in the educational context.

Conclusion: The systematic literature review has shown that scientific research on the use of the ChatGPT tool in education is still scarce, as it turns out to be a novel tool launched in late 2022. The use of ChatGPT in education has emerged as an innovative and promising tool that seeks to enhance the learning experience and foster greater interaction between students and teachers. In this sense, this artificial intelligence tool proves to be a motivating tool for students, by having to apply Information and Communication Technologies, and significantly improves students' academic performances, if it is used appropriately. However, it is essential to bear in mind that its use presents a series of challenges, which teachers must be aware of to avoid incorrect use. Along these lines, proper training of teachers and students can be effective to know how to use the application and avoid its misuse in the academic environment. With ethical implementation and proper supervision, this technology can open new educational possibilities and enrich the teaching and learning process.

ChatGPT for Education and Research: Opportunities, Threats and Strategies
Author: Md. Mostafizer Rahman and Yutaka Watanobe
Publisher: MDPI Books
Link: www.mdpi.com

Introduction: In this study, we explore the opportunities, challenges, and strategies of using ChatGPT in education and research and identify strategies for potential threats. To demonstrate the effectiveness of ChatGPT in programming support, we performed coding-related experiments, such as code generation from problem descriptions, pseudocode generation of algorithms from texts, and code correction. These generated solution codes were validated using an online judge system. In addition, we conducted a comprehensive survey with students and teachers to find out how ChatGPT supports programming learning and teaching.

Conclusion: ChatGPT has the potential and can be supporting tools for educational and research work. ChatGPT is a revolutionary that can maintain human-like conversations and generate human-like text for any natural language query that is nearly indistinguishable. However, although ChatGPT is a powerful tool that can generate impressive responses on a variety of topics, it still has certain limitations, such as a lack of common sense, potential bias, difficulty with complex reasoning, and inability to process visual information. It is important to keep in mind the limitations of ChatGPT when using it, and it should not be relied upon blindly.

ChatGPT in Education: A Blessing or a Curse? A qualitative study exploring early adopters' utilisation and perceptions
Author: Maria Giovina Pasca, Gabriella Arcese
Publisher: Science Direct
Link: www.sciencedirect.com

Introduction: To foster the development of pedagogically potent and ethically sound AI-integrated learning landscapes, it is pivotal to critically explore the perceptions and experiences of the users immersed in these contexts. In this study, we perform a thorough qualitative content analysis across four key social media platforms. The results of our research show that ChatGPT is most commonly used in the domains of higher education, K-12 education, and practical skills training. On the other hand, there is a degree of apprehension among concerned users. They worry about a potential overdependence on the AI system, which they fear might encourage superficial learning habits and erode students' social and critical thinking skills.

Conclusion: In this study, we investigated the adoption and perception of ChatGPT in education by analysing qualitative data collected from various social media platforms. Among the numerous applications of ChatGPT in higher education, content creation and editing emerged as the most prevalent, accounting for 78.11% of reported uses. Our findings unveiled a range of promising opportunities for ChatGPT to support learning, while simultaneously uncovering critical risks associated with overreliance on the tool. These risks encompass the potential to limit critical

thinking and creativity, impede a deep understanding of subject matter, and foster laziness and passivity.

Educational Applications of the ChatGPT AI System: A Systematic Review Research
Author(s): Michail Kallogiannakis, Stamatios Papadakis, Ali İbrahim Can Gözüm, Ziyaeddin Halit İpek
Publisher: Üniversite Park Ltd. Sti.
Link: www.ceeol.com

Introduction: ChatGPT is an artificial intelligence program released in November 2022, but even now, many studies have expressed excitement or concern about its introduction into academia and education. While there are many questions to be asked, the current study reviews the literature in order to reveal the potential effects of ChatGPT on education as a whole. The potential implications, possibilities, and concerns about the use of ChatGPT in education are disclosed as mentioned in the literature. Materials/methods – The data of the study were collected and then subjected to a systematic review. Research findings were analysed according to the themes and categories identified. Results – The results of this research were examined under themes according to the positive and negative aspects of ChatGPT. The positive categories and subcategories of ChatGPT's integration into education were determined, and the relationship between education and artificial intelligence determined. Similarly, the negative category highlighted the potential negative impact of artificial intelligence on educational processes.

Conclusion: The reviewed research evaluated and discussed the impact of AI on education and training processes. In conclusion, this review revealed the critical applications of ChatGPT for educational settings and the potential negative impact of its application. The findings established how ChatGPT and its derivatives would create a new paradigm in education as a whole.

5. RESEARCH METHODOLOGY

Population: Residents of Hyderabad who are studying in the universities and intermediate colleges of Hyderabad.

Sample Size: The number of survey respondents: 110
Note: Respondents are people who fill out the survey.

Sampling Technique: Random Sampling Technique: This technique is used when every person has an equal chance of getting selected to be part of the sample. There is no right or wrong answer, the option can be chosen according to their choice.

Methodology: Data collection was using Google forms. The sample has been selected at random Data collection using quantitative methods has been used. The data is collected from 110 of the people who are students of intermediate and of university.

Primary Data: Primary data is being collected via a Google form-based survey which has been shared with students of intermediate and of university. Google form plays a major role in collecting the primary data.

Tools and Techniques used for analysis:
Tools: Google Forms, Excel sheets, etc
Techniques: Data analysis techniques - Interpretations, Chi - Square Test

6. DATA ANALYSIS & INTERPRETATION

PART A: PERSONAL DATA

zTABLE 1.1: GENDER

Gender	No. of Respondents	Percentage of Respondents
Male	13	11.8%
Female	97	88.2%
TOTAL	110	100%

TABLE 1.2: AGE

Age	No. of Respondents	Percentage of Respondents
16 - 18	9	8.2%
19 - 21	81	73.6%
22 - 24	12	10.9%
25 - 27	8	7.3%
TOTAL	110	100%

PART B: RESEARCH - PROJECT RELATED QUESTIONS

1. Have you used virtual instructors for Academic Assistance before?

TABLE 2.1

Opinion	No. of Respondents	Percentage of Respondents
Yes	74	67.3%
No	36	32.7%
TOTAL	110	100%

2. If yes, please specify the platforms or tools you have used?

TABLE 2.2

Opinion	No. of Respondents	Percentage of Respondents
ChatGPT	62	83.8%
Bing AI	5	6.8%
Microsoft Copilot	1	1.4%
Chat Sonic	0	0%
Bard	6	8.1%
TOTAL	74	100%

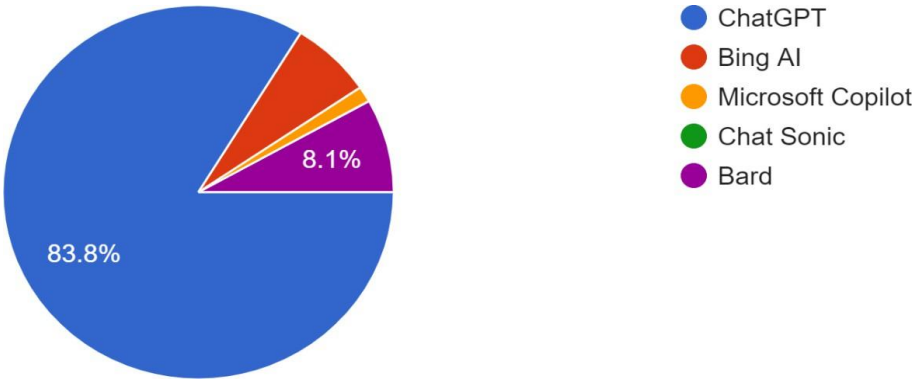

FIGURE 2.2

3. How did you first hear about ChatGPT as an academic assistant?

TABLE 2.3

Opinion	No. of Respondents	Percentage of Respondents
College/University	12	16.2%
Friends/Family	29	39.2%
Lecturers	8	10.8%
Social Media	25	33.8%
TOTAL	74	100%

4. How frequently do you use ChatGPT for academic assistance?

TABLE 2.4

Opinion	No. of Respondents	Percentage of Respondents
Daily	10	13.5%
Weekly	27	36.5%
Monthly	15	20.3%
Rarely	22	29.7%
TOTAL	74	100%

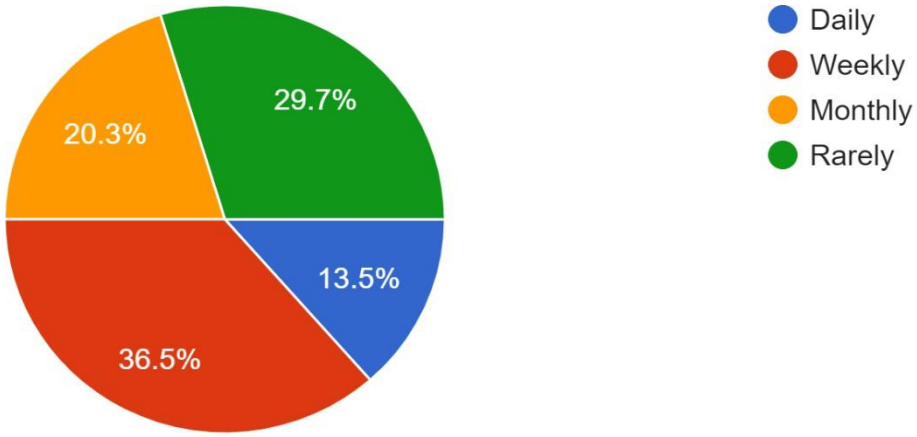

FIGURE 2.4

5. On a scale of 1 to 5, how would you rate the effectiveness of ChatGPT in assisting with academic queries? (1 being least effective, 5 being most effective)

TABLE 2.5

Opinion	No. of Respondents	Percentage of Respondents
1	3	4.1%
2	4	5.4%
3	20	27%
4	34	45.9%
5	13	17.6%
TOTAL	74	100%

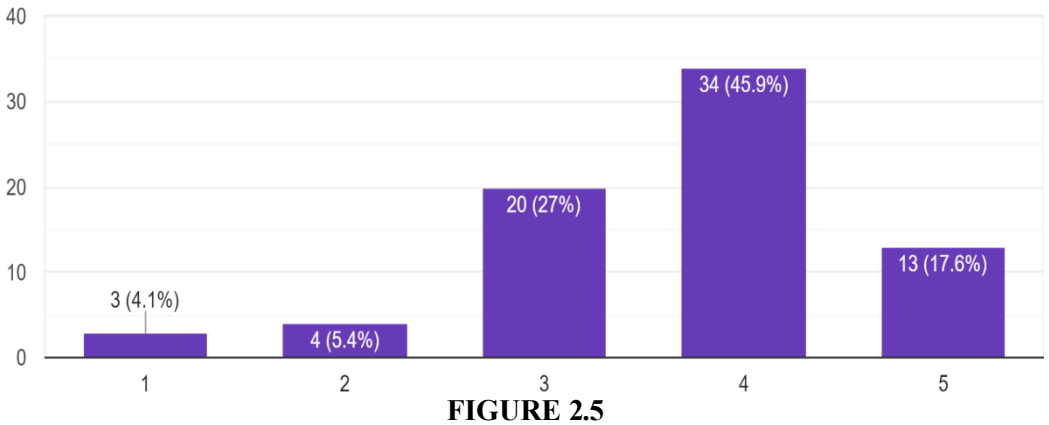

FIGURE 2.5

6. In what specific ways do you think ChatGPT could be improved to better assist with academic-related queries?

TABLE 2.6

Opinion	No. of Respondents	Percentage of Respondents
Provide a more detailed explanation.	32	43.2%
Generate citations for information.	20	27%
Clarify complex concepts with step-by-step breakdowns.	36	48.6%
Offer suggestions for further research or reading.	25	33.8%
Incorporate real-time updates for recent developments.	28	37.8%

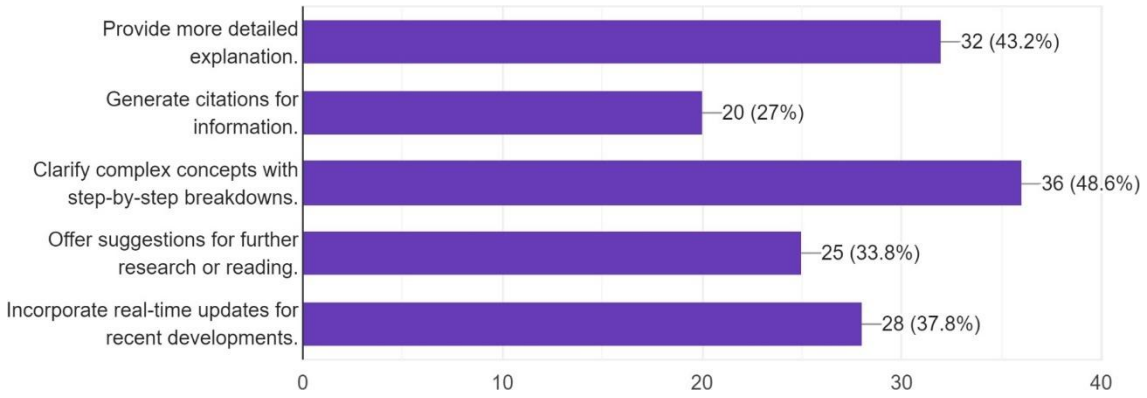

FIGURE 2.6

7. Are there specific subjects or topics for which you find ChatGPT more helpful? (Select more than one option)

TABLE 2.7

Opinion	No. of Respondents	Percentage of Respondents
General Knowledge	43	58.2%
Language and Writing Assistance	30	40.5%
Programming and Coding Queries	11	14.9%
Science and Mathematics	18	24.3%
Explanations		
Problem-solving	24	32.4%
Learning new concepts	36	48.6%

8. How user-friendly do you find the interface of ChatGPT for academic assistance? (1 being least effective, 5 being most effective)

TABLE 2.8

Opinion	No. of Respondents	Percentage of Respondents
1	15	20.3%
2	26	35.1%
3	19	25.7%
4	10	13.5%
5	4	5.4%
TOTAL	74	100%

9. How confident are you in the accuracy and reliability of the information provided by ChatGPT? (1 being least effective, 5 being most effective)

TABLE 2.9

Opinion	No. of Respondents	Percentage of Respondents
1	10	13.5%
2	15	20.3%
3	37	50%
4	11	14.9%
5	1	1.4%
TOTAL	74	100%

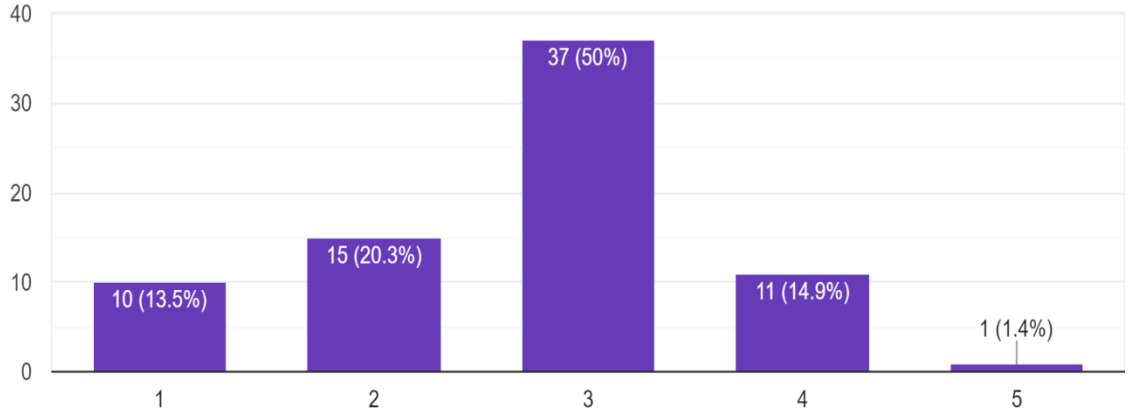

FIGURE 2.9

10. How can ChatGPT be better integrated into academic settings to enhance its utility?

TABLE 2.10

Opinion	No. of Respondents	Percentage of Respondents
Customization	21	28.4%
Subject Specialisation	27	36.5%
Integrated with Learning Platforms	22	29.7%
Privacy and Security	4	5.4%
TOTAL	74	100%

11. On a scale of 1 to 5, how satisfied are you with the overall performance of ChatGPT as a virtual instructor? (1 being the lowest and 5 being the highest)

TABLE 2.11

Opinion	No. of Respondents	Percentage of Respondents
1	1	1.4%
2	4	5.4%
3	26	35.1%
4	30	40.5%
5	13	17.6%
TOTAL	74	100%

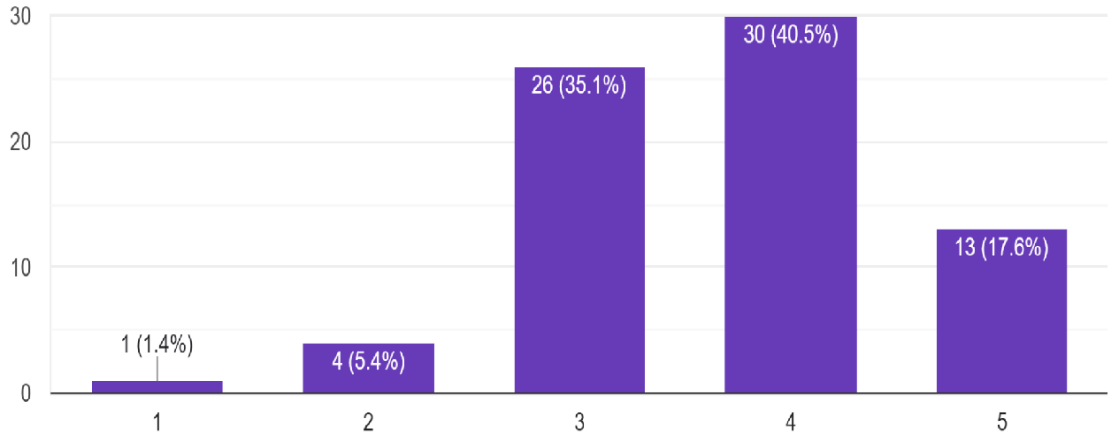

FIGURE 2.11

12. How do you think ChatGPT is affecting Human Creativity?

TABLE 2.12

Opinion	No. of Respondents	Percentage of Respondents
It enhances human creativity by giving brainstorming ideas	26	35.1%
It limits independent thinking and hinders the development of creative expressions	48	64.9%
TOTAL	74	100%

13. In what other ways does ChatGPT help you with?

TABLE 2.13

Opinion	No. of Respondents	Percentage of Respondents
Tutoring Assistance	12	16.2%
Language Learning	7	9.5%
Homework Help	20	27%
Exam Preparation	35	47.3%
TOTAL	74	100%

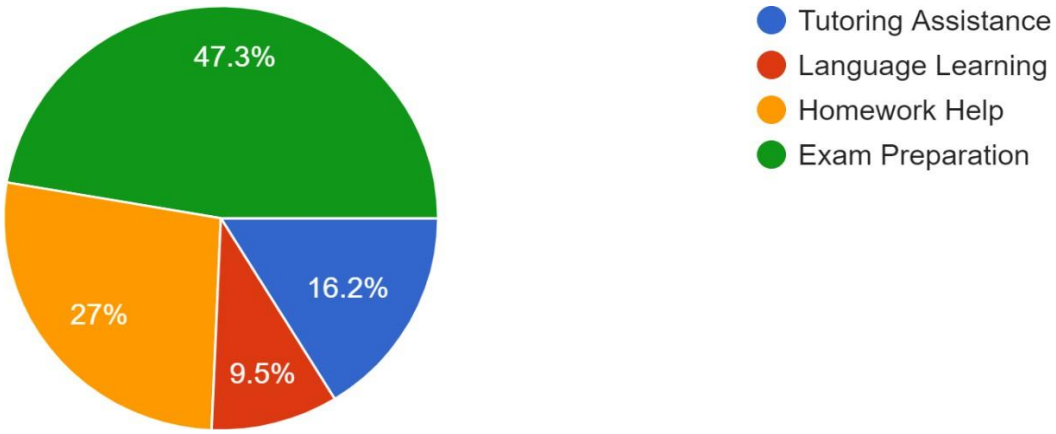

FIGURE 2.13

14. How would you describe the pace of instruction provided by ChatGPT?

TABLE 2.14

Opinion	No. of Respondents	Percentage of Respondents
Too Fast	19	70.3%
Too Slow	3	4.1%
Neutral	52	70.3%
TOTAL	74	100%

15. Rate on a scale of 1-5 as to how ChatGPT is exceeding or falling short of your expectations as a virtual instructor? (1 being the lowest and 5 being the highest)

TABLE 2.15

Opinion	No. of Respondents	Percentage of Respondents
1	5	6.8%
2	11	14.9%
3	32	43.2%
4	19	25.7%
5	7	9.5%
TOTAL	74	100%

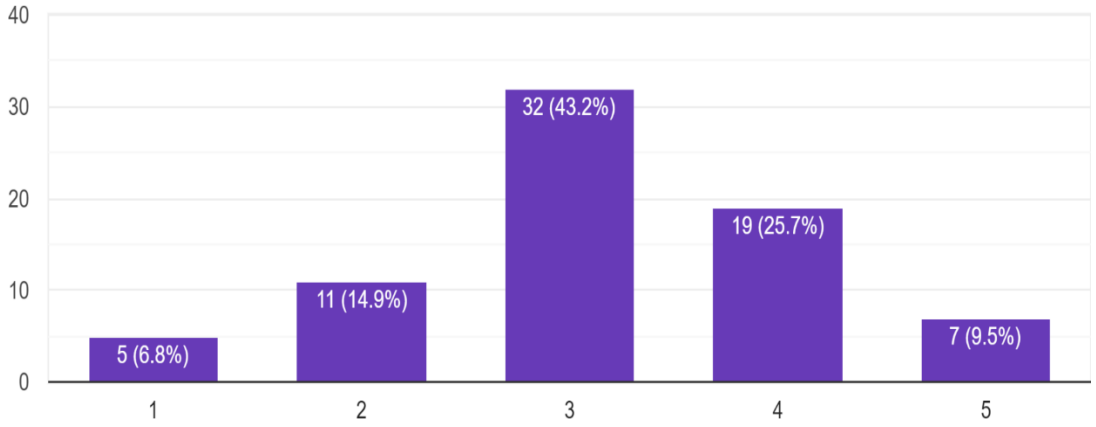

FIGURE 2.15

16. Rate on a scale of 1-5 as to what extent do you think ChatGPT was able to personalise the instruction based on your individual needs and preferences?
(1 being the least satisfactory and 5 being the most satisfactory)

TABLE 2.16

Opinion	No. of Respondents	Percentage of Respondents
1	1	1.4%
2	7	9.5%
3	30	40.5%
4	26	35.1%
5	10	13.5%
TOTAL	74	100%

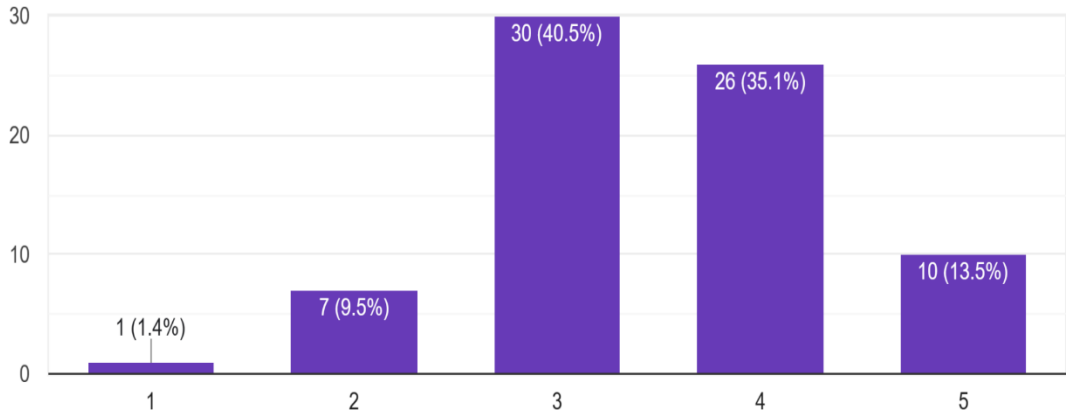

FIGURE 2.16

17. How often do you feel that the information provided by ChatGPT is not enough?

TABLE 2.17

Opinion	No. of Respondents	Percentage of Respondents
Often	19	25.7%
Sometimes	34	45.9%
Rarely	14	18.9%
Always	4	5.4%
Never	3	4.1%
TOTAL	74	100%

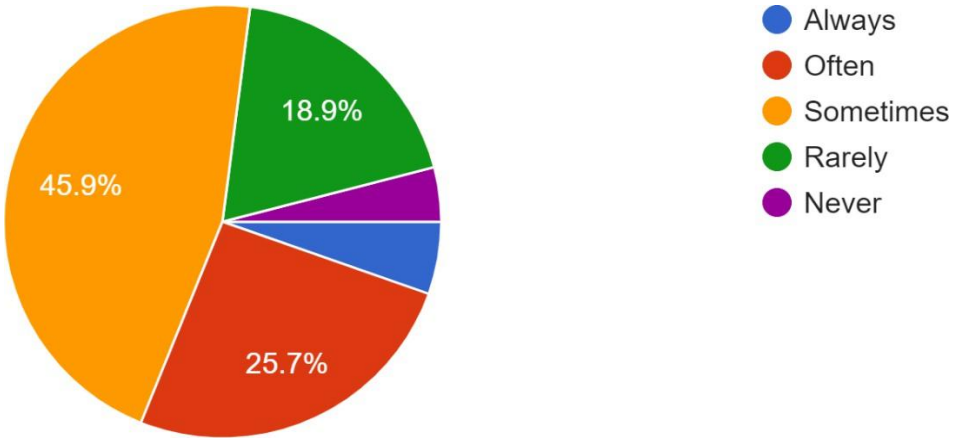

FIGURE 2.17

18. Do you believe ChatGPT can be a suitable alternative or supplement to human instructors?

TABLE 2.18

Opinion	No. of Respondents	Percentage of Respondents
Yes	17	23%
No	25	33.8%
Maybe	32	43.2%
TOTAL	74	100%

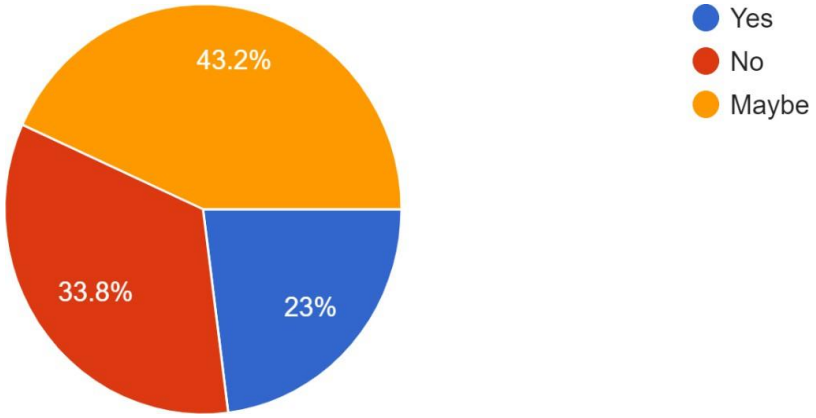

FIGURE 2.18

19. Please provide your reasons for the above choice.

TABLE 2.19

Opinion	No. of Respondents	Percentage of Respondents
Yes, because 24/7 Availability, Information Retrieval & Conceptual Explanation	30	40.5%
No, because of a lack of real-world experience or inability to assess practical skills.	44	59.5%
TOTAL	74	100%

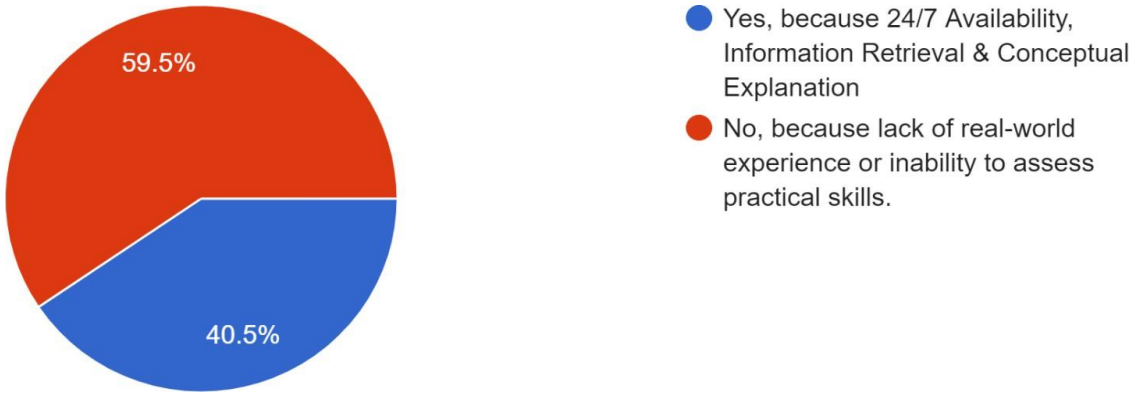

FIGURE 2.19

20. How comfortable are you with interacting and learning from an AI-based virtual instructor? (1 being the least and 5 being the highest)

TABLE 2.20

Opinion	No. of Respondents	Percentage of Respondents
1	7	19.4%
2	8	22.2%
3	10	27.8%
4	6	16.7%
5	5	13.9%
TOTAL	36	100%

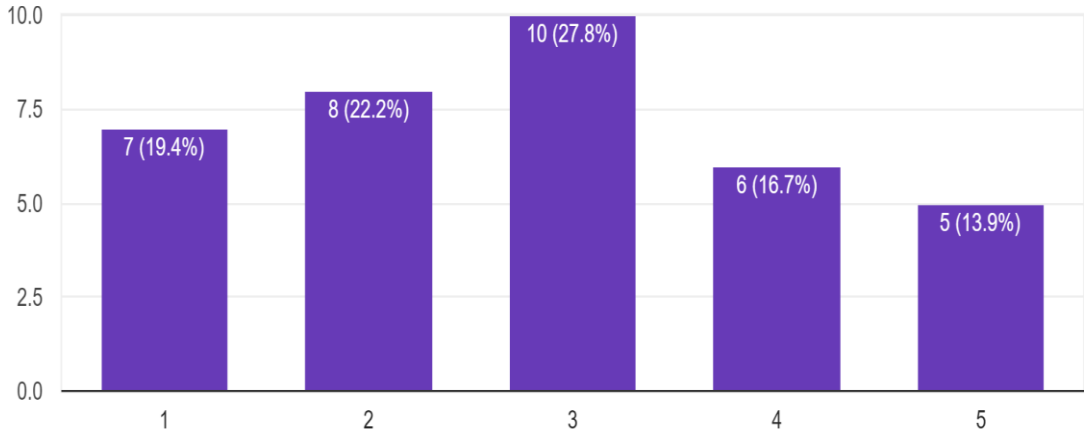

FIGURE 2.20

21. Are you open to incorporating AI technology like ChatGPT into your regular learning routine?

TABLE 2.21

Opinion	No. of Respondents	Percentage of Respondents
Yes	9	25%
No	8	22.2%
Maybe	19	52.8%
TOTAL	36	100%

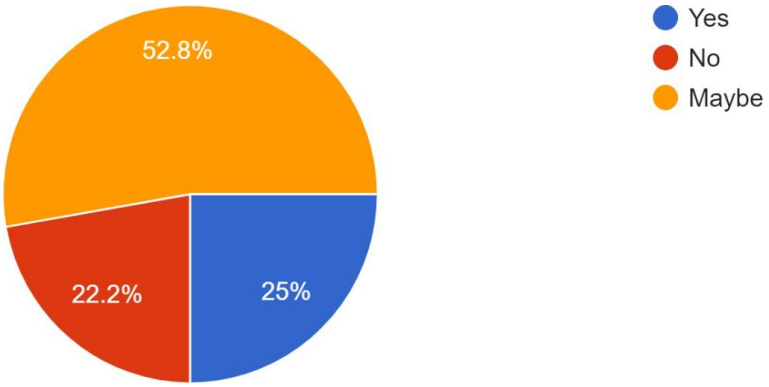

FIGURE 2.21

22. How do you typically prefer to receive information and guidance in your studies?

TABLE 2.22

Opinion	No. of Respondents	Percentage of Respondents
Lecturers	13	36.1%
Friends/Batch Mates	11	30.6%
Through Internet	12	33.3%
TOTAL	36	100%

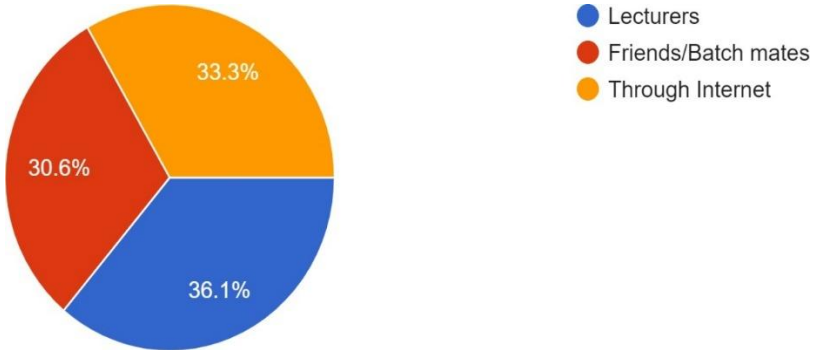

FIGURE 2.22

23. Are you comfortable with technology-driven learning experiences, or do you prefer traditional teaching methods?

TABLE 2.23

Opinion	No. of Respondents	Percentage of Respondents
Technology - Driven Learning Method	19	52.8%
Traditional Teaching Methods	17	47.2%
TOTAL	36	100%

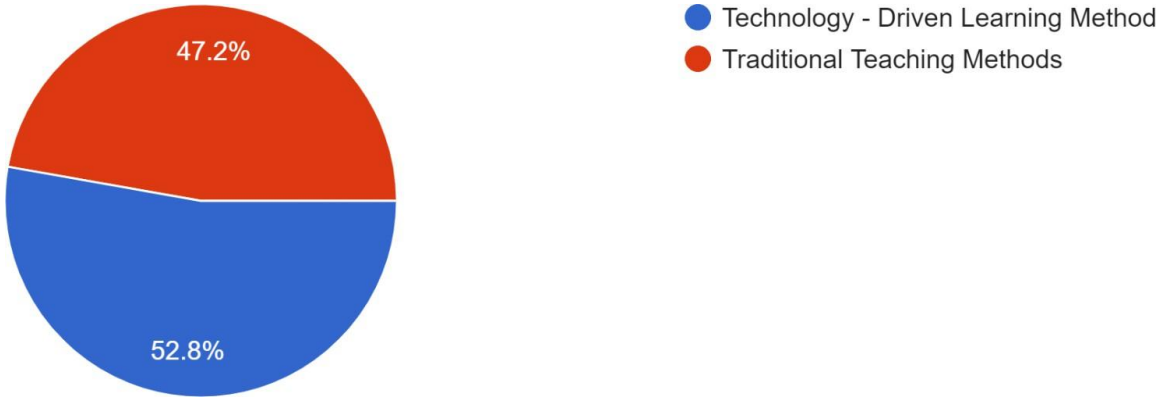

FIGURE 2.23

24. Based on your initial impressions, how likely are you to recommend ChatGPT as a virtual instructor to others?

TABLE 2.24

Opinion	No. of Respondents	Percentage of Respondents
1	9	25%
2	10	27.8%
3	8	22.2%
4	4	11.1%
5	5	13.9%
TOTAL	36	100%

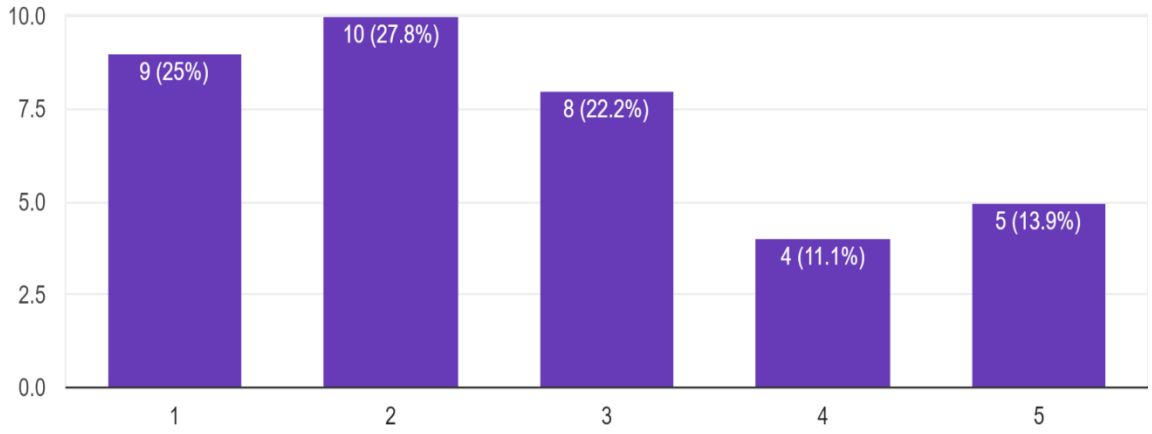

FIGURE 2.24

25. Do you prefer to use Virtual Instructor in future?

TABLE 2.25

Opinion	No. of Respondents	Percentage of Respondents
Yes	9	25%
No	8	22.2%
Maybe	19	52.8%
TOTAL	36	100%

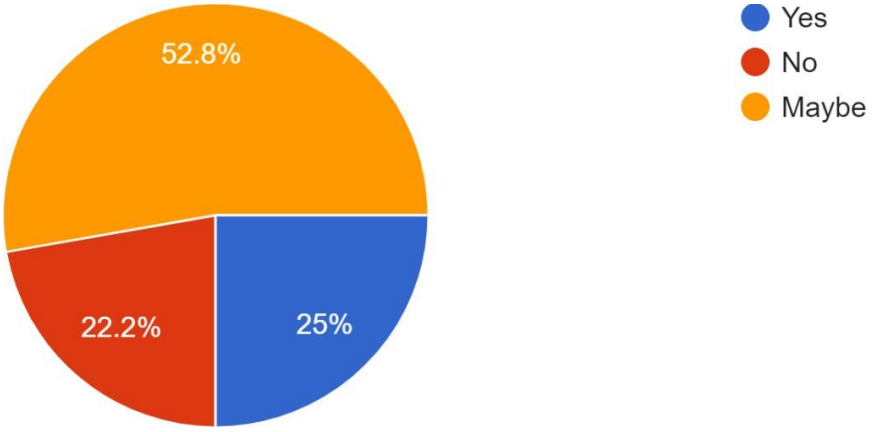

FIGURE 2.25

CHI - SQUARE TEST

Do you believe ChatGPT can be a suitable alternative or supplement to human instructors?

- Yes
- No
- Maybe

Are you open to incorporating AI technology like ChatGPT into your regular learning routine?

- Yes
- No
- Maybe

Here, we are combining two questions to use the CHI - SQUARE Technique for analysis and interpretation.

NULL HYPOTHESIS: There are no significant differences between substitution of AI to human instructor and incorporation of AI in regular learning routine.

ALTERNATIVE HYPOTHESIS: There are significant differences between substitution of AI to human instructor and incorporation of AI in regular learning routine.

	No. of Responses for Question 18	**No of Responses for Question 21**	**Row Total**
Yes	17	9	**26**
No	25	8	**33**
Maybe	32	19	**51**
Column Total	**74**	**36**	**110**

Expected Frequency = Column Total * Row Total / TOTAL

Outcome	**Expected Frequency**	**O - E**	2 **(O - E)**	2 **(O - E) /E**
17	17.5	-0.5	0.25	0.014
25	22.2	2.8	7.84	0.353
32	34.3	-2.3	5.29	0.154
9	8.5	0.5	0.25	0.029
8	10.8	-2.8	7.84	0.725
19	16.7	2.3	5.29	0.316
				1.591

Degree of Freedom = (n - 1) = (3 -1) = 2
Significance Level = 5%
Table Value = 5.99

Therefore, the calculated value of x^2 is less than the table value, Null Hypothesis is accepted. Hence, it is indicated that there are no significant differences between substitution of AI to human instructor and incorporation of AI in regular learning routine.

7. FINDINGS

The Findings of the study are as follows:

- Majority of the Respondents were Female in the age group 19-21
- Most of the people are using ChatGPT as Virtual Instructors for Academic Assistance
- Most Of the Respondents use ChatGPT for Academic Assistance on a weekly Basis and helpful for general knowledge inquiries
- A Higher percentage of 48.6% expects ChatGPT to "Clarify complex concepts with step-by-step breakdowns"
- Results indicated a mixed perception of the user-friendliness of ChatGPT's interface for academic assistance and has at least average confidence in the accuracy and reliability of the information provided by ChatGPT.
- The lowest portion of respondents prioritize the importance of "Privacy and Security" measures.
- Majority of respondents rated their satisfaction with the overall performance of ChatGPT as a virtual instructor
- Respondents believe that ChatGPT has a positive impact on human creativity by offering ideas for brainstorming.
- According to the survey, opinions on ChatGPT as a virtual instructor vary among respondents.
- The survey showed mixed opinions on ChatGPT's ability to personalize instruction and require more information from ChatGPT.

- We could also conclude that there are conflicting views on whether ChatGPT can serve as a viable substitute or complement to human instructors.
- Among the respondents we could make out a moderate to high level of comfort with interacting and learning from an AI-based virtual instructor
- The survey results also showed that people have diverse preferences for receiving information and guidance in their studies.

8. SUGGESTIONS

i. **Use of ChatGPT -** As per the above collected responses, we can say that 36.5% of the respondents use ChatGPT weekly.

ii. **Overall experience of ChatGPT -** Almost all the respondents find ChatGPT effective but then 9.5% of the respondents feel that ChatGPT is least effective.

iii. **Effect on Human Creativity -** From the collected responses it is clear that 64.9% of the respondents think that ChatGPT hinders Human Creativity.

iv. **Pace of ChatGPT -** Almost 70.3% respondents find the pace of ChatGPT neutral, that means it is neither too fast nor slow.

v. **Interacting and Learning from Virtual Instructor -** From the 32.7% respondents who have never used ChatGPT, 41.6% respondents are not comfortable to use Virtual Instructor, while the others are interested in using Virtual Instructor for interacting and learning.

9. CONCLUSION

The Overall findings of the survey reveal that ChatGPT is helpful for academics but all the users are moderately satisfied with its performance. ChatGPT is undeniably a valuable tool for academics, offering a wealth of information, assistance, and insight across various subjects. Its ability to generate coherent responses and provide relevant resources makes it a go-to resource for students. However, while many users find ChatGPT to be beneficial, there is a general consensus that its performance is satisfactory but not exceptional. While it can offer assistance on a wide range of topics, there are instances where its responses may lack depth or fail to fully address the user's query. A portion of respondents have just the average confidence in the accuracy and reliability of the information provided by ChatGPT.

Overall, while users appreciate ChatGPT's utility, there is room for improvement to enhance user satisfaction and fulfill their academic needs more effectively as a significant portion of respondents found ChatGPT's performance to be above average and satisfactory.

***

Review on Challenges in Securing Emerging Cyber-Physical Systems

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ABSTRACT

As we hurtle towards a future of interconnected devices, protecting the security and privacy of the cyber-physical landscape has emerged as a formidable challenge. The boundary between the digital and physical worlds has become a prime target for attackers seeking to inject nefarious signals or extract sensitive information from sensing systems. While previous research has largely focused on abstract models for signal injection, this review paper presents a comprehensive survey of the broader CPS arena, illuminating attack patterns, potential new threats, and effective countermeasures against emerging cyber-physical hazards. From signal injection and side-channel information leakage to sensor-based attacks, we explore various facets of security and privacy in CPS, laying bare the complexities of safeguarding our interconnected systems. Our review underscores the pressing need for holistic approaches to secure CPS and charts a roadmap for future research directions. With in-sights borne of rigorous analysis and careful evaluation, this paper serves as an invaluable resource for researchers and professionals navigating the ever-changing terrain of the cyber-physical world.

Keywords: Interconnected devices, Cyber-physical landscape, Security challenges, Privacy concerns, Sensitive information, Attack patterns and models, Systematic review, Emerging threats, Countermeasures and defenses, Holistic security approaches.

1. INTRODUCTION

In the past decade, the field of Cyber-Physical Systems (CPS) has experienced a meteoric rise in popularity across various industries. By integrating embedded systems, communications, and controls, CPS has enabled seamless communication between the physical and digital worlds, unlocking revolutionary new capabilities in aerospace, healthcare, and manufacturing domains.

The widespread adoption of IoT devices has further fueled the growth of CPS in consumer-facing applications and software. Industry projections suggest that by 2022, there will be an estimated 29 billion connected devices, with 18 billion belonging to the IoT ecosystem. As the deployment of embedded systems and IoT devices continues to accelerate, the need for robust security measures in CPS has never been more critical.

However, the integration of cyber and physical domains presents novel and complex challenges in safeguarding against malicious attacks [1]. The safety-critical nature of CPS, coupled with the potentially catastrophic effects of any attack on human life and the environment, underscores the urgent need for comprehensive security protocols.

Within this comprehensive review, we delve deeply into the intricacies of as-saults directed at the nexus between the cyber and physical domains. Our focus centers explicitly on signal injection and information leakage attacks [2], undertaking a meticulous examination of current research delineating these threat categories. This analysis extends to the exploration of existing countermeasures, acknowledging their strengths and limitations. Moreover, we cast our gaze for-ward, identifying potential avenues for future advancements and opportunities in the perpetual cat-and-mouse game between cyber assailants and defenders.

Our contributions encompass a comprehensive model for cyber-physical at-tacks [3], formalization of attack requirements, and diverse threat models. We address the impact of advancements in

computer networks and embedded systems on the evolving landscape of attack and defense in CPS, emphasizing the necessity for holistic security approaches for interconnected systems.

2. EXISTING STUDIES

A. Prior Research Work conducted in the Field

As cyber-physical systems (CPS) become integral to society, concerns about their safety and security have escalated. Prior research has categorized security challenges in CPS, spanning overviews, domain-specific analyses, algorithm-level examinations, and sensing pipeline analyses [4]. This paper adopts a distinctive approach, concentrating on cyber-physical interaction, specifically signal injection attacks [5] from the physical to the cyber realm and information leakage attacks from the cyber to the physical realm. This unique perspective offers a complementary analysis, introducing novel insights for devising defenses against cyber-physical attacks.

In this section, we will present existing literature on CPS security and the issues they address. Our review highlights the need for more comprehensive and robust approaches to securing CPS, given the potential consequences of malicious attacks on human life and the environment. Ultimately, our paper makes a valuable contribution to the existing body of work on CPS security, offering fresh perspectives and recommendations for future research directions

1) **Synopsis of the Security of CPS:** The realm of Cyber-Physical Systems (CPS) security has been the subject of several high-level surveys aimed at summarizing the key security issues. These studies endeavor to provide com-prehensive assessments of security risks across all layers of CPS architecture, including discussions on potential threats posed by sensors. However, these dis-cussions are typically restricted to in-band injection attacks and classical attack types such as signal jamming [6] and replay attacks [7]. As a result, privacy breaches from sensing components have not been explored extensively, indicating a research gap in the literature on CPS security.

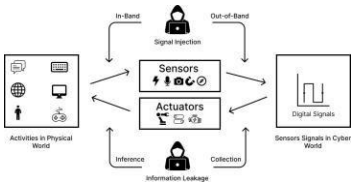

Fig. 1. Depiction of Sensors Signals in Cyber World

Evaluation of Existing Research Methods: Previous research in CPS security has primarily focused on analyzing trends and distributions of research topics through statistical analysis of representative research papers. This traditional method utilizes systematic mapping to quantitatively analyze CPS security research papers, providing a comprehensive overview of various security issues with an emphasis on publication trends and research strategies.
In contrast, this paper takes a distinct approach by emphasizing on cyber-physical interaction [8] while excluding traditional network security discussions. Our unique perspective offers fresh insights into the field of CPS security and provides a critical evaluation of existing research methods.

By comparing different approaches to CPS security research [9], we can gain a more comprehensive understanding on the field associated with it and also identifying and detecting the areas for further exploration and research development. Ultimately, our evaluation of existing research methods highlights the need for a more holistic approach to CPS security research, one that acknowledges the complexities and inter-dependencies for the proposed systems.

2) Study analysis of Domain-Specification:
Ensuring the security of Cyber-Physical Systems (CPS) is a very challenging task which requires a thorough analysis and understanding of potential attacks and defenses. Several surveys have attempted to systematize these aspects in specific application domains, such as power grids, medical devices, ICS, drones, and others. However, these studies are often limited since their insights and conclusions are tailored to a particular area.

Analysis of Gap: For instance, attacks on circuit breakers and heavy electricity attacks may be highly dependent within the power grid domain but not relevant to other CPS types. To address this issue, we propose an approach that focuses on the physical medium used by attackers to target cyber-physical systems. By examining cyber-physical attack vectors, we can analyze how existing techniques leverage them to compromise various CPS domains. This way, we can offer insights into new attack and defense directions that can be adapted to different CPS areas. In essence, instead of analyzing a specific CPS domain's security, our approach centers on analyzing attack vectors and how they can be exploited to compromise CPS security more generally. By doing so, we can pro-vide generalizable findings that offer new research directions for securing CPS.

3) Study of Sensing Pipeline: Recent research has demonstrated the potential for malicious actors to manipulate physical signals in order to launch at-tacks on cyber systems. In response, researchers have tried to formalize methods for assessing how such attacks can impact the components, specifically sensors, used in cyber-physical systems (CPS).

Evaluation of Existing Research Methods: Several studies have introduced methods for evaluating the security of sensing pipelines in cyber-physical systems. For example, one study proposed a model for signal injection attacks and an algorithm for assessing the security of real-world systems such as smart-phones. Another study focused on out-of-band signal injection attacks, where the injected signal is outside the intended range of receivers. A third study expanded on these ideas by examining transduction attacks [10] that combine effects from multiple processing stages.

These approaches constitute significant contributions to the CPS security field, providing valuable insights into sensing pipeline vulnerabilities and potential attack vectors. By expanding upon these studies and developing new techniques for evaluating sensing pipeline security, we can continue to advance CPS security.

This section highlights the importance of continually evaluating existing re-search methods in CPS security and building upon them to drive innovation and progress. By improving our understanding of potential threats and vulnerabilities, we can better protect against cyber-physical attacks and ensure the safety and security of society.

B. Analysis of Gap and Our Core Aim
In the landscape of cyber-physical systems (CPS) security, considerable attention has been paid to conventional concerns like network and control security. However, the critical interface between the physical and cyber worlds has been largely overlooked. Unexplored are emerging threats involving the transmission of signals between these realms, such as physical-to-cyber signal injection attacks and cyber-to-physical information leakage attacks [8]. The former manipulates physical signals to impact cyber systems, while the latter allows cyber systems to eavesdrop on the physical world.

Addressing this gap, our focus is on a structured analysis of attacks targeting sensing components within cyber-physical interactions. We've developed a comprehensive CPS system model and distinct attack models for each threat, spanning applications like autonomous vehicles, drones, medical implants, and voice-controlled systems. This unique approach allows us to evaluate attacks effectively, recognizing that traditional security measures may fall short. By summarizing

and categorizing these threats, we aim to offer a concise yet comprehensive understanding, paving the way for more effective defense strategies.

2 SYSTEM MODEL OF CPS

This section delves into the architecture of Cyber-Physical Systems (CPS) and the intricate interactions among its components. The focal point is the elucidation of the cyber-physical interface [11], encompassing the system's sensing and actuation elements. By elucidating this interface, we aim to shed light on the nuanced dynamics within CPS.

The discussion unfolds with an exploration of CPS architecture, unraveling the interplay between its diverse components. This narrative seamlessly transitions into an in-depth examination of the cyber-physical interface, offering insights into the crucial roles played by sensing and actuation mechanisms. This holistic understanding sets the stage for a nuanced exploration of threats specific to cyber-physical interfacing, distinct from conventional cyber network and software system attacks [12].

A. System Framework of Cyber Physical Systems (CPS)

The overarching design of a Cyber-Physical System (CPS) is structured into two primary layers: the application layer and the cyber-physical layer. In this framework, the application layer serves as the interface facilitating communication between the cyber-physical layer [13] and diverse local or external appl-cations. This functionality ensures a fluid integration of the CPS with broader systems. Conversely, the cyber-physical layer encompasses pivotal components, including sensors, actuators, embedded systems, IoT devices, and the tangible physical environment. This dual-layered architecture forms the foundation for the intricate interplay between digital and physical elements within the CPS, marking a distinctive characteristic in its design.

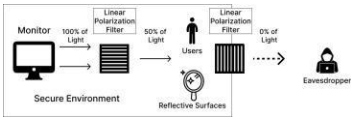

Fig. 2. Securing the environment using Linear Polarization Filter

In the realm of Cyber-Physical Systems (CPS), sensors assume a pivotal role by gathering physical signals from the environment. Subsequently, these signals undergo digitization within the embedded system. The embedded system, acting as a nexus of software or hardware controllers, processes these digitized signals, producing control signals that govern the actions of actuators. This intricate process forms a feedback loop characterized by predictable timing behavior, ensuring both safety and timeliness in signal processing and subsequent actions.

Moreover, in scenarios where the CPS is network-connected, the embedded system takes on the additional responsibility of managing the transmission and reception of network signals. This functionality enables seamless communication with cloud services, showcasing the versatility of the embedded system in orchestrating a comprehensive and interconnected CPS framework.

This paper directs its attention toward security challenges emerging from cyber-physical interactions, with a specific emphasis on discussions pertaining to the cyber-physical layer within CPS. Notably, Sections III-B and III-C delve into the intricate interplay between cyber data and physical phenomena, giving rise to distinct threats that demand swift attention. The imperative lies in promptly addressing these unique threats to safeguard the safety and security of Cyber-Physical Systems (CPS). This approach underscores the paper's commitment to a nuanced exploration of the vulnerabilities inherent in the convergence of cyber and physical realms within CPS.

B. Interfacing of the Cyber-Physical World

In Cyber-Physical Systems (CPS), sensors and actuators serve as critical components that facilitate interaction with the physical world. Sensors act as nodes acquiring data from the environment and

providing valuable outputs in response to specific measurements. This allows CPS to create accurate representations of their surroundings. In contrast, actuators permit the systems to alter the physical state of their environment, allowing for greater control over their surroundings. It is worth noting that IoT devices have started incorporating actuation capabilities that coordinate among various devices.

Unfortunately, attackers frequently initiate malicious attacks through user input, and false command injection is a common technique used to exploit vulnerable systems. Attackers inject false commands into the system by sending false cyber-domain messages or using control flow hijacking techniques in software. They may also take advantage of unintended receivers in electronic components to deliver malicious signals. Furthermore, sensors located at the boundary be-tween CPS and the physical world are more susceptible to attacks since they reside in both domains. As a result, this paper focuses primarily on discussing the vulnerabilities of sensing systems.

Sensors serve as indispensable components within Cyber-Physical Systems (CPS), acting as crucial mediators between the tangible realm and digital systems. A distinctive classification of sensors categorizes them into two primary types: passive and active. This classification underscores the nuanced roles these sensors play in orchestrating the dynamic interplay between the physical and digital domains within CPS. The unique categorization reflects the paper's commitment to providing a fresh perspective on the integral role of sensors in facilitating seamless interaction within CPS.

Passive sensors, exemplified by devices like microphones and MEMS motion sensors [14], are adept at discerning pre-existing physical signals without introducing any external stimuli. These sensors operate with a keen observational capacity, capturing the ambient data in their surroundings.

In contrast, active sensors, typified by technologies like radar and LiDAR [15], engage in a more proactive approach. They emit signals into their environment, probing and exploring, and subsequently measure the reflected signals to extract valuable insights about environmental features. This dynamic inter-action characterizes active sensors, showcasing their ability to actively engage with the surroundings to acquire pertinent information. The nuanced descriptions highlight the diverse functionalities of passive and active sensors within Cyber-Physical Systems, contributing to a unique understanding of their roles and capabilities.

Overall, this section emphasizes the crucial role played by sensors and actuators in enabling the interaction between the physical world and digital systems in CPS. It highlights the unique challenges posed by malicious attacks and the vulnerabilities of sensing systems. By understanding these issues, we can develop effective security measures that mitigate emerging threats and ensure the safe and secure integration of physical and digital domains in CPS.

C. Different Threats of Interfacing of Cyber-Physical

1) Different Vector Attacks: Cyber-physical attacks pose unique risks to society because they can impact both the cyber and physical domains. Despite research in securing areas such as power grids, new attack vectors, such as cyber-physical interfacing, which gets evaded due to limitations in the information received by the cyber domain.

2)

Navigating the challenges posed by cyber-physical threats in CPS demands a comprehensive understanding of existing attacks and corresponding defenses, categorized by their implementation domain. Adversaries wield the ability to manipulate data through physical emanations or surreptitiously eavesdrop on sensor data, underscoring the imperative to identify and counteract these evolving threats. Sections IV and V of this paper meticulously illuminate a spectrum of attacks, shedding light on their intricacies.

Furthermore, the paper meticulously synthesizes defenses, categorizing them based on their implementation domain. This categorization unveils a strategic approach, unraveling the principles and acknowledging the limitations inherent in each domain. By accentuating these nuanced aspects, the paper aims to contribute to a holistic comprehension of cyber-physical attack landscapes and foster effective defense strategies within the dynamic realm of Cyber-Physical Systems (CPS).

As the threat landscape continues to evolve, it is crucial to prioritize understanding and implementing effective mitigation measures to protect cyber-physical systems. This requires a comprehensive approach, including regular threat assessments, continuous monitoring, and proactive defense strategies to mitigate potential risks. By adopting a holistic approach, organizations can minimize the impact of cyber-physical attacks and ensure the security and reliability of their systems.

3) Appearance of Consumer IoT: The Internet of Things (IoT) originally referred to tracking physical objects with radio-frequency identification (RFID) [16], but it has evolved to include networked devices and systems like smart farms and cities. This overlaps significantly with cyber-physical systems, as both share essential technologies such as machine-to-machine communication and sensing. he past few years have witnessed a notable surge in the proliferation of consumer electronics fostering smart connections, often referred to as consumer IoT devices. These technological advancements have reshaped the dynamics of interaction between our physical and cyber realms. Intriguingly, despite their transformative impact, the security of these devices has only recently garnered substantial attention. While prevailing research has dedicated efforts to unraveling IoT security challenges, the foundational principles and techniques gleaned from this exploration hold the potential to be extrapolated and applied to the broader landscape of cyber-physical systems.

4) This paper strives to accentuate the evolving security landscape surrounding consumer IoT devices, recognizing their pivotal role in the intricate fabric of cyber-physical interactions. By acknowledging the intersectionality of IoT and larger cyber-physical systems, the research endeavors to bridge the gap, offering insights that transcend the confines of individual device security to contribute to the holistic fortification of interconnected technological ecosystems.
To address these challenges, it is important to prioritize the security of consumer IoT devices. Given their widespread adoption, even minor vulnerabilities can have a significant impact on users' privacy and security. It is essential to ensure that these devices are designed with security in mind, including secure communication protocols, appropriate access controls, and regular vulnerability assessments.

Overall, the appearance of consumer IoT devices presents new challenges for cyber security, but effective strategies can be developed by applying existing research principles and techniques. By prioritizing security and adopting best practices, we can ensure that the increasing number of connected devices does not expose users to unnecessary risks.

5) Analyzing Attacks on the IoT and CPS: IoT devices and cyber-physical systems are vulnerable to different types of attacks due to their varying software architecture, physical environment, and impact. Consumer IoT devices rely on lightweight embedded devices [17] and cloud backends [18], while larger CPS use desktop/server class control stations. Attacks on critical CPS, such as power grids, can cause significant harm, whereas consumer IoT attacks may have a limited impact. Unsecured Internet of Things (IoT) nodes expose vulnerabilities, enabling the formation of botnets and giving rise to conventional security issues. The diversity in the physical safeguards implemented across complex Cyber-Physical Systems (CPS) poses a considerable challenge in formulating a comprehensive model for both attack and defense. Nevertheless, the distinct environments of consumer IoT devices provide a more defined scope, facilitating the development of overarching methodologies for the analysis and safeguarding against potential attacks

3 BRIDGING REALMS: COMPREHENDING SIGNAL INJECTION ATTACKS ACROSS PHYSICAL AND DIGITAL SPHERES

Signal manipulation assaults represent a category of cyber threats utilizing physical signals to disrupt the operations of cyber-physical systems (CPS). There exist two primary manifestations of these attacks: in-band and out-of-band. In the context of in-band attacks, adversaries inject malevolent signals strategically

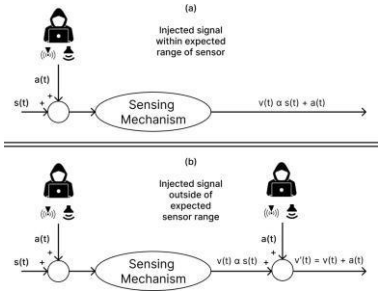

Fig. 3. Sensing Mechanisms (a) Injected signal within expected range of sensor (b)

Injected signal outside of expected sensor range within the designated frequency range of sensors. This intrusion holds the potential to distort sensor readings, leading to unintended and potentially detrimental behaviors within the CPS. On the other hand, out-of-band attacks capitalize on vulnerabilities in hardware, enabling the injection of signals beyond the anticipated frequency range. This approach poses substantial security risks, presenting a noteworthy threat to the integrity of CPS.

The consequences of signal injection attacks on CPS can be catastrophic, as they can cause widespread disruptions and compromise the system's integrity. The effectiveness of these attacks lies in their ability to bypass traditional cyber-security measures and exploit the physical characteristics of the system to induce unexpected behavior. Hence, preventing signal injection attacks necessitates an integrated approach that considers both cyber and physical security measures.

To prevent signal injection attacks in CPS, organizations should implement strong security protocols, such as updating firmware and software regularly to address vulnerabilities, implementing intrusion detection mechanisms to detect unusual behavior, and educating stakeholders about the dangers of signal injec-tion attacks. Additionally, secure communication protocols between devices can help prevent unauthorized access and manipulation of signal data.

Fig. 4. Data Analysis, Classification and Extraction

Overall, signal injection attacks pose a serious threat to the resilience and stability of cyber-physical systems. It is critical consisting a comprehensive approach to security that encompasses both digital and physical aspects of the system. By putting in place robust security measures and remaining vigilant, organizations can reduce the risk of signal injection attacks and protect their critical infrastructure.

A. The Threat Model Signal injection attacks are a type of cyber threat that exploits physical signals to manipulate the operation of cyber-physical systems (CPS). These attacks can be classified into two categories: in-band and out-of-band. In-band attacks [19] involve injecting malicious signals within the intended frequency range of sensors, which can alter sensor readings and trig-ger unintended behavior in CPS. Meanwhile, out-of-band attacks [20] exploit hardware vulnerabilities to inject signals outside the intended frequency range, leading to significant security risks for CPS.

B. Executing a signal injection attack with success necessitates two critical elements: ensuring the credibility of the input and eliciting a coherent response. Credible input involves the adept crafting of malicious signals in a manner that the system perceives them as legitimate inputs. Simultaneously, a coherent response requires the injected signals to manifest discernibly in the system's behaviors. The attacker's ultimate goal is to effectively compromise the system, emphasizing that alterations in the sensor mechanism alone are insufficient un-less they unequivocally dictate the entire system's behavior.

The pathway for a signal injection attack is contingent upon the frequency attributes of the signal and its nature, encompassing acoustic, electromagnetic, or optical categories. Predominantly, attackers concentrate on these three classifications, affording them the capability to initiate either sensor spoofing or perpetrate denial-of-service (DoS) attacks [21]. The intended consequences of a signal injection attack may vary, contingent upon the unique application domain.

In the realm of cyber-physical systems, the utilization of sensor feedback to determine control signals for actuators is commonplace. Consequently, should an assailant gain control over sensor readings, they hold the potential to exert influence over or trigger actuation within the system, presenting a formidable threat. This form of attack can be executed either locally within the embedded controller[22] or at a more potent edge or cloud node. In scenarios where sensor data is wirelessly transmitted to a remote node for control computation, this type of attack gains prominence. An illustrative instance is an attack leveraging acoustic signals to manipulate the gyroscope of a drone, thereby impacting its aviation actuation.

The software within the control application layer is tasked with manipulating the cyber realm rather than directly altering physical states. Through the injection of signals to induce inaccurate sensor readings, an attacker can deceive the operator, fabricating a distorted perception of the system's state. An illustrative scenario involves GPS spoofing attacks targeting navigation applications on aircraft, trains, and ships. Such attacks have the potential to misguide the driver, resulting in erroneous driving operations.

C. Methods of Injecting Malicious Signals Within Intended Frequency Range

In the realm of Cyber-Physical Systems (CPS), in-band signal injection at-tacks focus on delivering malicious signals within the specified frequency range of receivers. The strategies employed for executing these attacks exhibit variations contingent on the type of sensor under scrutiny. Passive sensors, by their nature of not actively emitting signals, emerge as comparatively more vulnerable targets. An instance of this vulnerability is illustrated when an assailant capitalizes on intense light to obstruct a camera's vision or deploys heightened infrared rays to overwhelm infrared sensors. This unique approach highlights the nuanced vulnerabilities specific to each sensor type within the landscape of in-band signal injection attacks. Challenging the security of active sensors presents formidable obstacles, given their active transmission and reception of signals. Technologies such as LiDAR and ultrasound-based sensing, falling under the realm of active sensing, heavily depend on the feedback derived from echoes or reflections to perceive their surroundings. Exploiting this vulnerability, attackers can fabricate or replay reflected signals originating from various distances and angles, thereby deceiving the receiving end of active sensors.

Fig. 5. Utilizing Modulated Signals for Analog-to-Digital Conversion (ADC)

In a strategic move, attackers can employ signal generators to transmit pulses, fabricating false echoes. This manipulation can lead to distorted object recognition systems, detecting objects in incorrect locations, or even triggering false positives, identifying non-existent objects. This

intricate manipulation of active sensor feedback underscores the sophistication and potential impact of attacks on technologies relying on active sensing principles.

D. Methods of Injecting Malicious Signals Out-Side the Intended Frequency Range

Injecting malicious signals outside the intended frequency range presents several challenges for attackers. The primary challenge is to ensure the plausibility of the injected signals within the system. The attacker must ensure that these signals survive signal conditioning processes and are converted into valid in-band signals.

To achieve this, the attacker needs to identify system components that unintentionally act as receivers for out-of-band signals. These components possess im-perfect designs that inadvertently capture these signals, which are subsequently down-converted into in-band signals. This down-conversion allows the injected signals to pass through the system undetected.

Once the out-of-band signals are successfully injected, the next challenge is to make them meaningful. Depending on the attacker's objectives, this could involve either disrupting the sensor readings by introducing noise or injecting specific waveforms to elicit desired responses.
To disturb sensor readings, an assailant may deploy a continuous out-of-band signal created by an unauthorized receiver coupled with a down-converting element. The introduced interference should possess ample strength to elicit a substantial reaction from the system.

Alternatively, if the attacker intends to introduce specific waveforms into the sensing system, these must bear a close resemblance to a known sensor output capable of eliciting the desired behavior. In this context, the attacker deploys an out-of-band signal as the carrier wave, incorporating the intended sensor output through modulation. The subsequent down-conversion process involves demodulation, accomplishing not only the shift of the injected signal to the in-band but also the recovery of the modulated intended sensor output.

To consolidate various methodologies employed in sensor spoofing attacks, the development of a comprehensive mathematical model for out-of-band signal injection attacks assumes paramount importance.

Framework for Out-of-Band Signal Injection: Developing a mathemat-ical model for out-of-band signal injection attacks requires an understanding of the system's response to these injected signals. The proposed model builds upon previous research, incorporating adaptations to better represent each component in the sensor's signal conditioning path. The model comprises six main compo-nents, corresponding to different segments of the sensor's signal path affected by the attack. These components include:

1. The modulated signal intended for injection into the system.
2. The transmitted signal experiences attenuation as it traverses the system.
3. An unintended receiver unintentionally captures the signal.
4. An amplifier boosts the signal strength.
5. A low-pass filter eliminating LEAKED SIGNAL-frequency noise.
6. An ideal analog-to-digital converter (ADC) converting the signal.

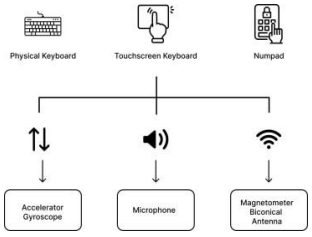

Fig. 6. Use of various wireless Devices in the form of wireless communications mecha-nisms

Through comprehensive comprehension and modeling of these constituents, valuable insights can be derived into the dynamics of out-of-band signal injection attacks. This knowledge can then be leveraged to progress countermeasures, enhancing our ability to thwart such attacks effectively.

Modulated Signal: To execute the assault, the assailant produces an in-jected signal encompassing a modulated waveform that includes their desired sensor output signal, labeled as j(t), coupled with an out-of-band carrier wave [23] at frequency *Nc*. This waveform adheres to the principles of amplitude mod-ulation. In mathematical terms, the signal can be represented as:

$$s(t) = (1 + j(t))Sc \cos(2\pi Nct + \varphi)$$

Here, *Ac* represents the amplitude of the carrier wave, and ϕ denotes the initial phase. The modulation of the injected signal is a crucial aspect of a successful attack, as it enables the attacker to achieve their objectives. Further explanation on the significance of modulation will be discussed in detail below.

Signal Damping: As the malicious signal propagates towards the target system, it experiences attenuation values [24] caused by multiple factors that hinder its strength. These factors collectively contribute to the attenuation value, denoted as Ad. The magnitude of Ad relies on various parameters, including the characteristics of the transmitted signal itself, environmental properties, the attacker's distance from the target system, and other relevant factors. Consequently, the attacker needs to determine an optimal configuration that minimizes the effects of signal attenuation.

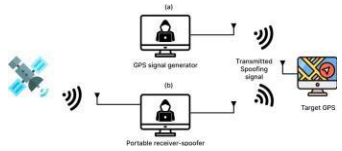

Fig. 7. Target GPS generation

Unintended Receiver:
In situations involving inadvertent receivers, the frequency response is commonly characterized through transfer functions. The magnitude of the unintended receiver's frequency response, represented as $|HU \cdot R(j\omega)|$, can be conceptualized as a bandpass filter with a lower frequency limit, fL, and an upper-frequency limit, *Nh* [25]. Signals outside of this frequency range undergo substantial attenuation. To effectively introduce an attack signal, the injected signal must undergo modulation in a manner that enables it to traverse this filter.

For example, in the scenario of an electromagnetic interference attack, the wires connecting the sensors to the analog-to-digital converter (ADC) inadvertently function as receivers, capturing signals with minimal gain. Short wires may manifest resonant frequencies in the gigahertz (GHz) range, necessitating the injected signal to be modulated over a FREQUENCY CARRIER WAVE [26] for optimal reception. Typically, this modulation is accomplished using formulas like $\cos(2\pi Nct)$ for the carrier waveform and j(t) for the message signal, resulting in a modulated output expressed as:

$$s(t) = S \cos(2\pi Nct + \Phi)j(t)$$

Here, A represents the amplitude of the carrier wave, *Nc* denotes its frequency, ϕ represents its phase, and $j(t)$ represents the message signal being transmitted.

Fig. 8. Formation of Partial and Complete Recover

Analog-Digital Converter:
The transformation of analog signals into digital format plays a pivotal role in numerous sensor-based systems, facilitated by the analog-to-digital con-verter (ADC). Although ADCs may manifest in various types, they generally encompass three fundamental components: the track-and-hold circuit (also recognized as sample-and-hold), the analog-to-digital converter proper, and the level-comparison mechanism.

The track-and-hold circuit [27] engages in the initial sampling of the analog signal, retaining it until digitization becomes feasible. Additionally, this circuit acts as a low-pass filter [28], eradicating high-frequency noise from the analog signal before conversion. After the signal has been held, the analog-to-digital con-verter transforms it from the analog domain into the digital realm. The specific conversion technique employed can vary based on the ADC type. Some sensors integrate ADCs within their chips, while others necessitate distinct components to ensure accurate signal conversion.

Apart from ADCs, amplifiers frequently find application in various signal con-ditioning processes unrelated to ADCs. The level-comparison mechanism within an ADC operates as a non-linear amplifier, potentially introducing DC offsets. Ideally, the amplifier's gain (P), represented by P(x), should multiply the input signal by a constant factor *A*, resulting in

$$P\,(v(t)) = I \cdot v(t) + K \cdot v2(t)$$

(equation 2). However, real-world amplifiers exhibit non-linear behavior and demonstrate second-order responses. Coefficients I and K capture the level of non-linearity exhibited by the amplifier, and their values may vary based on the input signal's frequency and magnitude.

To quantify the amplifier's non-linearity, we propose the use of a non-linearity factor called alpha *α*. Alpha is calculated as the ratio of coefficient B to coefficient *I* and indicates the extent to which the amplifier's non-linear behavior affects its overall response under specific input conditions. Understanding the non-linearity factor can assist engineers in designing and optimizing signal processing systems for diverse applications.

Low-Pass Filter: The track-and-hold circuit embedded in an ADC can be analogized to a low-pass filter. Analogous filters find application in diverse sensors, including microphones and cameras. The filter's attributes are delineated by its transfer function, labeled as HLP(s). An essential parameter of this filter is the cutoff frequency, fcut [29]. This pivotal frequency delineates the spectrum of frequencies subject to attenuation by the filter. Precisely, frequencies surpassing fcut will experience notable attenuation.

Optimal Analog-to-Digital Converter (ADC): In the analog-to-digital conversion process, an ideal ADC samples an analog signal at a specific frequency and converts each sample into an N-bit digital representation. The sample-and-hold circuit is commonly employed for this purpose. The resolution of the ADC is determined by the value of N, which corresponds to the number of bits in each digital representation generated during the con-version. Additionally, the sampling frequency is denoted as Fs [30]. Both the resolution (N) and sampling frequency (Fs) are crucial parameters that define the operation of an ideal ADC.

Demodulating Out-of-Band Signals: Suppose an adversary intends to generate a specific voltage signal [31], j(t), within the intended frequency range at the output of a sensor. To achieve this, the adversary employs modulation techniques to embed the desired signal over an out-of-band carrier wave, allowing it to be captured by an unintended receiver. Once received, the injected signal undergoes demodulation within the system, aiming to recover the original j(t). The choice of modulated injected waveform by the adversary is contingent upon the demodulator employed within the circuit, which may be either the amplifier or analog-to-digital converter. Both of these components have the potential to serve as demodulators in the system.

ADCs as Demodulators: A research investigation conducted by Giechaskiel et al. unveiled that prominent analog-to-digital converters (ADCs) harbor the capacity to demodulate amplitude-modulated (AM) signals [32]. When a potential attacker endeavors to inject their desired signal, denoted as $j(t)$, through the receiver, it must surpass the receiver's band-pass filter. The attacker's objective could involve manipulating the sensor readings to exhibit a constant DC value, achievable by setting $j(t) = M$. Following the traversal through the ADC, the signal undergoes sampling at a rate Ns, resulting in a sequence of consistently spaced samples. Opting for the carrier frequency Nc as a multiple of the sampling frequency $Nc = n \cdot Ns$ (where n is a positive integer), allows the representation of the ADC output as:

$$V[i] = KM \sin(2\pi ni + \varphi)]$$

where K incorporates the impact of attenuation and the band-pass filter, representing ϕ as the phase shift.
This configuration aligns the samples with every nth peak of the modulated injected signal, effectively transforming the ADC into an envelope detector and demodulating the signal. Given a constant ADC sampling frequency, Fs, this process, known as signal aliasing [33], occurs when the analog signal is under sampled. According to the Nyquist sampling theorem [34], for accurate re-construction of the analog signal's shape, the sampling rate must be at least twice the highest frequency component of the input signal. Deviation from this condition results in aliasing of the digitized signal.

In signal injection attacks, malicious actors deliberately induce aliasing by selecting a carrier frequency that is a multiple of the ADC sample rate but falls outside the intended frequency range. Consequently, two primary prerequisites must be met for the attacker to effectively utilize the ADC as a demodulator: (1) the ADC's sample rate, Ns, must remain constant over time, and (2) the carrier frequency Nc must satisfy the condition $Nc < Ns$ and $NL \leq Nc \leq NH$. This mandates the attacker to identify an out-of-band carrier frequency that aligns with the ADC's sample rate while still falling within the unintended receiver's frequency response range.

Demodulating Signals using Amplifiers: Amplifiers featuring non-linear characteristics, as delineated in Equation (2), hold the potential to demodulate signals injected by malicious actors. Let's consider a scenario where an attacker injects a signal resembling Equation (1) with the aim of manipulating the sensor output signal, represented as $j(t) = \sin(2\pi Nmt)$. In this instance, the Fourier transform of the attack signal reveals a solitary spectral component at the carrier frequency, Nc. By substituting Equation (1) into Equation (2), we can articulate the amplifier's response to this specific input signal. This gives rise to spectral components at the in-band frequency, Nm, alongside spectral components at integer multiples of these frequencies (harmonics), intermodulation products, and the carrier frequency, Nc. When processed by the non-linear amplifier, the spectrum of the injected signal encompasses the frequency components intrinsic to the intended sensor output signal.

Upon passing through the non-linear amplifier, the signal's The spectrum en-compasses frequency components related to the attacker's intended sensor output signal, encompassing inter-modulation products, harmonics, and the carrier frequency. Subsequently, the amplifier's output undergoes low-pass filtering, diminishing frequency components beyond Nm. Consequently, the resultant spectrum predominantly features a component at Nm. To emulate this behavior, an LT-Spice schematic is employed, wherein a behavioral voltage source serves as the non-linear amplifier with specific parameters. The simulation results illustrate that non-linear amplifiers exhibit demodulating properties when the input signal undergoes appropriate modulation, as elucidated earlier.

Nevertheless, the effectiveness of non-linear amplifiers as demodulators hinges on factors like the non-linearity factor, α, and the cutoff frequency of the low-pass filter, $Ncut$. The non-linearity factor should be sufficiently substantial to demodulate the injected signal, while the cutoff

frequency must be low enough to attenuate frequency components at *Nc*, yet sufficiently high to preserve the vital frequency components of $j(t)$.

In summary, non-linear amplifiers harbor the potential to demodulate signals injected by adversaries, contingent on factors such as the non-linearity factor and the cutoff frequency of the low-pass filter. Adversaries must be cognizant of these prerequisites when endeavoring to effectively deploy amplifiers for demodulating injected signals.

E. Cyber-Physical Attacks: Signal Injection Techniques and Vulnerabilities

This section furnishes an insight into current research concerning signal injection attacks directed at sensors within cyber-physical systems. The attacks are systematically classified into in-band and out-of-band categories. In the con-text of in-band attacks, assailants introduce optical, electromagnetic, or acoustic signals with the intention of executing sensor spoofing or perpetrating denial-of-service attacks. The targeted sensors encompass a diverse range, including cameras, radars, MEMS motion sensors, ultrasonic sensors, LiDARs, GPSs, infrared sensors, microphones, or magnetic sensors.

Electromagnetic deception attacks: It could be either gray-box or white-box, as the attacker needs familiarity with either the communication protocol or the control logic interpreting sensor readings. In contrast, signal jamming attacks usually demand less pre-existing knowledge from the attacker and can be categorized as black-box or gray-box. To execute a jamming attack [38], the adversary produces an assault signal surpassing the voltage generated by the sensed physical signal.

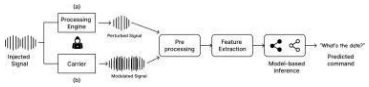

Fig. 9. Model-based Inferencing using Injected Signal

Radar as Target: Radar systems emit radio waves and analyze the reflected waves to gather information about surrounding objects, including distance, velocity, and orientation. An instance of a signal injection attack is illustrated on the millimeter-wave (MMW) radar system [36] employed in automobiles, primarily for collision avoidance and detecting pedestrians and cyclists. The system's insufficient protection exposes vulnerabilities, enabling attackers to ana-lyze the emitted radar signal and falsify legitimate reflections. This manipulation leads to erroneous distance reports concerning objects in the system's trajectory.

Magnetic Sensor as Target: Magnetic field sensors utilized in anti-lock braking systems (ABS) [37] can become targets in signal injection attacks. Electromagnetic actuators placed in the car wheel are employed to inject signals into the ABS's magnetic sensors. The attack encompasses two types, one being crude and disruptive to the system, while the other deceives magnetic signals to produce inaccurate wheel rotation speed readings. Such an attack has the potential to create life-threatening situations for drivers.

Similarly, GPS systems are susceptible to signal injection attacks. Adversaries can employ a signal simulator to generate authentic spoofing signals or construct a portable GPS receiver-spoofer to manipulate received signal parameters. These attacks could result in perilous consequences, including misleading navigation information and unauthorized tracking.

Electromagnetic Denial-of-Service (DoS) Attacks: GPS receivers are vulnerable to attacks that disrupt their ability to navigate. These attacks, known as jamming attacks, work by overwhelming the GPS signal with a local, high-powered signal. This causes the GPS receiver to fail in decoding signals from satellites orbiting the Earth, resulting in a loss of navigation capabilities.

Due to the substantial distance between the Earth's surface and GPS satellites, the authentic signals transmitted by these satellites undergo notable trans-mission losses. Consequently, GPS jamming attacks [38] can be executed using inexpensive jammers available for purchase at less than US dollar 10. These jammers have the capability to disrupt GPS receivers within a radius of up to 300 meters from the jamming device. Individuals might utilize these jammers to conceal their location from tracking systems, but the repercussions can be severe for critical infrastructure like aircraft, train, and ship navigation systems. For instance, if an aircraft encounters jamming while in flight, it may lose its ability to navigate accurately, leading to potentially life-threatening situations.

In addition to GPS receivers, the radar sensors employed in autonomous vehicles are also susceptible to jamming attacks. Attackers can employ high-powered signals to overwhelm the radar receiver, causing it to report no objects in its surrounding environment. This has the potential to make autonomous vehicles unable to detect obstacles or other vehicles, resulting in accidents or collisions.

Table 1. Cyber-Physical Systems (CPS) Examples and Applications

CPS Example	Application
Smart Grid	Energy distribution
Autonomous Cars	Transportation
Smart Cities	Urban infrastructure
Industrial IoT	Manufacturing processes
Healthcare	Patient monitoring
Agricultural	Precision farming

Summary of the various sensors used: Optical sensors in various devices can be vulnerable to spoofing attacks, where an attacker can manipulate the sensor data to deceive the device's algorithms. For instance, medical infusion pumps that use infrared drop sensors can be spoofed by overloading the sensor with an infrared laser and periodically turning it off to create fake drops, resulting in under-infusion of medicine.

LiDAR systems implemented in autonomous vehicles are susceptible to exploitation by attackers who replay transmitted pulses from diverse locations using a pulse generator to fabricate spurious echoes. This manipulation can prompt the receiver to identify objects as either closer or farther away than their actual positions, resulting in misinterpretation by control software and potentially influencing the vehicle's mission planning.

Cameras are also susceptible to optical spoofing attacks, particularly targeting facial recognition and object recognition algorithms [39]. In such scenarios, an assailant might employ infrared LEDs embedded into headwear or specially crafted eyeglasses to strategically project dots onto their face, altering facial features and eluding facial recognition authentication systems. Moreover, introducing minor alterations to stop signs or other objects can lead to mis-classification by object recognition algorithms used in autonomous vehicles, potentially resulting in accidents. In conclusion, spoofing attacks on optical sensors and algorithms present substantial threats to the proper functioning and safety of various de-vices, including medical equipment, autonomous vehicles, and security systems.

Table 2. Existing Security Solutions for Cyber-Physical Systems

Security Solution	Description
Verification and Access Control	User authentication and role-based access control
Intrusion Detection and Deterrence	Monitoring and preventing unauthorized activities
Encryption and Data Protection	Securely encrypting sensitive data at rest and in transit
Secure Software Development Practices	Implementing secure coding and testing practices
Incident Response and Recovery	Rapid response and recovery from security incidents

Acoustic Attacks and the summary of sensors used in It: Cyber-physical systems are susceptible to attacks that exploit sound waves. One ex-ample is the manipulation of ultrasonic sensors used in autonomous vehicles for parking assistance and self-parking systems. Attackers can simulate reflections from non-existent objects or disrupt legitimate signals through acoustic cancellation. These attacks can compromise the system's ability to detect real objects accurately. Voice-activated assistants like Amazon Echo and Google Home are also susceptible to acoustic attacks. Adversaries can introduce distorted voice commands that are incomprehensible to humans but still acknowledged by speech recognition algorithms. They accomplish this by altering Mel-Frequency Cepstral Coefficients (MFCCs) [40], which are utilized as features in characterizing human speech. Various methods, including modifying the time domain signal, introducing random phase information, incorporating high-frequency components, or adjusting the audio speed, can generate the distorted signal. In certain instances, music can act as a carrier for the manipulated speech command.

To thwart these attacks, researchers propose various defense mechanisms. Passive notification defense involves notifying users when an acoustic attack is detected. Active confirmation defense requires users to confirm critical commands to prevent unauthorized actions. Additionally, machine learning algorithms can be trained to distinguish between computer-generated and human audio samples, thereby enhancing the system's ability to identify and reject manipulated commands.

In the context of sensor fusion, multiple sensors are employed to establish a comprehensive perception of the physical world, encompassing tasks such as estimating motion or orientation. However, sensor fusion algorithms '[41] be-come targets for attackers seeking to compromise the system's state estimation. Researchers have specifically investigated spoofing attacks against the Kalman Filter-based sensor fusion algorithm [42], crucial for measuring inclination in mo-tion tracking and altitude control systems for robots and drones. Through metic-ulously orchestrated spoofing attacks on multiple sensors (accelerometer, gyro-scope, and magnetometer) using magnetic and acoustic vectors, the researchers successfully manipulated the system's estimation of inclination.

Moreover, another study delved into the repercussions of sensor spoofing at-tacks on closed-loop control systems. The researchers illustrated that corrupting a subset of sensor readings can destabilize the system and circumvent failure detection mechanisms in linear time-invariant Gaussian control systems [43] equipped with Kalman Filters for state estimation.

Protecting sensors against acoustic attacks and ensuring the integrity of sen-sor fusion algorithms are essential for maintaining the security and reliability of cyber-physical systems. Robust defense mechanisms and continuous research in this area are crucial to mitigate the risks associated with these vulnerabilities.

LIMITATIONS AND OPPORTUNITIES UTILISED:

Signal injection attacks encounter certain limitations, but researchers have also identified opportunities to enhance the security of cyber-physical systems. When signals undergo encryption or obfuscation, spoofing attacks become more challenging. For instance, military-grade GPS systems utilize encryption techniques like P(Y) codes and hidden markers. These markers obscure GPS sig-nals within the noise level using secret keys unknown to attackers. Encryption keys are essential for validating received signals, making it challenging for at-tackers to reconstruct original navigation signals and execute successful spoofing attacks. A notable constraint in jamming attacks involves overpowering high-power signals. Attackers typically depend on more potent signals to overwhelm legitimate signals and instigate a denial-of-service (DoS) attack. However, this becomes challenging when the legitimate signal is already robust. Terrestrial positioning system jamming attacks, for instance, pose more difficulties than satellite-based positioning system jamming attacks because eLORAN signals employ high-power, low-frequency signals

compared to low-powered GPS signals. Attackers would need physically tall or lengthy antennas to effectively transmit low-frequency signals and surpass the strong eLORAN signal [44].

One notable limitation of signal injection attacks is their lack of stealthiness. While numerous attacks are executed remotely and without physical contact, certain attacks may attract human attention or trigger machine detection. For instance, attacks utilizing visible light or employing colorful masks might raise suspicion among observers. Optical attacks that introduce visible perturbations to road signs for deceiving object recognition systems must be meticulously crafted to resemble common objects in daily life and evade detection. Likewise, acoustic attacks [45] targeting voice-controlled systems encounter the difficulty of remaining undetected. Current attacks aim to conceal malicious commands by distorting audio signals or modulating them with music to avoid arousing suspicion. However, observable effects of the injection, such as a response from the voice assistant, may still unveil the attack. To mitigate this, researchers propose injecting commands that minimize observable effects, such as lowering the volume at the beginning of the attack, ensuring that subsequent responses do not raise suspicion from victims.

The ambient environment can influence the efficacy of certain attacks. For instance, acoustic attacks targeting voice-controlled systems may face disruption from environmental noise. Similarly, optical attacks utilizing adversarial machine learning methods to mislead recognition systems may encounter challenges due to environmental variability.

To address this, researchers have taken into account environmental variations in their investigations. For instance, one study scrutinized the distance and angle between a camera and a road sign within the context of autonomous vehicles. Another examination assessed the impact of distance and angle factors on an out-of-band acoustic Denial-of-Service (DoS) attack targeting Hard Disk Drives (HDDs), revealing significant variations among different HDDs in terms of maximum distance and effective angles.

These constraints and possibilities underscore the ongoing necessity for re-search and countermeasures to fortify the resilience of cyber-physical systems against signal injection attacks.

4 INFORMATION LEAKAGE ATTACKS IN CYBER-PHYSICAL SYSTEMS

Information leakage attacks can be categorized into two types: co-located at-tacks [46] and remote attacks [47]. Co-located attacks occur when the source of the leaked signal is within the same computing system as the sensor used to measure it. In contrast, remote attacks occur when the source is external and measured by a sensor in the attacker's CPS. These attacks are commonly executed via trojan applications implanted on the device, gathering data from the sensors, processing it, and then transmitting the information to the attacker. Devices with high-precision sensors, like smartphones, are frequent targets for in-formation leakage attacks, given their widespread ownership. Often, third-party applications gain unrestricted access to these sensors without needing explicit permission. In general, information leakage attacks present a notable menace to the security and privacy of cyber-physical systems.

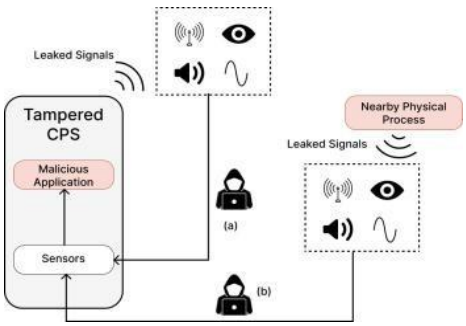

Fig. 10. Detection of Tampered CPS procedure in the form of Leaked Signals

The Discussion on The Threat Model

This section offers an overview of the attack model for information leakage attacks in cyber-physical systems (CPS), delineating the prerequisites, attack vectors, generalized attack model, and attack objectives.

Perpetrators intending to execute information leakage attacks on CPS must satisfy three primary prerequisites: surreptitious extraction, data exfiltration, and information recovery.

Surreptitious extraction entails acquiring access to the stream of sensor data using diverse methods, such as crafting malicious applications or embedding harmful code in web pages.

Data exfiltration [48] involves transmitting the amassed sensor data to a remote server controlled by the attacker, granting them access to the sensitive information.

Information recovery involves utilizing a classification model to extract the desired private information from the amassed sensor data. This phase frequently involves the utilization of machine learning techniques for feature extraction and classification purposes.

The comprehensive workflow of an information leakage attack involves two stages: data collection and transmission, and data analysis.

In the initial stage, the attacker's malware infiltrates the CPS and gathers raw data from the sensors. Subsequently, the collected data is dispatched to the attacker's remote server for further processing.

In the subsequent stage, the attacker scrutinizes the amassed data to ex-tract the desired private information. This process includes employing machine learning techniques to extract pertinent features and classify the data to unveil sensitive details.

The goals of information leakage attacks encompass various aspects: Keystroke inference [49] aims to detect user input by exploiting optical,

electromagnetic, acoustic, or vibrational side-channel leakage.
Task inference [50] involves identifying ongoing tasks or physical activities by leveraging vibrational and electromagnetic side-channel leakage.

Location inference [51] focuses on uncovering details about the user's location using acoustic side-channel leakage.

Speech extraction [52] involves capturing human speech by exploiting vibrational, optical, and electromagnetic signals.

By achieving these attack goals, the attacker can obtain sensitive information and potentially compromise the security and privacy of the targeted CPS.

To mitigate the risks associated with information leakage attacks, it is crucial to implement robust security measures, including intrusion detection systems [53], access controls, encryption, and regular security updates. Additionally, user awareness and education regarding the risks of granting permissions to unknown or untrusted applications can contribute to enhancing the overall security of Cyber Physical Systems (CPS).

Approaches for Information Leakage

The implementation of an information leakage attack involves two key stages: data collection and transmission, followed by data analysis. These stages dictate the prerequisites and obstacles encountered by attackers. A significant hurdle for attackers is acquiring data from targeted Cyber-

Physical Systems (CPS) discreetly. Malicious software has streamlined access to sensor data on devices like smartphones. However, executing remote attacks requires the establishment of suitable CPS infrastructure at the target location.

Attackers typically adhere to three stages to deduce private information: pre-processing, feature extraction, and classification.

Pre-processing: In this stage, attackers choose, standardize, and pre-calculate data to generate an altered data matrix. The aim of pre-processing is to enhance the quality of the acquired data and prepare it for subsequent analysis.

Feature extraction: This step involves extracting informative and non-redundant features from the pre-processed data matrix. The goal is to identify significant patterns, characteristics, or properties that can improve the accuracy of the attack. Feature extraction techniques [45] play a crucial role in identifying relevant information and reducing the dimensionality of the data.

Classification: Classification forms the core part of data analysis in an information leakage attack. Machine learning-based methods are commonly employed to extract private information from the collected data. These methods utilize algorithms and models to categorize and identify specific patterns or characteristics associated with the desired private information. In some cases, techniques from other domains, such as dictionary mapping, Hidden Markov

Models (HMM) [54], or image deconvolution, have been utilized to infer private information.
By combining pre-processing, feature extraction, and classification techniques, attackers can effectively extract private information from the collected sensor data. To defend against information leakage attacks, countermeasures such as data encryption, access control, anomaly detection, and user awareness programs should be implemented to protect the security and privacy of CPS.

Information Exposure: Known Incidents
In this section, we will delve into documented incidents of information exposure. The incidents are classified based on their objectives, as the strategies employed in different information exposure incidents are contingent on the nature of the information being exposed.

1) Keystroke Revelation Incidents: The inputs provided by users to a cyber-physical system (CPS) through mechanical or touch-based keyboards can inadvertently produce acoustic, electromagnetic, and vibrational side-channel disclosures. Previous research has explored leveraging sensors to capture this side-channel disclosure and unveil users' keystrokes. Keystrokes on diverse de-vices, including physical keyboards, touchscreen keyboards, POS keypads, and numpads, have been scrutinized as leaked information, recoverable from various sensor data.

a) Keystroke revelation through vibrational disclosure: Mechanical keyboards exhibit vibrational side channels that can be remotely measured by the accelerometer and/or gyroscope of the CPS sharing a surface with the key-board. Each keystroke generates a distinct, acoustically transmitted, vibrational imprint. Thus, by scrutinizing raw data from these sensors, an intruder can deduce the typed keystrokes. In touch-based keyboards, user inputs alter the de-vice's orientation and generate vibrations. Similar to mechanical keyboards, this side channel can be measured by a co-located gyroscope and/or accelerometer to infer keystrokes on a touch-based keypad.

Co-located Keystroke Revelation: Attempts have been made to deduce keystrokes based on co-located motion sensors like accelerometers and gyroscopes. A covert application installed on a victim's smartphone measures raw device orientation data, utilized to train a Gaussian classifier predicting keystrokes with an overall accuracy of up to 71.5. Further experiments aim to decipher 59 out of 99 passwords logged during text entry on smartphones using analogous techniques.

Remote Keystroke Revelation: Remote attacks demonstrate the measurement of vibrational leakage generated by user input using the inertial sensors of a proximate system. This attack manifests in either of two scenarios: first, the inertial sensors of a wearable device, like a smartwatch, infer keystrokes on a mechanical or touch-based keypad; second, the inertial sensors of a CPS sharing a surface with a mechanical keyboard, typically a smartphone, predict keystrokes on the keyboard.

b) Keystroke revelation through acoustic disclosure: Keystroke rev-elation through acoustic side-channel disclosure has also been studied. On me-chanical keyboards, there is sufficient correlation between the spectral signature of a keystroke and the actual key pressed, allowing an attacker to pre-dict keystrokes by recording their acoustic emanations. By simply recording the sound of typing, extracting time and frequency domain features via FFT, and employing a neural network, it is possible to predict keystrokes. Techniques accommodating different typing styles bring the attack closer to feasibility in a real-world scenario.

c) Keystroke Revelation through EM Exposure: Researchers show-case the feasibility of intercepting keystrokes on physical keyboards (wireless or wired) by exploiting electromagnetic emissions. Their strategy effectively cap-tures keystrokes 95 percentage of the time at distances of up to 20 meters between the keyboard and the antennae used for eavesdropping. They categorize four dis-tinct types of emanations from physical keyboards and successfully implement their approach in four different scenarios.

Optical side-channel exposure can be utilized to deduce activities and is classified into two categories: visible light exposure and reflection exposure.

Visible light exposure employs photodetectors [55] to gauge leaked light from sources like blinking LEDs or screens. For example, Loughry and Umphress showcased that the LED indicators on wireless routers can reveal information about transmitted and received packets. Kuhn analyzed optical side-channel leakage from a CRT display [56] at a distance and demonstrated that intensity readings can be deconvolved to recover the text on the screen.

Reflection exposure involves identifying reflections from computer monitors and screens using cameras or telescopes.

Drawbacks and Possibilities

Information leakage attacks in Cyber-Physical Systems (CPS) have certain limitations and present opportunities that require careful consideration. The success of an attack hinges on the ability of malware to collect raw data from the targeted CPS without arousing suspicion. However, there are limitations to the level of stealthiness that malware can achieve. For example, a study highlighted the issue of high-power consumption by a malicious application in-stalled on a smartwatch, which raised suspicion. Monitoring power consumption or resource usage can serve as a defense mechanism against such attacks. Another limitation is the lack of generalization in proposed models, as they need to account for variations in users and targeted devices to accurately infer information. Some models may not generalize well across different targets with significant variations, necessitating separate training for each configuration. It has been observed that keystroke inference accuracy decreases when the training and evaluation data sets come from different keypads, emphasizing the need for testing models on multiple experimental devices or different users to validate their generalizability. Typing styles also introduce uncertainty into the effectiveness of acoustic and vibrational keystroke inference attacks. Variations in scenarios, such as typing with both hands or the orientation of the attacker's deployed device, can further impact the success of these attacks. Researchers must take these factors into account when proposing information leakage attacks and assessing their effectiveness. Addressing these limitations presents opportunities for further research and improvement. Developing more sophisticated and stealthier malware that can evade detection while collecting data is an area worth exploring. Additionally, enhancing the generalization capabilities of models to accommodate variations in users and

devices can lead to more robust and accurate information inference. Further investigations into typing styles and their impact on attack effective-ness can provide insights for developing more reliable attack models. Overall, addressing these limitations and capitalizing on opportunities will contribute to the advancement of defense mechanisms against information leakage attacks in CPS.

5 SECURING AGAINST CYBER-PHYSICAL ATTACKS

As the threat of cyber-physical attacks continues to increase, it is crucial to develop effective defenses to counter these attacks. The existing literature pro-poses several defense techniques in various domains, including physical, cyber, cyber-physical, and application domains.
In the cyber domain, techniques such as intrusion detection systems, fire-walls, and access control mechanisms have been suggested to detect and prevent attacks. These methods focus on safeguarding the network infrastructure, protecting against unauthorized access, and identifying malicious activities.

The physical domain presents unique challenges for defending against cyber-physical attacks since manipulating physical phenomena while probing them is not feasible. Two defense strategies have been proposed to address these challenges: environment verification and physical barriers. Environment verification involves actively probing the surroundings and validating signals through responses, while physical barriers aim to isolate the Cyber-Physical Systems (CPS) from specific types of signals by implementing physical separation.

To prevent information leakage through signals, environment verification suggests clearing the surrounding area before interacting with CPS. Physical barriers involve isolating the CPS from open environments to minimize the risk of signal leakage. However, these defense approaches have limitations, including imperfect isolation, potential impact on CPS functionality, and practicality concerns.

In the cyber-physical domain, techniques such as secure communication protocols, firmware updates, and secure boot processes can be employed to pre-vent attacks. These measures focus on ensuring the integrity and confidentiality of communication channels and the authenticity of firmware. Additionally, application-level defenses, such as error checking and anomaly detection, can enhance the security of the system by detecting abnormal behavior and unauthorized access attempts.

In the cyber domain, traditional cybersecurity measures are often inadequate for protecting against cyber-physical attacks. New methodologies have been proposed, including signal analysis techniques that utilize machine learning or frequency analysis to differentiate between malicious and legitimate signals. Data filtering and adaptive filtering are defense mechanisms that aim to remove unwanted content or cancel out injected signals through signal processing techniques. Sensor fusion, which combines data from multiple sensors, can also enhance defense capabilities by increasing the complexity of attacks.

The cyber-physical domain requires the combination of physical stimuli with cyber processing techniques to reduce system susceptibility. Defenses against signal injection attacks involve adding non-spoof able patterns to signals and conditioning paths to distinguish malicious signals and improving the design of the cyber-physical layer to mitigate injected signals. Randomized sampling patterns, dynamic sampling, and out-of-phase sampling techniques have been proposed to prevent predictable and manipulative signal injection attacks.

In the application domain, defending against information leakage attacks can be challenging as the sensor data may already be compromised. However, authentication and access permission control mechanisms can be implemented to prevent unauthorized access and information leakage. Reducing application sampling rates can also be employed to limit the frequency at which applications access sensor data, making it more difficult for attackers to infer useful information.

Table 3. Existing Security Solutions for Cyber-Physical Systems

Security Solution	Description
Verification and Access Control Intrusion Detection and Mitigation Encryption and Data Protection Secure Software Development Practices Incident Response and Recovery	User authentication and role-based access control Monitoring and preventing unauthorized activities Securely encrypting sensitive data at rest and in transit Implementing secure coding and testing practices Rapid response and recovery from security incidents

To provide comprehensive defense against cyber-physical attacks, a combi-nation of these techniques from different domains should be considered. Regular testing and updating of defenses are crucial to ensure their effectiveness in coun-tering evolving attack strategies. By continuously improving defense mechanisms and addressing the specific challenges of cyber-physical attacks, the security and resilience of CPS can be enhanced.

6 THE OVERVIEW OF THE FUTURE CYBER-PHYSICAL SYSTEMS SECURITY

The future outlook of cyber-physical security is characterized by the need for new research and innovative defense strategies to address emerging threats and challenges. While recent advancements have demonstrated progress in under-standing cyber-physical attacks and developing defense mechanisms, there are still limitations that need to be overcome.

To begin with, the security and other emerging technologies introduces new potential threats to cyber-physical systems. While these technologies offer significant benefits, they also increase the attack surface and require new defense strategies. Therefore, conducting research to identify and mitigate security threats in the context of these technologies is crucial.

Table 4. Security Challenges in Cyber-Physical Systems

Security Challenge	Description
Network Attacks System Tampering Data Integrity and Trust Privacy Breaches Interoperability and Integration Firmware and Software Updates	Unauthorized access, DoS attacks, eavesdropping Unauthorized modification of CPS components Ensuring data authenticity and reliability Unauthorized access to sensitive information Ensuring secure communication between components Secure and timely deployment of updates

Exploring the evolution of the attack landscape is another important aspect. methodically cyber-physical attacks not only helps Enhance robust defenses but also enhances the understanding of security threats. By focusing on unexplored areas from an offensive perspective, researchers can gain insights into new attack vectors and sensors that have received limited attention. This includes targeting known sensors with novel attack strategies, exploring attacks on new sensors, and considering physical correlations to exploit as attack surfaces. In terms of defense, traditional cybersecurity measures are insufficient to handle cyber-physical at-tacks. Defenses should be developed at every layer of the cyber-physical system architecture, taking into account the specific conditions required for different types of attacks. For example, preventing plausible input and meaningful response can be an effective defense against signal injection attacks. Techniques such as signal analysis, data filtering, and improved sensing-layer designs can contribute to detecting and eliminating malicious signals. Similarly, defenses against information leakage attacks may involve limiting data extraction, masking sensor data, and employing network techniques to detect unauthorized data traffic.

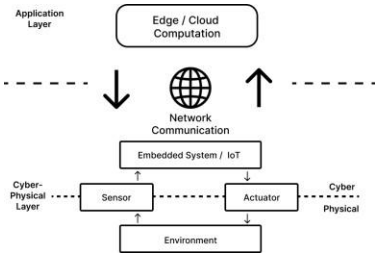

Fig. 11. Network Communication between Application Layer and Cyber-Physical Layer

A deeper understanding of the attack requirements is essential for the devel-opment of effective defenses. By considering the remaining challenges and un-explored attack requirements, new defense strategies can be devised. This may involve shielding sensors from specific types of attacks, determining the optimal fusion of multiple defenses, and finding the right balance between security and system functionality.

In conclusion, the future of cyber-physical security relies on continued re-search and collaboration between experts from various fields. By addressing emerging threats, exploring new attack strategies, and developing innovative defense mechanisms, we can ensure the safety and security of cyber-physical systems in the face of evolving cyber threats.

7 CONCLUSION

In conclusion, this paper presents a thorough examination of a newly identified class of cyber-physical attacks that exploit the interface between digital and physical systems, specifically targeting signal injection and information leak-age. Recognizing the limitations of conventional defense methods, we carefully analyze and categorize existing defense strategies proposed in the literature to address each unique attack vector.

Gaining a deep understanding of the evolving landscape of cyber-physical attacks is crucial for the development of effective defense mechanisms. Through our systematic exploration of this field, we uncover previously unexplored areas where vulnerabilities exist. For instance, malicious actors may exploit geographically specific signals to surreptitiously gather physical information.

To establish robust defenses against cyber-physical attacks, we propose targeting the essential conditions required for their execution. By disabling or mitigating these conditions, we can construct more resilient defense strategies. This approach opens up promising avenues for bolstering the security of cyber-physical systems.

The primary goal of this manuscript is to offer a unique outlook on the evolving field of cyber-physical security and underscore the significance of cooperation between academic and industrial entities to propel additional exploration in this field. This collaboration is crucial for protecting vital technologies and guaran-teeing their robustness against impending threats.

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The Hyper-Personalization Paradox: Balancing AI-Driven Marketing Innovation with Consumer Trust and Privacy in the Digital Era

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ABSTRACT

The paper explores the contradictory nature of hyper-personalization through Artificial Intelligence (AI) online marketing, consumer buying intentions, and the mediating factor of the issue of data privacy. The study assesses the perception of AI methods such as behavioral targeting, dynamic pricing, and chatbot-assisted interactions using a quantitative survey of 512 online consumers using three major e- commerce platforms. Results show that although 71% of the participants were able to acknowledge that personalized recommendations made them engage more, and 64% of them said they were more inclined to buy products, 68% of them were also more worried of personal data surveillance. Moreover, 59% of people viewed AI-powered advertisements as manipulative, and 42% said that they made unintentional purchases during AI influence. Regression analysis supported the fact that deficiency of transparency in data management explains a 46% decline in consumer trust, which undermines the personalization purchase intention channel quite a lot. Regardless of these difficulties, 73 percent of consumers expressed readiness to interact with AI-powered platforms under the condition of ethical protection, transparency, and user control systems. The paper finds that the key to long-term marketing success is the organization having responsible AI frameworks with a focus on ethical data management, fairness of the algorithm, and open communication flow. By this approach to the hyper- personalization paradox, firms can, at the same time, encourage innovation and maintain consumer trust in the online market.

Keywords: AI-based Hyper-Personalization, Consumer Trust, Data Privacy, Purchase Intention, Ethical AI, Digital Marketing, Predictive Analytics.

1. INTRODUCTION

The digital marketing environment has been transformed radically with the incorporation of artificial intelligence and predictive analytics in the consumer engagement strategies. The change in the modern marketing practices where live information, behavioral analysis and machine learning algorithms are applied to deliver personalized experience to a consumer is the new component of the modern marketing trends, which is called hyper-personalization. Compared to the previous method of demographic segmentation, hyper-personalization focuses on the individual level and employs the browsing behavior, the buying behavior, and the social media use, and even the emotional feeling to produce a marketing message that excels only on the consumer.

The result of this technological advancement has helped businesses to attain new levels of interaction, conversion and retention of customers. Amazon, Netflix, and Alibaba are some of the companies that have used AI-driven recommendation engines to achieve high revenue growth and brand loyalty. Within the framework of e- commerce platforms, AI applications such as chatbots, dynamic pricing algorithms, and behavioral targeting have redefined brand-to-consumer relationships with digitally native consumers.

Nonetheless, the emergence of hyper-personalization has introduced a primordial conflict, which is what these paper calls the hyper-personalization paradox. The consumers are more and more demanding personalized and relevant experiences, yet at the same time, they are becoming more anxious about the privacy of their data, the manipulation of algorithms, and the loss of control. Research has shown that personalization has increased satisfaction and purchase intentions but over targeting and non-transparent data practices greatly undermine consumer trust. This paradox poses crucial issues to both the marketers and the policymakers. On the one hand, AI-based personalization provides competitive advantages due to better customer insights and maximized marketing investments. Conversely, the ethical violations, including unauthorized data collection to psychological manipulation, pose a threat to derail the trust on the basis of which long-term customer relations are based. The Cambridge Analytica scandals and others like them have increased worldwide awareness on the subject of misusing data, which has led to increased regulatory attention in the form of laws like GDPR and China Personal Information Protection Law (PIPL). It is on this context that the present research seeks to empirically investigate the two sides of the coin that determine the effectiveness of AI-driven marketing: the benefits of personalization versus the cost of privacy. The study utilizes quantitative survey data of 512 online consumers to examine the effect of behavioral targeting, dynamic pricing and chatbot interactions on purchase intentions considering the moderating variables of privacy concerns and perceived manipulation. The results may be added to the current discourse of accountable AI implementation in marketing and can be applied to the creation of consumer-centric, ethically-driven digital strategies.

2. LITERATURE REVIEW

2.1. Theoretical Foundations

Technology Acceptance Model (TAM)

Technology Acceptance Model is a theory that states that the perceived usefulness and perceived ease of use are the two components that mainly determine whether a consumer adopts new technologies. Perceived usefulness in the context of AI-driven marketing is the degree to which customers feel that personalized recommendations increase their shopping experience, and ease of use is the level of ease and intuitiveness associated with using AI-powered interfaces.

According to empirical data, Chinese millennials and digitally native buyers are very free to accept AI technologies as long as they are introduced to the existing platform and do not disrupt its functionality and offer an observable advantage. Nonetheless, this explanatory power of TAM fades away in the situations when the ethical issues (e.g., the invasion of privacy and algorithmic discrimination) prevail over practical advantages. This weakness reflects the need to continue developing TAM to incorporate trust, transparency, and ethical perception as significant moderating factors.

Stimulus-Organism-Response (SOR) Model

SOR model can be used to obtain a psychological image of how the external factors (e.g., AI-based ads, personalized suggestions, etc.) may influence the internal state (cognition and emotion) of the consumers, which, in its turn, may cause them to act in a particular way (e.g., making a purchase decision). AI-generated content in the digital marketing environment has become a motivator that evokes emotions to either excitement and trust towards anxiety and skepticism and thus changes in consumer behavior.

As per research, AI-driven stimulus (like indicating urgency, social proof) can stimulate impulse purchase by exploiting cognitive biases. Nonetheless, an excess or miscalibrated stimuli could misfire and lead to algorithms aversion where consumers intentionally discredit their recommendation as they feel they are being hacked or are not authentic.

2.2. AI-Driven Personalization: Opportunities and Mechanisms

AI-based personalization uses various methods to deliver marketing messages and product proposals to individual consumers according to their preferences. Includes some tricks.

1. **Behavioral Targeting:** Behavioral targeting involves machine learning algorithms that use purchase data, clickstream data, and browsing history to forecast consumer needs and provide targeted advertisements.
2. **Dynamic Pricing:** The use of AI can change the price of the products in real-time according to fluctuations in the demand, competitor prices, and personal willingness to pay.
3. **Recommender Systems:** Collaborative filtering, and deep learning algorithms produce personalized product recommendations, which lead to a lot more engagement and conversion.
4. **Conversational AI:** Chatbots and virtual assistants offer real-time and context-based customer service, improving user experience and operational effectiveness.

It has been empirically shown that personalization can dramatically increase consumer engagement, and studies have found that it has improved conversion rates (25-30% +) and customer retention (up to 35). Taobao, JD.com and Douyin (Tik Tok China) are the platforms that have been able to use AI-based personalization to conquer the Chinese e-commerce market.

2.3. The Dark Side of Personalization: Privacy, Manipulation, and Trust Erosion

Although hyper-personalization is quite a successful venture in terms of business, it also poses some serious ethical issues. These are the main concerns:

Data Privacy Violations: Often collected aggressively and without prior explicit consent of the consumer, the data collection techniques scrimp on privacy expectations and regulatory standards. 78% of consumers have no idea how much information is gathered the concept of being spied on and being exposed. Research shows a tremendous amount of info those gathering.

Algorithmic Manipulation: AI systems utilize an extensive toolbox of persuasive design patterns like scarcity, social proof, and personalized pricing to exploit users' psychology. Studies have found that these techniques can cause people to buy items unwittingly and these people can include youth and compulsive buyers.

Lack of Transparency: The "black box" nature of machine learning makes it hard for consumers to understand the process of decision making. When consumers can't understand why they see certain ads or prices, they perceive the system as biased or manipulative.

Discrimination and Bias: Algorithms used in AI can reflect biases linked to sex, ethnicity, or economic status and result in inequitable pricing or product recommendations.

2.4. Research Gaps and Study Objectives

Although the relationship between personalization and privacy has been recognized in existing literature, not many studies have quantitatively measured the moderating role of privacy concerns to the personalization -purchase intention relationship in emerging markets. Furthermore, the few studies that investigate consumer perceptions of various AI methods simultaneously (behavioral targeting, dynamic pricing, chatbots) are conducted in one framework

This study addresses these gaps by pursuing the following objectives:

1. To conduct empirical research on the impact of AI-based hyper-personalization on consumer purchase intentions in e-commerce.
2. To study how data privacy concerns and perceived manipulation affect personalization and purchase intention.
3. Understanding customer preferences about ethical AI practices and transparency mechanisms.
4. Offer marketing and policy professionals the recommendation for balancing innovation and consumer protection.

3. Research Methodology

3.1. Research Design

The research design in this study is quantitative, cross-sectional based on the use of structured online surveys to gather primary data of active e-commerce consumers. The study takes a positivist epistemological position because it aims to determine causality between AI-based personalization methods and consumer behavioral outcomes and consider moderating factors.

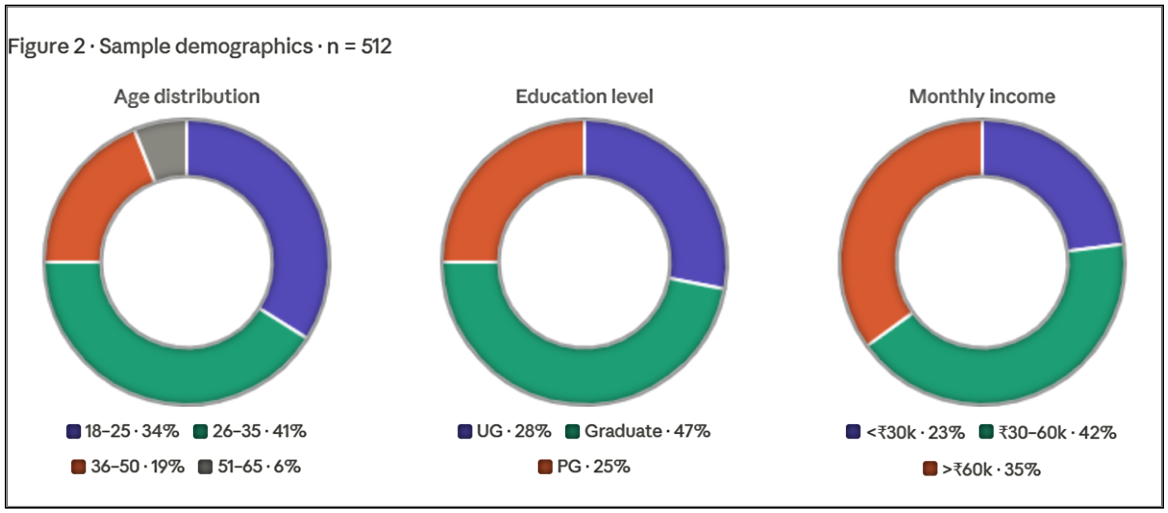
3.2. Sampling Strategy

Population: The chosen target population will be the adult consumers in the age group of 18-65 who are online shoppers (at least three purchases made in the last six months) on large online stores like Amazon India, Flipkart, Myntra.

Sampling Method: To ensure that the main demographic factors, namely age, sex, education level, and income group were adequately represented, the researchers utilized stratified random sampling.

Sample Size: The study received 512 valid responses which is more than the sample size of 384 (95% confidence level, 5% margin of error) determined from Cochran formula.

Sample Characteristics:



- Gender: 52% Female, 48% Male
- Age Distribution: 18-25 years (34%), 26-35 years (41%), 36-50 years (19%), 51-65 years (6%)
- Education: Undergraduate (28%), Graduate (47%), Postgraduate (25%)
- Monthly Income: <₹30,000 (23%), ₹30,000-₹60,000 (42%), >₹60,000 (35%)

3.3. Data Collection Instrument

The structured questionnaire containing 42 items was created using validated scales of previous studies. The tool had five main components.:

Section A: Demographics – Their age, Gender, education, income and frequency of online shopping.

Section B: AI Personalization Exposure – Each of the items are about behavioral targeting, dynamic pricing, recommendations, and chatbot interactions.

Section C: Purchase Intention – Purchase Intention for which the likelihood of buying based on AI recommendations (6 items, Dodds et al., 1991).

Section D: Privacy Concerns – Views on collection and usage security of data (10 items; adapted from Malhotra et al., 2004).

Section E: Trust and Manipulation Perception – Perceived transparency and fairness of AI systems and their manipulative intent. This section contains 12 items from Gefen et al. (2003).

Section F: Willingness to Engage – The conditional acceptance of AI technology given ethical safeguards. (6 items, newly developed)).

3.4. Data Collection Procedure

The researcher collected the data over a period of six weeks (August – September 2024) by online sharing of questionnaires through Google Forms. Sources of recruitment utilized:

- Social networking sites (LinkedIn Instagram Facebook)
- Groups and forums of E-commerce consumer
- University alumni networks
- Snowball sampling through participant referrals

The attendance was voluntary and anonymous. Informed consent was taken and the respondents were assured of data confidentiality. The average time of completing the surveys was 12-15 minutes.

3.5. Reliability and Validity

Reliability: The reliability must be estimated using an internal consistency indicator, especially when multi-item scales are in use. Reliability: Cronbach alpha coefficients were calculated of all multi-item scales and the value was less than.
The range 0.82 to 0.91 is better than the acceptable one of 0.70.

Content Validity: Three scholarly professionals in the field of digital marketing and consumer behaviour were to review the questionnaire to make sure that it covers all the constructs.

Construct Validity: To establish dimensional structure, the Exploratory Factor Analysis (EFA) was performed. All the items have been loaded on their respective factors with a loading of more than 0.60.

3.6. Data Analysis Techniques

Data analysis was conducted using SPSS version 26.0 and included:

1. **Descriptive Statistics:** Frequencies, means, and standard deviations to summarize response patterns.**Correlation Analysis:** Pearson correlation coefficients to examine bivariate relationships between variables.
2. **Multiple Regression Analysis:** To assess the direct effects of personalization techniques on purchase intention and the moderating effects of privacy concerns.
3. **Moderation Analysis:** Hayes' PROCESS macro (Model 1) was employed to test interaction effects between personalization and privacy concerns.
4. **Chi-Square Tests:** To examine associations between categorical variables (e.g., demographics and privacy awareness).

3.7. Ethical Considerations

The research followed ethical standards of research such as:

- Voluntary participation with no coercion
- Informed consent with clear explanation of research purpose
- Anonymity and confidentiality of responses
- Right to withdraw at any stage without penalty
- Secure data storage with restricted access

4. RESULTS AND FINDINGS

4.1. Descriptive Analysis

AI Personalization Exposure

The following trends were identified in the analysis of the experiences of consumers with AI-based personalization:

- **Behavioral Targeting:** 87 percent of the interviewees said that they have seen personalized advertisements depending on their browsing history and 71 percent said that such advertisements made them more interested in the products.
- **Recommendation Engines:** 82% regularly received personalized product recommendations, with 64% reporting that recommendations positively influenced their purchase decisions.
- **Dynamic Pricing:** 56% noticed price variations across different sessions or devices, with 47% expressing frustration regarding perceived pricing discrimination.
- **Chatbot Interactions:** 73% had used AI chatbots to get customer service, and 68% of them said the experience was satisfactory or highly satisfactory.

Purchase Intention

In terms of the purchase intention due to the AI personalization:

- 64% reported increased likelihood of purchase due to personalized recommendations
- 52% made purchases directly through chatbot-assisted shopping
- 38% admitted impulse purchases triggered by AI-generated urgency cues
- 42% acknowledged making unintended purchases under AI influencePrivacy Concerns

Privacy concern levels were notably high:

- 68% expressed heightened concern over personal data surveillance
- 74% were unaware of the specific types of data being collected
- 61% felt they lacked control over their personal information
- 79% demanded greater transparency in data handling practices
- 59% perceived AI-driven advertising as manipulative

Trust Metrics

Consumer trust in AI-enabled platforms showed mixed results:

- Only 32% fully trusted e-commerce platforms with their personal data
- 46% expressed moderate trust conditional on transparency measures
- 22% reported low or no trust in AI-driven marketing systems
- 73% indicated willingness to engage with AI platforms provided ethical safeguards are implemented

4.2. Correlation Analysis

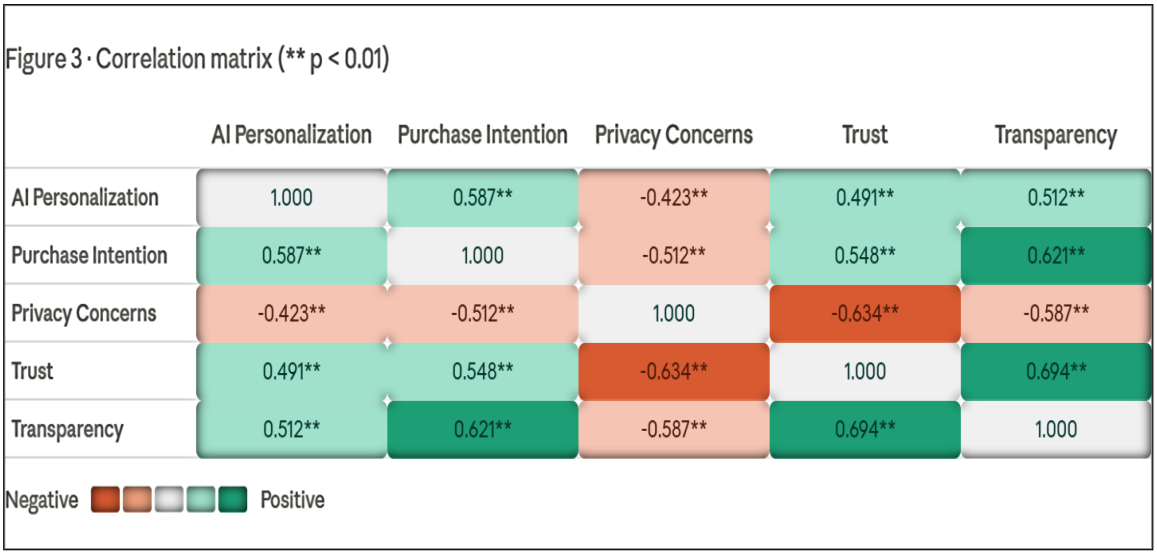
Pearson correlation analysis revealed significant relationships between key variables:

Variable Pair	Correlation Coefficient (r)	Significance (p)
Personalization → Purchase Intention	0.587**	<0.001
Privacy Concerns → Purchase Intention	-0.512**	<0.001
Transparency → Trust	0.694**	<0.001
Perceived Manipulation → Trust	-0.623**	<0.001
Trust → Purchase Intention	0.548**	<0.001

Note: Indicates significance at $p < 0.01$ level. Key findings:

- Strong positive correlation between personalization and purchase intention ($r = 0.587$)
- Strong negative correlation between privacy concerns and purchase intention ($r = -0.512$)
- Transparency emerged as the strongest predictor of consumer trust ($r = 0.694$)

Figure 3 · Correlation matrix (** p < 0.01)



4.3. Regression Analysis

Direct Effects Model

Multiple regression analysis was conducted with purchase intention as the dependent variable and AI personalization techniques as independent variables:

Model Summary:

- $R^2 = 0.423$
- Adjusted $R^2 = 0.417$
- $F(4, 507) = 93.47$, $p < 0.001$

Regression Coefficients:

Predictor	β	t	p	95% CI
Behavioral Targeting	0.234	5.87	<0.001	[0.156, 0.312]
Recommendation Systems	0.318	8.12	<0.001	[0.241, 0.395]
Chatbot Interaction	0.156	4.23	<0.001	[0.083, 0.229]
Dynamic Pricing	-0.089	-2.34	0.020	[-0.164, -0.014]

Interpretation:

- Recommendation systems showed the strongest positive effect on purchase intention (β = 0.318)
- Dynamic pricing exhibited a negative effect, suggesting consumer resistance to perceived price discrimination
- The model explained 42.3% of the variance in purchase intention

Moderation Analysis: Role of Privacy Concerns

To determine the relationship between personalization and purchase intention, Hayes used the PROCESS macro to test the hypothesis of the moderating effect of privacy concerns.

Moderation Model Results:

- Main effect of Personalization: β = 0.542, $p < 0.001$
- Main effect of Privacy Concerns: β = -0.387, $p < 0.001$
- Interaction effect (Personalization × Privacy): β = -0.463, $p < 0.001$

The negative interaction factor (= -0.463) is significant, which validates that the apprehension of privacy is indeed a crucial element that undermines the positive association between

personalization and purchase intention. In particular, absence of data handling transparency explains a 46% decrease in the personalization -purchase intention pathway strength.

Conditional Effects Analysis: There was a difference between the effects of personalization on purchase intention at various levels of privacy concerns:

- Low privacy concern: $\beta = 0.687$, $p < 0.001$
- Moderate privacy concern: $\beta = 0.412$, $p < 0.001$
- High privacy concern: $\beta = 0.158$, $p = 0.042$

This proves the point that in cases where the level of privacy is high then the positive impact of personalization on purchase intention is highly invalidated.

Trust as Mediator

The mediation analysis tested whether there is a mediating effect of the relationship between transparency and purchase intention by consumer trust.

Results:

- Direct effect of Transparency on Purchase Intention: $\beta = 0.385$, $p < 0.001$
- Indirect effect through Trust: $\beta = 0.294$, $p < 0.001$
- Total effect: $\beta = 0.679$, $p < 0.001$

The role of transparency in purchase intention was mediated by trust approximately 43 percent, which confirms the importance of the trust-building mechanisms in AI-based marketing performance.

4.4. Demographic Differences

Chi-square tests and ANOVA revealed significant demographic variations:

Age Differences:

- Younger consumers (18-25) showed higher acceptance of AI personalization ($\chi^2 = 23.47$, $p < 0.001$)
  but also greater sensitivity to manipulation tactics
- Older consumers (51-65) expressed lower trust overall but valued transparency more highly

Gender Differences:

- Female respondents reported significantly higher privacy concerns ($M = 4.12$) compared to males ($M = 3.76$), $t(510) = 4.23$, $p < 0.001$
- No significant gender difference in purchase intention was observed

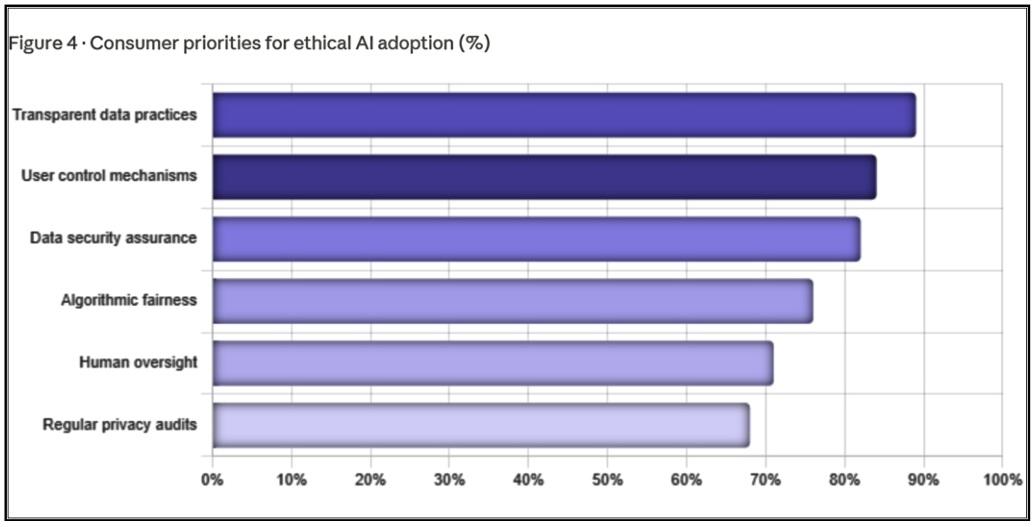
Education Level:

- Higher education correlated with greater awareness of data practices ($r = 0.287$, $p < 0.001$)
- Postgraduate consumers demonstrated more skepticism toward AI-driven dynamic pricing

Income Level:

- Higher-income consumers showed greater willingness to pay premium for privacy-assured platforms ($F(2, 509) = 12.34$, $p < 0.001$)

4.5. Consumer Preferences for Ethical AI



When asked about conditions under which they would fully embrace AI-driven personalization, respondents prioritized:

- **Transparent Data Practices (89%):** Clear disclosure of what data is collected and how it is used
- **User Control Mechanisms (84%):** Ability to opt-out, delete data, and control personalization intensity
- **Data Security Assurance (82%):** Strong encryption and protection against breaches
- **Algorithmic Fairness (76%):** Assurance that pricing and recommendations are not discriminatory
- **Human Oversight (71%):** Option to interact with human representatives when needed
- **Regular Privacy Audits (68%):** Third-party verification of data handling practices

Significantly, 73 percent said that they were ready to interact with AI-enabled platforms under the condition that these ethical considerations were considered. protective measures are put in place in a meaningful way, which indicates that the issue of hyper-personalization paradox can be addressed with the help of responsible AI governance.

5. DISCUSSION

5.1. Interpretation of Findings

This paper confirms empirically the presence of the hyper-personalization paradox in the digital marketing situation. The results prove that although AI-based personalization can make consumer involvement and purchasing intentions much higher, they are undercut to a great extent when the perception of manipulation and privacy concerns are high.

The Dual Reality of AI Personalization

The fact that the relationship between personalization and purchase intention is positive ($r = 0.587$) proves that consumers attach importance to relevant and customized experiences. The most useful recommendations systems proved to be especially effective, as 71 percent of the respondents agreed that they engaged more. This is in line with the findings of previous studies that have shown that AI-based platforms such as Amazon and Netflix have been commercially successful and have transformed the customer experience with predictive analytics.

The high negative relationship between the privacy concerns and purchase intention ($r = -0.512$) however, shows that there is a major weakness. The consumers feel that the data practices are opaque or invasive, it is at this point that the willingness to participate is reduced significantly.

This tension was also numerically measured by the moderation analysis: this high level of privacy concerns decreased the effectiveness of personalization by 46 points, which effectively nullified its beneficial effect on the purchase behavior.

The Trust Crisis in Digital Marketing

The result that merely 32 percent of consumers completely trust e-commerce services with their personal information is a major challenge to digital marketing business. Trust proved to be an important mediator that explained the relationship between transparency and the purchase intention with 43 percent. This implies that even functional high AI systems will not perform to their expectations without trust-building systems.

Of special concern is the impression of manipulation (mentioned by 59% of the respondents). The customer-brand relationship is destroyed when the consumers perceive AI techniques as exploitative- they use psychological vulnerabilities to make unintended purchases. The discovery echoes issues that have been brought up after scandals such as Cambridge Analytica that caused data misuse to harm the general trust that people had in digital platforms.

Dynamic Pricing: A Double-Edged Sword

The impact of dynamic pricing on the purchase intention (0.089) is worth noting negatively. Theoretical efficiency in terms of economics, but in practice, personalized pricing is seen as discriminatory and unjust by the consumers. This result questions the premise that every kind of personalisation is positive, and it is necessary to implement the strategies of optimization and fairness in a subtle way.

5.2. Theoretical Contributions

The study has a number of theoretical implications on the digital marketing and consumer behaviour literature:

Extension of TAM: The research adds to the Technology Acceptance Model by showing that ethical perception, especially transparency and fairness are essential moderators that can dominate functional advantages. Traditional TAM puts emphasis on usefulness and ease of use, yet our results indicate that in high stakes situations that deal with personal data, ethical considerations take the center stage.

Refinement of SOR Model: The study improves the Stimulus-Organism-Response model by establishing privacy issues and trust as important organismic variables that can mediate between AI stimuli and behavioral actions. This implies that feelings and cognitive responses to AI are not homogenous and that they strongly rely on contextual elements connected to the control of data.

Paradox Resolution Framework: The research offers a basis to work on the development of integrative frameworks to consider both commercial and consumer protection interests by objective quantification of the opposing forces of the benefits of personalization and the costs of privacy.

5.3. Comparison with Existing Literature

Our results are consistent with previous studies and elaborate on them in the following aspects:
Consistency with Privacy Calculus Theory: The result in this study of a trade-off between the benefits of personalization and privacy risks is consistent with the theory of privacy calculus which argues that consumers conduct cost- benefit analysis when giving personal information. Our investigation is however adding depth to this calculus by demonstrating that this calculus is skewed by the factors of trust and transparency.

Divergence on Demographic Patterns: On the one hand, some studies point at younger consumers being universally more open to AI technologies; however, on the other hand, our results show that digital natives (18-25) are both more accepting and more sensitive to

manipulation, which implies the possibility of a more advanced perception of AI capabilities and risks.

Enabling Ethical AI Frameworks: The normative argument of responsible AI development based on transparency (89%) and control mechanisms (84%) are proven empirically as it is strongly supported by consumers. This fills the gap between what is in theory ethical and what consumers expect.

5.4. Practical Implications

For Marketing Practitioners:

Adopt Transparency-First Strategies: Organizations have to actively disclose data collection and use practices using easily understandable language. Transparency is not to be considered as a legal compliance issue but rather as a part of value proposition.

Implement Granular Control Mechanisms: Offer consumers meaningful control over the degree of personalization, data sharing choices, and opt-out. Studies indicate that 84 percent of consumers attach importance to such mechanisms, implying that they can be used as competitiveness point of difference.

Audit for Algorithmic Fairness: Conduct frequent reviews of AI systems on the discriminatory biases and make sure that pricing algorithms do not produce an impression of unfairness.The backlash against dynamic pricing points to the reputational costs of optimization strategies that lack ethical concerns.

Balance Automation with Human Touch: Although 68 percent of the respondents felt content with the interaction of a chatbot, 71 percent of them appreciated the fact that they have an opportunity to see a human. The hybrid models that should be both AI efficient and human empathetic can be the best approach.

Invest in Trust-Building Initiatives: Since trust mediates 43% of the relationship between transparency and purchase intention, marketing investments need to focus on building trust by establishing security certifications, privacy seals, and open data breach disclosures.

For Technology Developers:

Design to Explainability: Build AI systems that are capable of making comprehensible explanations of recommendations and decisions. The black box schemes undermine trust, and explainable AI increases the perceived fairness.

Privacy by Design: Build privacy features into the architectural design, as opposed to viewing privacy as an add-on. Differential privacy, federated learning, and on-device processing are all techniques that can be used to minimize the exposure of data and still achieve high-quality personalization.

Create Ethical Override Mechanisms: Build up protections that avoid the exploitation of psychological vulnerabilities by AI systems, and especially vulnerable groups. These involve limitations on rapacious scarcity and manipulative urgency indicators.

For Policymakers:

Strengthen Regulatory Frameworks: GDPR and PIPL are a positive step, but the enforcement processes should be enhanced. The regulators need to require transparency reports, algorithmic impact measurement, and penalties of manipulative behavior.

Promote Digital Literacy: Consumers should be educated through public education on the use of AI, data rights, and data protection measures. Educated consumers are in a better position to follow through the virtual market.

Develop Industry Standards: Construct ethical AI in marketing certification schemes, like fair trade or organic ones. These criteria can help in responsible innovation and can give the consumers some signals of trust.

5.5. Addressing the Hyper-Personalization Paradox

The main question that arises as a result of this study is: How can companies reap the advantages of personalization using AI and retain consumer trust and autonomy?

The solution to this is a paradigm shift in extractive personalization to empower personalization:
Extractive Personalization also works on the premise that the more data the better the result, and it frequently gathers information without any explicit permission or clear explanation. This strategy makes the most out of the short-term interactions but kills the long-term trust.

Empowering Personalization recognizes consumers as partners in the value creation process. It emphasizes:

- Obtaining informed consent through clear communication
- Providing genuine value that justifies data sharing
- Offering meaningful control and easy opt-out mechanisms
- Maintaining transparency about algorithmic decision-making
- Auditing for fairness and non-discrimination
- Respecting consumer autonomy rather than exploiting vulnerabilities

Companies that are open to the practice of empowering personalization will be in a better position to manage the regulatory environment, establish long-lasting customer relations, and attain sustainable competitive advantage.

6. LIMITATIONS AND FUTURE RESEARCH

6.1. Study Limitations

There are a number of limitations that must be considered in considering these findings:
Geographical Scope: The research concentrated on Indian e-commerce buyers and could not be generalized to other. Cultural environments involving various privacy standards, regulation, and patterns of technological adoption

Self-Reported Data: Survey data could be susceptible to social desirability bias, in which the respondent exaggerates privacy issues or under-reports any unethical practices like impulse purchases.

Cross-Sectional Design: The research represents a picture in time and is not able to determine conclusive causal connections. A longitudinal design would be more helpful in understanding how consumer attitudes will change as AI technologies develop.

Platform Specificity: Although the major platforms such as Amazon India and Flipkart were used by the respondents, the findings might not be applicable to other emerging platforms or other types of e-commerce (e.g., luxury goods vs. fast-moving consumer goods).

Measurement Challenges: It is inherent to the method of using Likert scales to quantify complex constructs such as "trust" and "manipulation perception" that complex psychological phenomena are simplified.

6.2. Future Research Directions

Longitudinal Studies: Monitor consumer attitudes and behaviors over a long period to determine the influence of AI personalization experiences on long-term trust and loyalty. Positive experiences may alleviate or exacerbate privacy concerns and this may be determined by panel studies.

Cross-Cultural Comparative Research: Compare the hyper-personalization paradox in different cultural settings (e.g., Western vs. Eastern, individualistic vs. collectivistic societies) to find out general principles and culture-related differences.

Experimental Designs: Carry out controlled experiments by manipulating the level of transparency, control mechanisms and the intensity of personalization in order to determine causal effects and determine the best designs.

Qualitative Deep Dives: Use interviews, focus groups, and ethnography to study the emotional and psychological aspects of AI interactions that cannot be fully studied by quantitative surveys.

Vulnerable Population Studies: Research how AI personalization influences vulnerable populations such as adolescents, elderly consumers, and those with compulsive buying disorders with a consideration of protective interventions.

Newer Technologies: Continue with the research of newer AI applications such as voice assistants, augmented reality shopping experiences, and emotion recognition systems in order to predict the upcoming challenges.

Regulatory Impact Studies: Evaluate how effective data protection regulations (GDPR, CCPA, PIPL) are in the real world of increasing consumer trust and behavior and identify the loopholes between the law and implementation.

Business Model Innovation: Consider other business models including ad-free subscription plans, data co-ops, and personal data stores owned by the consumer which could eliminate the privacy- personalization trade-off.

7. CONCLUSION

This paper proves empirically that the hyper-personalisation paradox is one of the essential issues of modern digital marketing. Although the AI-driven personalisation methods considerably increase the consumer engagement and purchase intentions, as 71% of the surveyed respondents agree that they feel more engaged and 64% respond that they feel more inclined to purchase, the advantages are heavily eroded by the privacy concerns and perceptions of manipulation. The discovery that 68 percent of the consumers concurrently express. the fact that increased data surveillance anxiety, and privacy issues decrease the effectiveness of personalization by 46 percent points to the weakness of modern marketing strategies.

The study shows that the way ahead does not consist in decision-making between innovation and ethics but in the process of integrating them. The fact that 73% of consumers are ready to use AI platforms with the proper safeguards in place portrays that there is quite a significant latent demand of responsible AI applications. Those that are first to introduce transparent data practices, meaningful consumer control, algorithmic fairness, and trust-building mechanisms will receive competitive advantages in a market that is becoming more privacy-conscious.

Key Takeaways:

- **Individualization is effective, but not without trust:** AI-based marketing can reach amazing levels of engagement when the consumers trust the catalogs and feel that the information exchange is valuable to them.
- **Transparency is non-negotiable:** Since 89 percent of consumers value transparent data practices, organizations cannot have opaque black box thinking.
- **Consumers and business gain power:** Giving real control (eighty four per cent valued by consumers) turns consumers into active partners and no longer just targets.
- **Dynamic pricing requires caution:** The backlash against personalized pricing is not positive, and this method means that it should be applied with caution and keeping the notion

of fairness in mind.

- **Trust is measurable and manageable:** The trust is a quantifiable variable influenced by transparency and purchase intention, as well as, it has actionable measures to assess organizational performance.

The hyper-personalization paradox is not an impossibility to overcome but a call to arms to re-define the digital marketing practices. Organizations can eliminate the paradox by adopting responsible AI models and frameworks that put consumer autonomy, transparency, and fairness at the center of their business aims and create long-lasting digital landscapes where innovation and trust may coexist.

With the further development of the AI, the incentives will only grow. Companies, technology providers and government agencies should cooperate to build up preventable governance frameworks to avoid destruction of trust among consumers as well as develop productive innovation. The future of the digital marketing is not in the amount of data that can be extracted, but in the ethical and efficient use of such data in order to generate true, real value to all the stakeholders.

The study is also able to assist in that future by offering concrete findings, intellectual resources, and practical advice to the complex landscape of the AI-driven marketing being in the age where consumer empowerment and corporate responsibility are not the antagonistic ideas but the synergistic requirements.

8. RECOMMENDATIONS

8.1. For Organizations

Immediate Actions (0-6 months):

1. Conduct comprehensive privacy audits of current AI systems and data collection practices
2. Implement clear, accessible privacy policies written in plain language (avoiding legal jargon)
3. Deploy privacy dashboards allowing consumers to view, control, and delete their data
4. Establish ethics review boards to evaluate AI marketing campaigns before launch
5. Train marketing teams on ethical AI principles and consumer privacy rights

Medium-term Initiatives (6-18 months):

1. Redesign recommendation algorithms to incorporate explainability features
2. Develop fairness testing protocols for dynamic pricing and targeting systems
3. Implement A/B testing frameworks comparing transparent vs. opaque personalization approaches
4. Create consumer feedback mechanisms specifically addressing AI experiences
5. Establish partnerships with third-party privacy certification organizations
6. Invest in privacy-enhancing technologies (differential privacy, federated learning)

Long-term Strategic Shifts (18+ months):

1. Transition from extractive to empowering personalization business models
2. Develop industry leadership position in responsible AI marketing
3. Contribute to cross-industry standards for ethical AI in consumer contexts
4. Build competitive differentiation around trust and transparency
5. Cultivate organizational culture prioritizing ethical considerations alongside revenue metrics

8.2. For Policymakers and Regulators

Regulatory Enhancements:

1. Mandate algorithmic impact assessments for AI systems processing consumer data at scale

2. Require transparent disclosure of AI usage in marketing communications
3. Establish clear guidelines distinguishing acceptable personalization from manipulative practices
4. Create enforceable standards for meaningful consent (not just legal checkboxes)
5. Implement significant penalties for privacy violations to ensure deterrence
6. Develop fast-track complaint mechanisms for consumer privacy concerns

Capacity Building:

1. Fund digital literacy programs educating citizens about AI, data rights, and protective measures
2. Establish regulatory expertise in AI technologies through training and recruitment
3. Create cross-border cooperation frameworks for addressing multinational platforms
4. Support academic research on AI ethics and consumer protection

Proactive Governance:

1. Develop anticipatory regulations for emerging AI applications (emotion recognition, predictive analytics)
2. Create regulatory sandboxes allowing responsible innovation with oversight
3. Establish multi-stakeholder forums bringing together industry, consumer advocates, and technologists
4. Commission regular studies assessing regulatory effectiveness and consumer sentiment

8.3. For Consumers

Immediate Protective Actions:

1. Review and adjust privacy settings on all e-commerce and social media platforms
2. Use browser extensions blocking third-party trackers and cookies
3. Regularly delete browsing history and clear cached data
4. Exercise data deletion rights under applicable regulations (GDPR, CCPA, PIPL)
5. Read privacy policies before providing personal information

Ongoing Practices:

1. Question recommendations and advertisements: "Why am I seeing this?"
2. Recognize manipulation tactics including false scarcity, urgency pressure, and social proof
3. Implement cooling-off periods before impulse purchases prompted by AI recommendations
4. Support businesses demonstrating transparent, ethical data practices
5. Report privacy violations to regulatory authorities
6. Participate in digital literacy programs to enhance awareness

Advocacy and Collective Action:

1. Join consumer advocacy groups focused on digital rights
2. Provide feedback to platforms regarding AI experiences
3. Support legislative initiatives strengthening privacy protections
4. Share knowledge about protective measures within social networks
5. Demand accountability through consumer choice and public pressure

8.4. For Academic Researchers

Priority Research Areas:

1. Develop robust measurement instruments for trust, manipulation perception, and algorithmic fairness
2. Investigate long-term psychological effects of continuous AI personalisation exposure
3. Examine differential impacts on vulnerable populations and protective interventions
4. Create frameworks for evaluating trade-offs between personalisation benefits and

privacy costs
5. Study effective transparency mechanisms and their impact on consumer behaviour
6. Explore alternative business models resolving privacy-personalisation tensions

Methodological Innovations:

1. Design experimental studies isolating causal effects of specific AI techniques
2. Employ neuroimaging and psychophysiological methods to understand subconscious responses to AI
3. Develop computational models simulating consumer-AI interactions over time
4. Create interdisciplinary collaborations bridging computer science, psychology, marketing, and ethics
5. Build open datasets and tools enabling reproducible AI ethics research

Knowledge Translation:

1. Publish findings in both academic journals and accessible public formats
2. Engage with policymakers through policy briefs and expert testimony
3. Collaborate with industry on implementing research-based best practices
4. Contribute to public discourse on AI ethics through media engagement
5. Develop educational resources for practitioners and consumers

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Appendix A: Survey Questionnaire

Section A: Demographics

1. Age: years
2. Gender: □ Male □ Female □ Other □ Prefer not to say
3. Highest Education: □ High School □ Undergraduate □ Graduate □ Postgraduate
4. Monthly Income: □ <₹30,000 □ ₹30,000-₹60,000 □ >₹60,000
5. Online shopping frequency: □ Weekly □ Monthly □ Quarterly □ Rarely

Section B: AI Personalization Exposure *Rate your agreement (1=Strongly Disagree, 5=Strongly Agree)*

1. I regularly see advertisements based on my browsing history
2. Product recommendations on e-commerce sites match my preferences
3. I notice price changes when I revisit products
4. Chatbots have helped me find products quickly
5. AI-powered features make my shopping experience more convenient
6. I receive personalized email offers based on my past purchases
7. Social media ads seem to know what I'm interested in
8. I appreciate when platforms remember my preferences

Section C: Purchase Intention *Rate your agreement (1=Strongly Disagree, 5=Strongly Agree)*

1. Personalized recommendations increase my likelihood of purchase
2. I often buy products suggested by AI systems
3. AI-assisted shopping saves me time and effort
4. I trust product suggestions from e-commerce platforms
5. Personalized promotions motivate me to complete purchases
6. I prefer platforms that offer personalized experiences

Section D: Privacy Concerns *Rate your agreement (1=Strongly Disagree, 5=Strongly Agree)*

1. I am concerned about how my personal data is being used
2. E-commerce platforms collect too much information about me
3. I feel I have lost control over my personal information
4. I worry about unauthorized access to my data
5. Companies should ask permission before collecting my data
6. I am unsure what data is being collected about me
7. Data collection practices feel invasive
8. I fear my data might be shared with third parties without consent
9. Privacy policies are too complex to understand
10. I would prefer more transparency about data usage

Section E: Trust and Manipulation Perception *Rate your agreement (1=Strongly Disagree, 5=Strongly Agree)*

1. I trust e-commerce platforms with my personal information
2. AI-driven advertising feels manipulative
3. Platforms are transparent about how they use my data
4. I have made purchases I didn't intend due to AI recommendations
5. Dynamic pricing seems unfair
6. I feel pressured by urgency messages ("Only 2 left!")
7. Platforms prioritize my interests over their profits
8. I can easily understand why I'm shown certain ads

9. AI systems treat all customers fairly
10. I feel in control of my online shopping experience
11. Platforms respect my privacy preferences
12. I would report unfair AI practices if I encountered them

Section F: Willingness to Engage *Rate your agreement (1=Strongly Disagree, 5=Strongly Agree)*

1. I would use AI platforms more if data practices were transparent
2. I would share more data if I had control over its use
3. I would pay premium for privacy-assured platforms
4. I would engage more with platforms that explain AI decisions
5. I trust platforms with third-party privacy certifications
6. I would recommend ethical AI platforms to others

Appendix B: Statistical Tables

Table B1: Reliability Analysis (Cronbach's Alpha)

Construct	Number of Items	Cronbach's α
AI Personalization Exposure	8	0.87
Purchase Intention	6	0.89
Privacy Concerns	10	0.91
Trust	6	0.88
Manipulation Perception	6	0.82
Willingness to Engage	6	0.85

Table B2: Descriptive Statistics

Variable	N	Mean	SD	Min	Max
Age	512	31.24	10.47	18	65
AI Personalization	512	3.78	0.89	1.00	5.00
Purchase Intention	512	3.52	0.94	1.00	5.00
Privacy Concerns	512	4.01	0.86	1.50	5.00
Trust	512	2.94	1.02	1.00	5.00
Manipulation Perception	512	3.67	0.91	1.00	5.00
Willingness to Engage	512	3.89	0.78	1.67	5.00

Table B3: Correlation Matrix

	1	2	3	4	5
1. AI Personalization	1.000				
2. Purchase Intention	0.587	1.000			
3. Privacy Concerns	-0.423	-0.512	1.000		
4. Trust	0.491	0.548	-0.634	1.000	
5. Transparency	0.512	0.621	-0.587	0.694	1.000

Note: $p < 0.01$

Appendix C: Research Ethics Approval

This research was conducted in accordance with the ethical guidelines established by Woxsen University's Institutional Review Board (IRB). Ethics approval reference: WU-IRB-2024-037.

Key Ethical Considerations:

- Informed consent obtained from all participants
- Voluntary participation with right to withdraw
- Anonymity and confidentiality assured
- No vulnerable populations targeted
- Data stored securely with restricted access
- Results reported in aggregate form only
- No deceptive practices employed

Appendix D: Sample Demographic Distribution

Figure D1: Age Distribution

- 18-25 years: 34% (n=174)
- 26-35 years: 41% (n=210)
- 36-50 years: 19% (n=97)
- 51-65 years: 6% (n=31)

Figure D2: Education Level

- High School: 0% (excluded by sampling criteria)
- Undergraduate: 28% (n=143)
- Graduate: 47% (n=241)
- Postgraduate: 25% (n=128)

Figure D3: Monthly Income Distribution

- <₹30,000: 23% (n=118)
- ₹30,000-₹60,000: 42% (n=215)
- ₹60,000: 35% (n=179)

Figure D4: Online Shopping Frequency

- Weekly: 38% (n=195)
- Monthly: 47% (n=241)
- Quarterly: 12% (n=61)
- Rarely: 3% (n=15)

Appendix E: Platform Usage Patterns

Primary E-commerce Platforms Used:

1. Amazon India: 78% (n=399)
2. Flipkart: 71% (n=364)
3. Myntra: 52% (n=266)
4. Ajio: 34% (n=174)
5. Meesho: 28% (n=143)

Average Monthly Spending:

- <₹2,000: 31% (n=159)
- ₹2,000-₹5,000: 42% (n=215)
- ₹5,000-₹10,000: 19% (n=97)
- ₹10,000: 8% (n=41)

Product Categories Purchased:

1. Fashion & Apparel: 82%
2. Electronics: 68%
3. Home & Kitchen: 57%
4. Beauty & Personal Care: 54%
5. Books & Media: 43%

Author Contributions

Shikha Yadav: Conceptualisation, methodology, data collection, formal analysis, writing - original draft, visualisation.
Rajesh Kumar K V: Supervision, methodology, validation, writing, review and editing, project administration.

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Empowering Women through Cooperative Credit Institutions: An Analytical Study of Financial Inclusion in the Bundelkhand Region

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ABSTRACT

It is a thorough investigation of how the cooperative credit institutions have contributed to the empowerment and financial inclusion of women in the Bundelkhand state of India. With the help of a convergent parallel mixed methods design, the study combines the synthesis of secondary data and primary survey data on a sample of 400 women members of Self-Help Groups (SHGs) in five districts of Bundelkhand. Socio-economic profiles, economic empowerment indicators (income, assets, savings, loan utilisation) and social empowerment indicators (decision making, mobility, self confidence) and perceived challenges were encompassed in a structured questionnaire. The SPSS version 28 was used to apply descriptive statistics, paired t test, chi square, Pearson, and multiple linear regression tests. The outcomes show that there are high increases in monthly income (81 percent), assets held (109 percent), savings (309 percent) and loan utilisation towards productive purposes (37 percentage points). The social empowerment scores improved significantly and confidence on speaking before a crowd grew by 192%. Results of the regression analysis indicate that education, SHG tenure, loan amount, and decision making autonomy are the important predictors of income ($R^2 = 0.68$, $p < 0.001$). Along with these gains, there are bureaucratic delays (mean severity 4.5/5), low digital literacy (4.3/5), and family restrictions (4.2/5) that are also a significant obstacle. At the end of the paper are evidence based policy suggestions which include digital literacy camps, institutional reforms, gender sensitive financial product and efficient monitoring frameworks.

Keywords: Financial Inclusion, Women's Empowerment, Cooperative Credit, Bundelkhand, SHGs, SPSS Analysis, Primary Data.

1. INTRODUCTION

In all nations, the provision of a consistent supply of low cost, readily available and diverse financial services is widely viewed as essential for promoting equal economic access, particularly where people have been previously excluded due to their social or economic background; moreover, women benefit greatly from being able to use affordable and timely access to financial products, as access to said products helps women develop their own ability to make choices that positively influence their financial well-being (Kabeer, 1999). In order to further expand the provision of financial products to underserved populations in India, government programs targeted to achieve this goal, such as the Pradhan Mantri Jan Dhan Yojana and the SHG Bank Linkage Programme, have been put in place (NABARD, 2022); however, many disparities in the provision of financial products still exist throughout certain geographic areas, particularly in areas characterized as being ecologically sensitive and/or socio culturally conservative.

Such barriers are represented by Bundelkhand which is situated in Uttar Pradesh and Madhya Pradesh. The area of Bundelkhand is not a good developmental area. It also experiences frequent droughts, agricultural issues are high, most people move out to live in other places, and the patriarchal systems are very strong (Tripathi et al. 2023). The women of Bundelkhand are faced with various levels of disadvantage due to their illiteracy, and their inability to move around freely. Women lack access to property and instead have to rely on informal money lenders, with charging extremely high-interest rates on borrowing money (Yadav and Sharma, 2018). The main

institutions of offering cooperative credit are the District Central Cooperative Banks (DCCBs) and the Primary Agricultural Credit Societies (PACS); primarily they can offer accessible credit and credit without collateral-based lending, but also help women to become stronger together.

Nevertheless, in spite of the acknowledgment of the potential transformative potential of cooperatives, studies, which are more regionally based and are motivated by data, which is analyzed through the more advanced statistical techniques, thus, providing strict quantification of impacts and constraints analysis still lack. The study will address this gap by carrying out the research by taking a summation of the secondary literature and a sample size of (n=400) women all members of self-help groups and cooperative credit institutions. This research aims to achieve four elements; (a) an examination of operational structure of cooperative credit institutions in Bundelkhand; (b) an examination of the outcomes of economic and social empowerment of women who take cooperative credit institutions; (c) identification of greatest barriers faced by these women and (d) an evidence based policy recommendation, which is actionable. The research also has valuable information to the decision makers, development practitioners and financial institutions who would want to encourage gender-inclusive financial systems in other similar marginalized areas.

2. LITERATURE REVIEW

2.1 Cooperative Credit in India: Evolution and Contemporary Role

The Cooperative credit societies in India were created to emancipate rural households from exploitation by money lenders at the beginning of the last century through establishment pursuant to the Cooperative Societies Act of 1904. The cooperative model comprises of three levels of organization (1) State Cooperative Banks (SCB) at the national level (2) district-level banks (DCCB) and (3) Primary Agricultural Cooperatives Society (PACS) at the village and other level and has historically provided a structural network for providing rural finance by cooperating with one another." In the context of providing rural finance cooperatives, cooperatives have played a crucial role in contributing to rural development through the provision of credit, creating patterns of savings behaviour, and improving productivity in agriculture". Unfortunately, the cooperative system is experiencing an array of serious issues, including (1) lack of effective governance, (2) an increase of nonperforming assets, (3) increased competition from commercial banks and microfinance institutions". These difficulties notwithstanding, cooperatives provide the most extensive opportunity to participate in and develop their economy through access to financial services provided by cooperatives in the remote areas of the country. Thus, cooperatives represent an essential part of achieving financial inclusion in remote areas of the country.

2.2 Women's Financial Inclusion: Global and National Discourses

Inclusion of women in the financial sector is generally recognized as a necessity in addition to means of attaining broader equality in development. According to the 2022 Global Findex Database (World Bank), although the gap between genders regarding accounts ownership is narrowed, the access to credit, access to digital finance, and formal savings still have much to be desired. The Self Help Group (SHG) Bank Linkage Programme (SBLP) was a 1992 initiative of NABARD to facilitate women to receive financial services, through starting to save and offering credit access through financial institutions; in March 2022, over 14.2 million women SHGs (comprising 162 million women members) had received financial services through financial institutions (linked through the SBLP) (NABARD, 2022). Kakati and Kakoty (2022) observed that Jharkhand women who are SHG members had high, positive relationships between membership of SHGs, economic independence, decision-making power and social capital (Kakati and Kakoty, 2022). Microfinance via SHGs, mostly as women's co-operatives, is also a contributor to enhancing the financial inclusion of women, as the Bharat Microfinance Report (Sa Dhan, 2022) also supports.

2.3 Regional Studies: Bundelkhand Context

Studies have focused specifically on Bundelkhand and have always emphasize its extreme socio-economic susceptibility. Yadav and Sharma (2018) conducted a study on the accessibility to

financial services in Bundelkhand, which is one of the farmer suicide prone districts, identifying low financial literacy level, poor branch coverage, and the presence of widespread reliance on informal credit as the main limitations. Tripathi et al. (2023) discussed the limitations of SHGs in Bundelkhand, a state of Uttar Pradesh, and found that bureaucratic delays, inadequacy of loans, and family rejection were the primary barriers to the activity. Although these studies can be very useful, they fail to directly identify the role of cooperative credit institutions and use rigorous multivariate analysis to determine determinants of empowerment. The current study addresses this gap by explicitly addressing the cooperative SHG nexus and using the advanced statistical methods.

2.4 Theoretical Framework: Empowerment through Financial Access

The paper is grounded in the theory of empowerment whereby Naila Kabeer (1999) conceptualises empowerment as the process through which the denied get to have the power to make strategic life choices. The three interrelated dimensions include resource (including financial resource), agency (the capacity to establish goals and take action towards them) and achievements (well being outcomes). The access to credit by the cooperative institutions mediated by SHGs, increases the resource of women economically, and as such, builds their agency in their households and communities. Agency is also further enhanced by the cooperative model with its focus on collective decision making and peer support that forms a virtuous cycle of empowerment. This framework helps in choosing indicators, which are income, asset ownership, savings, decision making, mobility, and self confidence, and the interpretation of findings.

2.5 The SHG-Bank Linkage Model as a Catalyst

Particularly through the Self-Help Groups (SHGs) and official banking interaction, notably the NABARD-started SHG Bank Linkage Programme (SBLP) in 1992, is the major driver for rural financial inclusion. By March 2022, this project had connected more than 14.2 million women SHGs to authorised banking services. The studies have shown that this affiliation leads to a great level of independence in decision-making, social capital and financial freedom. Moreover perceived as critical support towards bridging the gap between gender as far as formal savings and credit access is concerned is microfinance delivered through the use of women cooperatives.

2.6 Relationships with the Socio-Economic Barriers in the Ecological Zones.

Unique geographic barrier, frequent droughts and high rates of migration characterize Bundelkhand. According to regional literature, women have high handicaps caused by low literacy and restricted physical freedom. These socioeconomic challenges are sometimes increased because of a lack of property ownership and thus, forcing the women to rely on informal moneylenders who charge them exorbitant interest rates. Earlier studies in the field have established that good use of credit is plagued by tremendous challenges despite the availability of institutional credit in the form of bureaucratic delays and family resistance.

2.7 Institutional and Digital gaps in Cooperative credit.

The contemporary institutional problems restrain the development of the cooperative approach, which is supposed to access the most distant destinations. Moving to the digital economy has exposed an observable digital divide in the rural credit systems. The low average scores on bureaucratic delays (4.6/5) and digital illiteracy (4.4/5) indicate the insufficient ability of the banks with the physical presence with no same technical repair. A large number of Primary Agricultural Credit Societies (PACS) as many research indicate are not computerized and trained in staffing to offer gender sensitive services.

3. Research Methodology

3.1 Research Design

Convergent parallel mixed methods design was chosen, which consists of the simultaneous analysis of secondary data and primary surveys. The design will allow the triangulation of the results and the comprehensive comprehension of the scope and depth of the influence of cooperative credit.

3.2 Study Area and Sampling

The fining was carried out in five districts of Bundelkhand; Jhansi, Jalaun, Tikamgarh, Chhatarpur and Mahoba. These were districts which were chosen deliberately to represent both the Uttar Pradesh and Madhya Pradesh sides of the region in order to have a geographical and social cultural diversity.

Sample Size: 400 women calculated by Cochran formula of finite populations (50% variability, 5% margin of error, 95 percent confidence level).

Sampling Technique: Stratified random sampling. The districts were considered as the stratum, within each of them, the villages were chosen randomly, and SHG members were sampled in proportion.

Inclusion Criteria: Women aged 1860 years, one-year-long active members of SHG, and whose SHG had reached credit linkage with a cooperative bank (PACS or DCCB).

3.3 Data Collection Instrument

A designed questionnaire that was created with a substantial literature review and consultancy with experts had 28 items, which were grouped into four sections:

Section A: Socio demographic profile (age, education, occupation, SHG tenure, household size, landholding).

Section B: Economic empowerment indicators (monthly income pre-SHG/post-SHGs linkage, asset ownership, savings, loan amount received, use of credit, source of credit).

Section C: Social empowerment indicators (decision making in the household, freedom of mobility, attendance at community meeting, confidence in speaking in front of people). They were rated in a 5 point Likert scale (1 = very low, 5 = very high).

Section D: Perceived challenges (13 items that included institutional, socio cultural, and financial barriers) were rated on a 5 point severity scale.
The questionnaire was pre-tested on 30 females in Jhansi district and changes were also made to make it clear and more culturally appropriate.

3.4 Data Collection Procedure

Female trained field investigators who spoke Bundelkhandi, Hindi were used to conduct face to face interviews. The leaders at SHG federation made the groups to be accessible, hence rapport and trust. Each of the interviews was 30-40 minutes. The time of data collection was April-June 2025.

3.5 Data Analysis

The SPSS version 28 was used to code and analyse the data. The framework of analysis included:

- **Descriptive statistics**: Frequencies, percentages, means, standard deviations.
- **Paired t tests:** To compare the difference in means of economic indicators between the pre pre-linkage of SHG.
- **Chi Square tests**: To analyze the relationship between categorical variables (e.g. education level and decision making score).
- **sPearson correlation**: To estimate the bivariate relationships between important variables that are continuous.
- **Serial multiple linear regression**: To determine which predictors are significant predictors of post linkage monthly income.
- **One way ANOVA:** To determine differences in the scores of empowerment based on the districts and SHG tenure groups.
- **Analysis of reliability:** Cronbach alpha of Likert scale items (= 0.87, large internal consistency).

3.6 Ethical Considerations

The respondents were participating voluntarily, and informed verbal consent was obtained. They were anonymized; no personal identifiable data were taken. Ethical requirements used in the study were the Indian Council of Social Science Research (ICSSR).

4. RESULTS AND ANALYSIS

4.1 Demographic Profile of Respondents

Table 1 presents the socio-demographic characteristics of the 400 respondents.

Table 1: Socio-Demographic Characteristics of Respondents (N=400)

Variable	Category	Frequency	Percentage
Age (years)	18–30	128	32.0%
	31–45	206	51.5%
	46–60	66	16.5%
Education	Illiterate	112	28.0%
	Primary	148	37.0%
	Secondary	100	25.0%
	Higher Secondary+	40	10.0%
Occupation	Agriculture	188	47.0%
	Animal Husbandry	96	24.0%
	Micro-enterprise	80	20.0%
	Others	36	9.0%
SHG Tenure	1–3 years	164	41.0%
	4–6 years	156	39.0%
	>6 years	80	20.0%

Interpretation: Most of the respondents (51.5) fall in the 3145 years bracket meaning that middle aged women are the major participants in SHGs. 28% are illiterate thus, requiring more education through outreach programs. The main livelihood (47%), however, is agriculture, but non farm micro enterprises are on the rise (20%). SHGs tenure of over three years is well appreciated (59%).

4.2 Economic Empowerment

Table 2: Economic Indicators Before and After SHG-Credit Linkage (N=400)

Indicator	Before (Mean)	After (Mean)	Mean Difference	% Change	t-value	p-value
Monthly Income (INR)	3,620	6,550	2,930	+81.0%	18.27	<0.001
Household Asset Score (0–10)	3.5	7.3	3.8	+108.6%	16.53	<0.001
Monthly Savings (INR)	210	860	650	+309.5%	22.14	<0.001
Loan Utilisation for IGAs	49%	86%	+37 p.p.	–	–	–

Note: The asset score incorporates ownership of livestock, sewing machines, bicycles, mobile phones, and durable household items. IGAs = Income Generating Activities. Indeed, statistically significant improvements in all indicators are established by paired t tests ($p < 0.001$).

Table 3: Sources of Credit Availed (Multiple Responses)

Credit Source	Frequency	Percentage
SHG Internal Lending	400	100.0%
PACS	296	74.0%
DCCB	252	63.0%
Commercial Banks	92	23.0%
Informal Moneylenders	48	12.0%

Interpretation: While all women rely on internal SHG savings for initial loans, cooperative institutions (PACS and DCCBs) serve as the primary external credit source for 74% and 63% of respondents respectively. Notably, dependence on informal moneylenders has dropped to 12%, a marked reduction from pre-SHG levels reported in qualitative responses.

4.3 Social Empowerment

Table 4: Social Empowerment Scores Before and After SHG Linkage (Mean on 5-Point Scale)

Dimension	Before	After	Mean Gain	% Improvement
Household Decision-making	2.2	4.1	1.9	+86.4%
Freedom of Mobility	1.9	3.5	1.6	+84.2%
Participation in Community	1.8	3.9	2.1	+116.7%
Confidence in Public Speaking	1.3	3.8	2.5	+192.3%

Interpretation: The most spectacular increase is in public speaking confidence, which shows the transformational impact of SHG meetings, leadership positions, and exposure to training courses.

Table 5: Cross-tabulation: Education Level vs. Decision-making Score (Post-Linkage)

Education Level	Low (1–2)	Moderate (3)	High (4–5)	Total
Illiterate	32	44	36	112
Primary	18	56	74	148
Secondary	8	30	62	100
Higher Secondary+	2	8	30	40
Total	**60**	**138**	**202**	**400**

Pearson Chi-square = 58.73, df = 6, p < 0.001.
Higher education is **quite** strongly **correlated with more** decision-making autonomy.

4.4 Inferential Statistics
4.4.1 Pearson's Correlation Matrix

Variable	1	2	3	4	5
1. Monthly Income (After)	1.00				
2. Loan Amount	0.68**	1.00			
3. SHG Tenure	0.61**	0.54**	1.00		
4. Education Level	0.55**	0.47**	0.39**	1.00	
5. Decision-making Score	0.59**	0.51**	0.56**	0.48**	1.00

**Correlation is cruacial at the 0.01 level (2-tailed).
All variables show moderate to strong positive correlations, with loan amount exhibiting the strongest association with income (r = 0.68).

4.4.2 Multiple Linear Regression

Dependent Variable: **Monthly Income (After)** Predictors: Age, Education Level, SHG Tenure, Loan Amount, Decision-making Score

Table 6: Regression Coefficients

Predictor	Unstandardized B	Std. Error	Beta (β)	t-value	p-value	VIF
(Constant)	2,210.45	295.80	–	7.47	<0.001	–
Education Level	480.60	72.15	0.29	6.66	<0.001	1.52
SHG Tenure	410.25	65.40	0.26	6.27	<0.001	1.48
Loan Amount	0.78	0.10	0.33	7.80	<0.001	1.61
Decision-making Score	330.80	62.90	0.21	5.26	<0.001	1.55
Age	–18.50	9.80	–0.07	–1.89	0.060	1.23

Model Summary: $R = 0.83$, $R^2 = 0.69$, Adjusted $R^2 = 0.68$, $F(5,394) = 56.78$, $p < 0.001$.

Interpreting: Collectively accounting for 69% of the variance in post linkage monthly income are education, SHG tenure, loan amount, and decision-making score—all important positive indicators. Age does not seem statistically meaningful. For loan amount, the highest standardized coefficient (β = 0.33) highlights how absolutely vital enough credit access is. Variance Inflation Factors below two reveal no multicollinearity issues.

4.4.3 One-way ANOVA: District-wise Differences in Empowerment Score

District	N	Mean Empowerment Score*	Std. Deviation
Jhansi	88	4.12	0.64
Jalaun	76	3.89	0.71
Tikamgarh	84	4.05	0.68
Chhatarpur	72	3.78	0.73
Mahoba	80	3.95	0.70

*Composite empowerment score (average of four social indicators).
ANOVA: $F(4,395) = 3.84$, $p = 0.004$.

Post hoc Tukey HSD tests show that Jhansi and Tikamgarh have notably higher empowerment ratings than Chhatarpur (p < 0.05). This could indicate discrepancies in historical SHG penetration, NGO activity, or cooperative bank reach.

4.5 Challenges Perceived by Women

Respondents rated 13 challenges on a 5-point scale (1 = not a barrier, 5 = severe barrier). Table 7 presents the top seven.

Table 7: Ranked Challenges in Accessing Cooperative Credit

Challenge	Mean Severity	Std. Deviation
Bureaucratic delays	4.6	0.58
Lack of digital literacy	4.4	0.67
Family restrictions	4.3	0.74
Inadequate loan amount	4.1	0.81
High interest rates	3.9	0.86
Lack of collateral	3.8	0.92
Poor staff behaviour	3.6	1.03

Interpretation: The most serious structural barrier is bureaucratic delays (loan processing time, excessive documentation) With only 18% of respondents claiming any mobile banking usage, digital literacy deficiencies are severe. Despite developments, social cultural obstacles—family resistance and mobility limitations—remain great.

5. DISCUSSION

The present study is strongly empirical in that cooperative credit institutions run using SHGs have triggered high levels of economic and social empowerment among rural women in Bundelkhand. The results are in line and fecund to earlier studies (Kakati and Kakoty, 2022; Lal, 2019; Tripathi et al., 2023). The 81 percent growth in the average monthly income and 109 percent growth in household asset scores are especially remarkable, meaning that the credit is not spent idly but is invested in productive processes. The drastic decrease in the rate of dependence on informal moneylenders (a rate of about 65 percent is estimated before SHG to 12 percent now) mechanisms emancipate women in vicious debt circles, which aligns with the aims of the SHG Bank Linkage Programme (NABARD, 2022).

The social empowerment, particularly the 192% increase in confidence when speaking publicly, are in line with the agency dimension of Kabeer (1999). Those women who were not comfortable speaking in family meetings before found themselves expressing their opinions in SHG meetings, bank deals and even gram sabhas. This agency is in itself righteous and useful in breaking patriarchal standards. The high correlation of the education and decision making (chi square, $p < 0.001$) explains the necessity to combine adult literacy and financial education with credit programmes.

The regression equation accounts 69 percent of the post-linkage income, with the loan amount turning out as the most influential predictor (=0.33). The direct policy implications of this finding are as follows: raising credit limits to women entrepreneurs and simplifying the disbursement process may significantly increase the economic effects. The value of tenure in SHGs (=0.26) indicates the significance of continued group membership; it supports the necessity to treat dropouts and develop older groups.

Nevertheless, the bureaucracy delays (4.6) and digital illiteracy (4.4) remain indicates that cooperative institutions have certain weaknesses on a systemic level. PACS are mostly not computerized and even the staff are not trained on customer-centric and gender sensitive service delivery. The digital divide in particular, is alarming as the financial sector is fast becoming digitalised; otherwise, women will be marginalized. Family restrictions, albeit diminished, continue to limit 65 per cent of the respondents, meaning that the efforts used in empowering the respondents need to involve the men and the community leaders.

The disparity in district-levels (ANOVA, $p = 0.004$) indicates that certain areas of the region are behind in the improvement process, even though the situation is improving overall. The lower scores on the lower empowerment dimension of Chhatarpur could also be connected to weaker cooperative infrastructure or a lack of NGO collaboration; this should be investigated qualitatively.

6. Policy Recommendations

The evidence-based recommendations based on the findings include the following:

1. **Digital Sakhi Initiative:** Initiate a massive digital literacy campaign, targeting rural women, through the federations of SHGs as training centres. Offer inexpensive phones and more streamlined mobile banking applications on local languages. Aim 80% digital banking penetration in 3 years.
2. **Cooperative Institutional Reforms:** Requirement to fully computerise all PACS and DCCBs in Bundelkhand. Launch one window, time bound loan approval system with maximum processing period of 15 days. Carry out a compulsory gender sensitivity training to all employees in the cooperative bank.

3. **Product Innovation**: Introduce flex products based on the livelihood of women e.g. livestock loans whose payments are tied to sale of milk, and working capital loans whose payments are tied to seasonal repayment schedules of micro enterprises. Introduce a credit-bundled group-based weather-indexed crop insurance.
4. **Increase Credit limits:** Increase the limit of SHG linkage loans to 5 lakh as opposed to 2-3 lakh on current groups with high repayment history. Encourage scale up of successful businesses by lending among members individually.
5. **Integrated Livelihood Support:** Liaise with Deendayal Antyodaya Yojana NRLM and Tejaswini programme to give skill development, market connections and enterprise mentoring in addition to credit. Focus on non farm industries (e.g. food processing, tailoring, solar products assembly, etc) to reduce reliance on agricultural income and to reduce agrarian risk.
6. **Social Mobilisation and Advocacy**: Implement social awareness activities among the community (fixed panchayat heads, school teachers, and male relatives) to combat the culture of patriarchy. Create women leadership schools in the federations of SHG to prepare future community leaders.
7. **Enhance Monitoring and Evaluation:** Introduce a real time digital dashboard at the district level monitoring key performance indicators: the number of women borrowers, amount of loans being disbursed, rate of repayment, and empowerment indicators (annual survey). Evidence-based course correction using data.

7. CONCLUSION

This paper indeed demonstrates that in the challenging setting of Bundelkhand, the empowerment of women is pegged on the cooperative credit institutions that are synergized with SHGs. Through an intensive mixed methods methodology and advanced statistics analysis, it has quantified large increases of income, asset creation, savings, decision-making autonomy and self-confidence. Concurrently, it has demonstrated the institutional, technological and socio-cultural obstacles that do not allow full inclusion.

The new path requires a multi-stakeholder approach, which does not just involve giving credit. The process of modernizing technologically, stable digital literacy, the sensitivity of product design, and unceasing social engagement of cooperatives are not optional extras but necessities. Females in Bundelkhand have already demonstrated themselves as community leaders and financial players; Financial institutions, Policymakers, and civil society need to eliminate the existing obstacles at this stage.

Not only can India encourage financial inclusion and women empowerment in Bundelkhand but also set a pilot example of replicability in other failed regions across the Global South through the development of the cooperative credit environment as a gender sensitive platform. The 400 women of this sample are only a small sample of millions of women seeking an equal opportunity. This research proves that they will not stand in vain with the assistance they will have.

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Appendix: Survey Questionnaire

Empowerment and Financial Inclusion of Women in Bundelkhand – SHG Member Survey
Section A: Demographic Information

1. District: _____
2. Age (in years): _____
3. Education Level: a) Illiterate b) Primary c) Secondary d) Higher Secondary e) Graduate+
4. Primary Occupation: a) Agriculture b) Animal Husbandry c) Micro-enterprise d) Wage Labour e) Other
5. Years in SHG: _____
6. Household size: _____
7. Land ownership (acres): _____

Section B: Economic Empowerment

8. Average monthly income (INR) before joining SHG: _____
9. Average monthly income (INR) after joining SHG: _____
10. Assets owned before SHG (tick): □ Livestock □ Sewing machine □ Bicycle □ Mobile phone □ Others
11. Assets owned after SHG (tick): □ Livestock □ Sewing machine □ Bicycle □ Mobile phone □ Land □ Others
12. Average monthly savings (INR) now: _____
13. Loan amount received from cooperative bank/PACS in last 3 years (INR): _____
14. Purpose of loan (tick all that apply): □ Agriculture inputs □ Livestock purchase □ Micro-enterprise □ Education □ Health □ House repair □ Other
15. Source of credit (tick all that apply): □ SHG internal □ PACS □ DCCB □ Commercial bank □ Moneylender □ Other

Section C: Social Empowerment

Please rate the following on a scale of 1 (very low/no) to 5 (very high/full):

16. Your involvement in household financial decisions now: _____
17. Your freedom to visit bank/market alone now: _____
18. Your participation in community meetings now: _____
19. Your confidence in public speaking now: _____
20. Your involvement in household financial decisions before SHG: _____
21. Your freedom to visit bank/market alone before SHG: _____

Section D: Challenges

22. Rate the severity of each challenge (1 = not a barrier, 5 = severe barrier):
    a) Bureaucratic delays (loan processing) _____
    b) Lack of digital literacy _____
    c) Family restrictions/opposition _____
    d) Inadequate loan amount _____
    e) High interest rates _____
    f) Lack of collateral _____
    g) Poor staff behaviour _____
    h) Distance to bank branch _____
    i) Illiteracy _____
    j) Lack of skill training _____
    k) Inadequate market linkages _____

23. What improvements would you suggest for cooperative credit services? (Open-ended)

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Journey and Recent Developments with Reference to Customer Protection Pertaining to Indian Financial Sector

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ABSTRACT

An important pillar of the financial sector is customer grievance redressal system. During the last few decades, a number of regulatory measures have been undertaken with reference to protection of customer rights and also grievance redressal by regulatory bodies. The purpose of this paper is to evaluate the impact of these measures and also to review the evolution of various customer protection related initiatives taken by the RBI over the past few years and also the way forward with reference to the financial sector. The most important initiative, has been introduction of Ombudsman scheme by RBI, particularly Reserve Bank Integrated Ombudsman Scheme 2021; automation of customer grievance redressal system, awareness and information dissemination related measures and also the usage of Artificial Intelligence by regulated entities, with reference to grievance redressal system.

INTRODUCTION

One of the important pillar or cornerstones of the financial sector industry is the presence of a robust grievance redressal system. The protection of consumer interest has been one of the core guiding principles of RBI as a regulator of the banking sector. One of the landmark initiatives taken in this regard has been the introduction of Banking Ombudsman Scheme in 1995. Over the years several refinements and improvements in the scheme have been brought about. The latest version of the Ombudsman Scheme, viz., 'Reserve Bank Integrated Ombudsman Scheme 2021', whose one of defining feature is jurisdiction neutrality and also making the definition 'service deficiency' more comprehensive. Efforts have also been made by RBI to improve the internal grievance redressal system at the end of regulated entities (REs).

Historical Background

In ancient India, Manu Smriti had delineated a code of conduct for merchants and had also outlined strict penalties for perpetrators of offenses against purchasers. As per Arth shastra, Kautilya had set up a comprehensive code of conduct for merchants, which had laid down penalties and imprisonment for individuals who had committed transgressions against purchasers. The judicial system provided for adjudication of civil and criminal cases separately.

In the past, a number of Committees were set up by RBI for examining the existing customer service with reference to banking sector and also make recommendations/suggestions in this regard. One of the earliest committees formed was the Talwar committee, which was set up in 1975 and it was headed by Mr. R.K. Talwar, who was the former chairman of SBI, the recommendations made by the committee formed the basis of the regulatory measures undertaken by RBI with reference to banking sector. Subsequently, Goiporia Committee (1990) made recommendations regarding deposit accounts, government business and exchange of mutilated notes. 'The Committee on Procedures and Performance Audit on Public Service' (CPPAPS 2004) had made several recommendations including setting up of Banking Codes and Standards Board of India, also in areas of foreign exchange, currency and government transactions. 'Damodaran Committee on Customer Service' (2010) headed by Shri M. Damodaran, Ex-Chairman of SEBI, had recommended strengthening of internal grievance redressal mechanism with reference to banks and launch of complaint management system. Recently, 'the Committee for Review of Customer Service in RBI Regulated Entities' (2022) was formed and which was headed by Mr. B.P. Kanungo, who was earlier Deputy Governor, RBI, it's recommendations pertained to

strengthening regulations, also improvement in the customer service in the REs and also for using technology for better customer service.

Global Practices with reference to Customer Protection:
World Bank had in it's report titled 'Good Practices for financial consumer protection' in 2017, outlined good practices with reference to the various financial products being offered by various financial services organizations, viz., deposit and credit products, insurance, securities and pensions, etc. Under each practice, the practices identified have been further categorized into categories such as data protection, and privacy, regulatory and supervisory framework, legal, oversight framework and also for regulation for fair practices, etc.

In this regard, the G 20/'Organisation for Economic Cooperation and Development' (OECD) high level principles (HLPs) on financial consumer protection were developed by G 20/OECD Task Force and were in turn endorsed by G 20 leaders in November 2011. These HLPs were focused on legal, regulatory and supervisory framework, access and inclusion, competition, disclosure and transparency, conduct and culture of providers and intermediaries and also protection of consumer data and privacy, etc,. Three themes were identified with reference to HLPs, which were digitalization, financial wellbeing and sustainable finance.

International Experience

i. USA: In US, Consumer Financial Protection Bureau (CPFB) was established in terms of 'Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010', for protection of consumers by ensuring compliance with consumer financial laws enacted by Federal Government. The primary functions of CFPB includes, protection of consumers from unfair, deceptive or abusive act; identification of outdated regulations concerning consumer financial products and also making sure that consumer financial products and services markets operate transparently.
ii. U.K.: In the United Kingdom, the 'Financial Conduct Authority (FCA)' was set up in terms of Financial Services Act of 2012, for regulating consumer credit industry with effect from April 01, 2014 and it took over the Office of Fair Trading. The primary role of FCA is to supervise banks in order to ensure that customers are treated fairly and also encourages innovation and healthy competition. FCA is endowed with powers for regulating conduct related to marketing of financial products.
iii. E.U.: European Banking Authority (EBA) in E.U. is responsible for promoting transparency, also for fair and simple internal market for consumers with reference to the financial products. EBA also aims to ensure protection of consumer rights of financial services across E.U. by identification of obstacles, which customers face. The role of EBA includes, collecting, analyzing and also reporting on consumer trends in the E.U.; also undertaking review and coordinating financial literacy; development of training standards for the industry.
iv. China: The Peoples' Bank of China had established Financial Consumer Protection Bureau in 2012. The main mandate of the Bureau includes financial inclusion and protection of financial consumers. The main responsibility is for undertaking comprehensive researches with reference to major issues whose subject matter pertains to financial consumer protection in case of China, formulating drafts of policies and regulation on financial consumer protection and also norms on cross-sector financial businesses, coordinating efforts in consumer protection.
v. Russia : In the context of Russia, protection of consumer related issues are handled by Bank of Russia and they are of two types, viz., reactive and proactive. In case of reactive, Bank of Russia handles complaints and also requests received from customers and in case of proactive measures, it eliminates market practices that might adversely impact customers financial interests. Individuals can also apply to Bank of Russia with reference to explanations regarding financial institutions operations or with reference to violation of their rights by such institutions.

Customer Protection Framework – Indian Financial System

The centrality of customer protection with reference to regulatory focus can be gauged from the fact that in the RBI Act, 1934, whereby it has been mandated that one of the condition for inclusion in the second schedule of RBI Act, 1934 is that the affairs of the concerned bank are not being conducted in a manner which is adverse to the interests of the depositors.

In order to provide low cost alternative grievance redressal platform for expeditious redressal of complaints of bank customers, RBI had introduced Banking Ombudsman Scheme under Section 35 A of the Banking Regulation Act, 1949, in 1995. This scheme underwent revision in 2002, whereby the coverage of the scheme was expanded to cover RRBs and also for undertaking review of the award granted by Banking Ombudsman Scheme could also be undertaken. The scheme was further revised in 2006 and the scope of complaints was enlarged to include, credit card complaints, banks' sales agents related complaints, complaints pertaining to levying of service charges without prior notice, inordinate delay in payments or collection of cheques, etc. The landmark initiative was the launching of 'Reserve Bank Integrated Ombudsman Scheme 2021' on November 12, 2021. The key features of this scheme included, removal of jurisdiction of individual ombudsmen office; merger of erstwhile three ombudsman schemes, viz., 'Banking Ombudsman Scheme 2006', 'The Ombudsman Scheme for NBFCs 2018' and 'The Ombudsman Scheme for Digital Transactions 2019'; setting up of a Centralised Receipt and Processing Centre for receiving and also undertaking initial processing of complaints and also enlargement of the definition 'deficiency in service'.

The Customer Service Department, was created in RBI in 2006, with the objective of having a focused approach with reference to the activities relating to customer service in banks and also in RBI. The main function of the Department was administering the Banking Ombudsman Scheme; monitoring the grievance redressal system being offered by various RBI Offices/Departments; dissemination of information regarding instructions pertaining to grievance redressal and also customer service customer service by banks and RBI; etc.

The 'Banking Codes and Standards Board of India (BCSBI)' was established in 2006, on the basis of the recommendation of 'Committee on Procedures and Performance Audit on Public Service' (Tarapore Committee). It was envisaged that BCSBI would be an independent and autonomous institution which would be responsible for monitoring and also ensuring voluntary adoption of banking codes and standards by banks. It was also envisaged that BCSBI would be responsible for planning, evolving, promotion and also for undertaking publishing of comprehensive codes and standards for banks. BCSBI was dissolved in 2021.

The charter of customer rights was issued by RBI on December 03, 2014, whereby 5 basic rights of bank customers were identified, viz., right to transparency; fair and honest dealing, right to suitability, right to fair treatment, right to privacy and right to grievance redress and compensation. In this regard, RBI had also instructed 'Indian Banks' Association' and 'Banking Codes and Standards Board of India' in order to lay down a model customer rights policy, with reference to the principles which were contained in the charter. The Department has been re-christened as 'Consumer Education and Protection Department' (CEPD) and it is responsible for monitoring the functioning of 24 Offices of RBI Ombudsman (ORBIOs) and also 32 'Consumer Education and Protection Cells' (CEPCs). The main function of CEPD is to administer the functioning of 'Reserve Bank Integrated Ombudsman Scheme 2021'.

With the object of strengthening the internal grievance redressal system at the level of regulated entities, RBI had issued guidelines for implementation of internal ombudsman scheme in 2018, with reference to all public sector banks and select private and foreign banks, the internal ombudsman was envisaged to act as an independent authority tasked with reviewing the complaints that had been wholly or partially rejected by the respective banks. Subsequently directions were issued in 2023 and it was made applicable to all banks having 10 or more banking outlets, NBFCs, Credit Information companies, etc.

In order to facilitate seamless registering of complaints with RBI, an online portal known as Complaint Management System was launched by RBI in 2019. This system provides the opportunity of online filing of complaints, acknowledgement through SMS, status tracking, etc.

In order to prevent and also address customer related grievances pertaining to digital lending, credit information companies, RBI has issued guidelines/master directions, viz., 'Reserve Bank of India (Digital Lending) Directions, 2025'; 'Master Direction – Reserve Bank of India (Credit Information Reporting) Directions, 2025'; Key Fact Statement on Loans and Advances, etc.

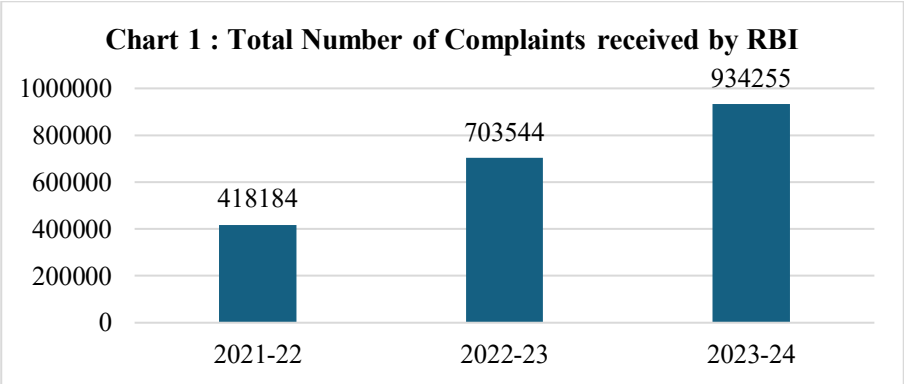
It can also be mentioned that currently RBI is engaged in developing a consumer protection assessment matrix (CoPAM) for assessing the quality of consumer protection being provided by regulated entities.

Awareness initiatives/Campaigns

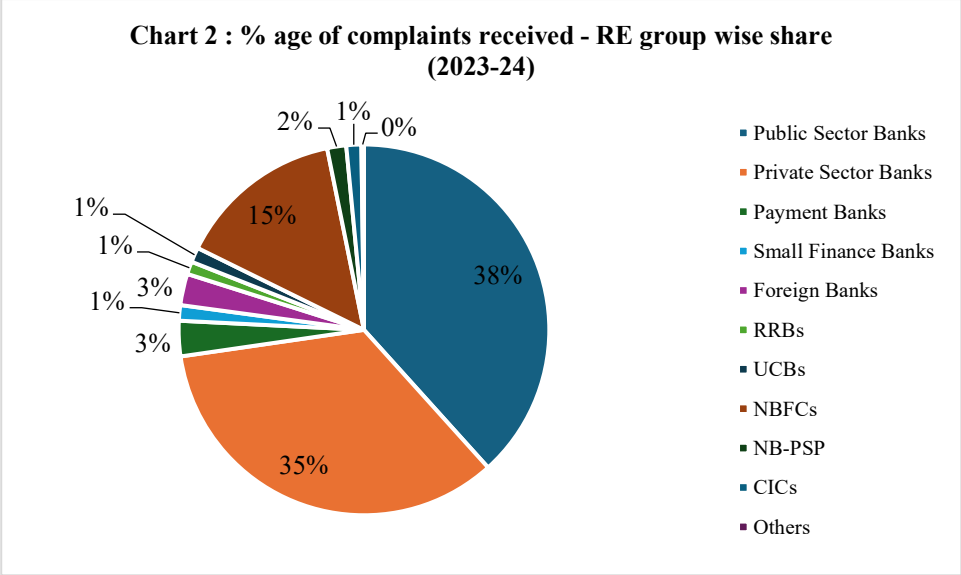
During 2023-24, RBI had undertaken eight SMS campaigns were released covering aspects of Reserve Bank Integrated Ombudsman Scheme 2021 and safe banking practices, each of the SMS campaign had covered 30-40 crore individuals. Thematic multi-media campaign and two print campaigns in newspapers with reference to Reserve Bank Integrated Ombudsman Scheme 2021 was undertaken. These campaigns were also released in various regional languages. 46 townhall meetings and 203 awareness campaigns were also conducted across the country during 2023-24. The third such event was conducted on March 15, 2024, wherein Ombudsmen interacted with local TV/Radio channels, whereby awareness was disseminated regarding grievance redress mechanism, safe digital banking practices. In 2022, RBI had released two booklets (in the format of a comic book), 'BE(A)WARE' and 'Raju and the Forty Thieves', for spreading awareness among general public regarding modus operandi of the frauds and also providing awareness on precautions to be adopted while undertaking financial transactions. Subsequently, a booklet 'The Alert family' was released on March 15, 2024, for disseminating awareness regarding financial transactions undertaken by individuals. The booklet is available both in Hindi and English and also 8 other regional languages.

Trend of Complaints

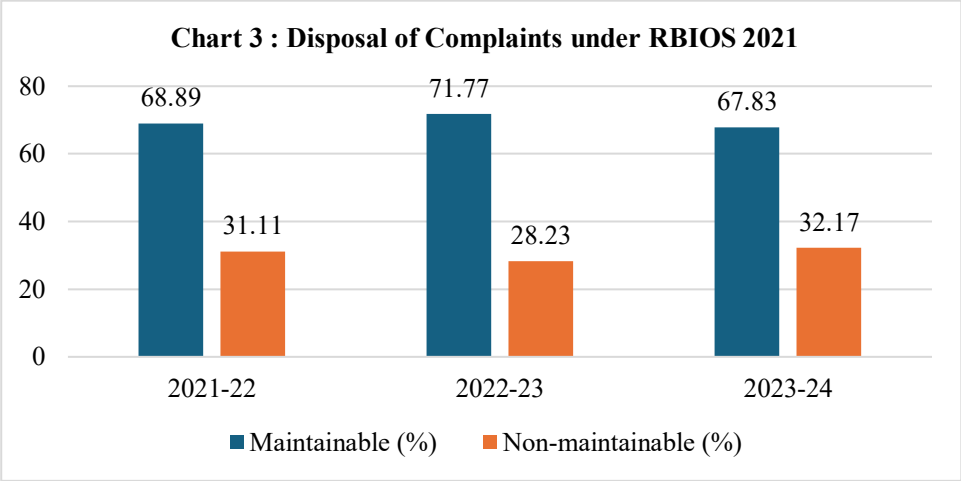
During 2023-24, a total of 9,34,355 complaints were received and it showed an increase of 123.43% over 2021-22 (Chart 1), in the year Reserve Bank Integrated Ombudsman Scheme 2021. Complaints amounting to 2,93,294 received by Offices of RBI Ombudsmen, out of which the maximum number of complaints were pertaining to loans and advances (42.70% of the total complaints). It has also been observed that out of 2,93,924 complaints received, a total of 91,469 complaints were closed as non-maintainable, implying that proper due diligence had not been undertaken by the complainants before registering the complaints with RBI and approx. on an average 31 % complaints have been closed as non-maintainable (Chart 3). Out of the complaints received by RBI, the majority of the complaints were with reference to public sector banks, with private sector banks being second and the foreign banks being a distant fourth (Chart 2).



Source: Reserve Bank – Integrated Ombudsman Scheme 2021, Annual Report – April 1, 2023 to March 31, 2024.



Source: Reserve Bank – Integrated Ombudsman Scheme 2021, Annual Report – April 1, 2023 to March 31, 2024.



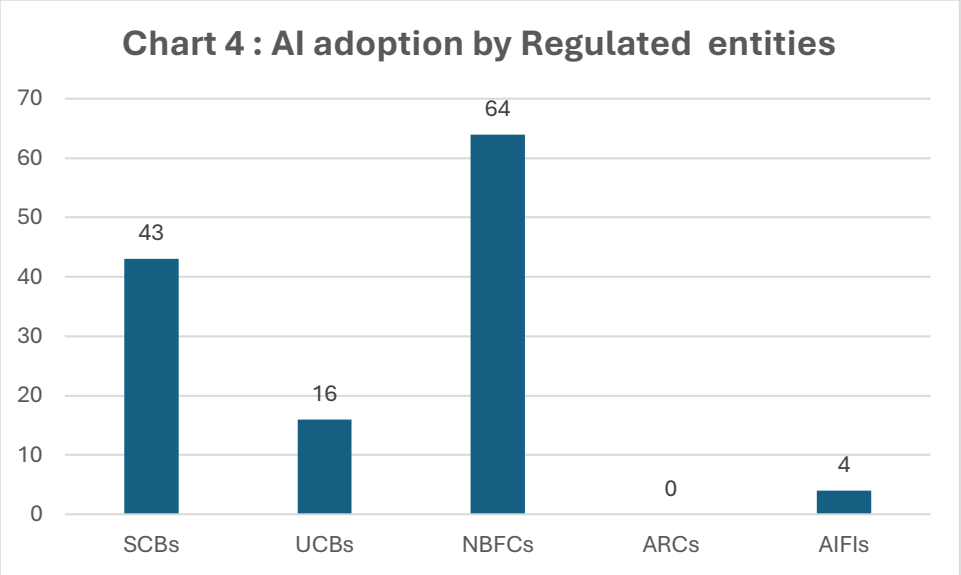
Source: Reserve Bank – Integrated Ombudsman Scheme 2021, Annual Report – April 1, 2023 to March 31, 2024.

Customer Protection – AI

The usage of AI can help in revolutionizing grievance redressal at the RE's level, since usage of AI can lead to marked improvements with reference to the speed, accuracy and also the fairness of grievance redressal mechanism. The AI can be used with reference to categorizing complaints received by REs, on account of urgency, complexity or subject area, so that complaints can be forwarded to the right team for redressal. AI can also be used for undertaking analysis of both unstructured and structured data, the examples of which are emails, chat logs and also call transcripts, in order to identify systemic gaps. This can also help in identifying training needs for the staff of REs. Data analytics, sentiment analysis and the predictive models, can also be used in order to analyze large volumes of data for detection of huge jump in the issues such as ATM failures or erroneous charges which are being charged by REs. In a multi-lingual country like India, the implementation of AI driven chatbots and voice recognition tools could be helpful in elimination of language barriers by operating in local languages. It can also be mentioned that the usage of conversational AI in the form of voicebots, chatbots and also advanced also usage of IVR techniques can also helpful in handling routine queries by consumers on a 24X7 basis and therefore it can help in releasing staff members of REs from this task, so that they can concentrate on solving complex issues with reference to customer service.

In the context of Indian banking sector, although there have been use cases of implementation of AI with reference to customer service, viz., in case of SBI, an AI based chatbot has been

implemented for capturing customer behaviour, HDFC Bank has also implemented AI in it's banking lobby in order to streamline banking operations using AI powered chatbots with reference to customer service. AI algorithms are being used for personalized recommendations and also usage of AI analytics for data-driven decision making. However, the usage of AI with reference to Indian financial sector has been quite limited, this is evidenced by a survey conducted of 612 REs by RBI during February-May 2025, in order to assess the implementation of AI in the financial sector. An important finding of the survey was that only 20.80% of the entities which had been surveyed had either adopted or were developing AI systems (Chart 4).



Challenges

1. There has been an increase in the number of complaints received by RBI under the aegis of Reserve Bank Integrated Ombudsman Scheme 2021, from 2,35,000 in 2022-23 to 2,94,000 in 2023-24, has been observed. Therefore, there appears to be cause of introspection regarding the functioning of internal grievance redressal system with reference to regulated entities.
2. Lack of root cause being undertaken with reference to reoccurrence of certain type of complaints, e.g. digital transaction disputes, unauthorized charges, etc. is leading to non-achievement of the complete potential of the customer service at the level of REs.
3. Another important issue pertains to the overall responsibility of the Board of Directors and also the Top Management of the regulated entities, whereby it is imperative that should ensure customer centricity with reference to design of various products, processes involved, delivery mechanism of products and post sales service.
4. Another major issue pertains to lack of customer education and awareness particularly in case of digital frauds, so that prevention of such frauds can be undertaken and also awareness regarding the action to be taken upon occurrence of such frauds.
5. The implementation of AI with reference to the banking sector can lay the door open to ethical concerns, which may consist of biased selection, mis-selling, biased credit scoring and also dissemination of incorrect information. The lack of explainability of AI algorithms in arriving at decisions, can also lead to lack of transparency with reference to customer related issues.

Suggestions/Way Forward:

1. There needs to be enhanced focus on customer education/awareness with reference to their rights, with reference to the existing alternate grievance redressal system being offered by RBI, internal grievance redressal system at the REs end. It is also important to make the customers aware regarding safeguards that can be taken in to prevent such customer related incidents, especially digital banking related complaints/frauds. This initiative needs to be taken not only by RBI and other government agencies but also by the private sector in co-ordination with the regulatory bodies.

2. There is need for strengthening of internal grievance redressal mechanism at the end of the regulated entities, since it has been observed that the volume of complaints being received by RBI have been increasing, out of which a substantial number of complaints have been first resort, implying that the customers/individuals trust RBI more rather than the REs, with reference to resolution of complaints.
3. There is a greater need for adoption of AI/ML within the Indian Finance Sector, in order to improve customer service by providing a platform in the form of chatbots for addressing the queries raised by the customers on a 24X7 basis and also analysis of complaints handled in the past, so that reoccurrence of such complaints can be prevented, by putting in place the necessary systems and processes in this regard.

CONCLUSION

There has been an huge jump in the number of complaints received by RBI over the past few years and a number of initiatives have been taken by RBI with reference to improvement of customer protection and an important initiative in this regard has been the introduction of Reserve Bank Integrated Ombudsman Scheme 2021. Important challenges being faced in this regard lack of root cause analysis by regulated entities, customer awareness regarding the grievance redressal system, low level of adoption of AI, lack of top management customer centricity.

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Legal and Regulatory Challenges in E-commerce Data Security: A Comparative Study

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ABSTRACT

E-commerce companies are on the frontlines of a rapidly changing data security landscape, where legal and regulatory hurdles are a daily reality. This study takes a close look at how online businesses grapple with the patchwork of rules designed to keep customer data safe, especially as these rules differ sharply depending on where a company operates. For example, strict laws like Europe's General Data Protection Regulation, expect explicit customer consent and clear data policies, while the U.S. and India have built their own frameworks that reflect different priorities about user privacy, data transfers, and enforcement. What often complicates compliance, however, are the frequent clashes between varying data retention schedules, requirements for how companies secure information, and regulations for moving data between countries.

Beyond the legal jargon, retailers and digital marketplaces must also work with sector-specific rules like Payment Card Industry Data Security Standard for payment processing that add extra layers of complexity. As the world gets more connected, companies need practical strategies that strike a balance between staying compliant, protecting their customers, and building trust. A central theme that emerges is the importance of ongoing dialogue between policymakers, tech experts, and businesses, especially as new technology brings fresh risks and opportunities. This research aims to spotlight both the progress and hurdles faced by online businesses and offers a realistic look at why flexibility, clarity, and collaboration matter so much for e-commerce data security.

Keywords: E-commerce, data security, privacy law, cross-border data transfer, regulatory compliance, GDPR, India data protection

INTRODUCTION

The development of e-commerce has transformed global economic activity and consumer behaviour. As more transactions shift online, the importance of securing personal and transactional data has become pressing. With increasing incidents of data breaches and cybercrimes, ensuring the confidentiality, integrity, and availability of consumer data is a paramount concern for businesses, regulators, and users alike.

Legal frameworks designed to protect data in the e-commerce context vary widely, often reflecting different cultural, economic, and political priorities. The European Union's General Data Protection Regulation represents a highly protective stance emphasizing individual rights and regulatory oversight. In the United States, protection tends to be more fragmented, often focusing on sector-specific regulations and state laws such as California's CCPA. China, meanwhile, adopts a model that combines stringent government regulation with emphasis on national security and rapid digital development.

Despite these varied efforts, challenges persist. Businesses operating transnational e-commerce platforms face complex compliance issues due to differing legal requirements and enforcement mechanisms. Consumers may experience inconsistent levels of protection depending on where they reside or shop.

This paper examines the key legal and regulatory challenges in protecting e-commerce data security through a comparative qualitative study of these three jurisdictions. Research questions

address the effectiveness of existing frameworks, their operational challenges, and possible paths forward for international harmonization and consumer protection.

The rapid expansion of e-commerce has transformed global commerce, reshaping how consumers shop and interact with brands across international boundaries. This digital revolution, while propelling economic growth, has also introduced significant challenges regarding the security and privacy of consumer data. With e-commerce platforms collecting and processing vast amounts of personal and financial information, ensuring data security has become an urgent priority for regulators, businesses, and consumers alike. The rise in cyberattacks targeting such sensitive information has amplified the importance of robust legal and regulatory frameworks designed to safeguard user data in the e-commerce ecosystem.

E-commerce platforms function by collecting large quantities of data to personalize shopping experiences, facilitate transactions, and optimize supply chain operations. This data often includes personally identifiable information (PII)—such as names, addresses, payment details, and browsing behaviors which, if compromised or misused, can lead to serious consequences including identity theft, financial fraud, and reputational damage for both businesses and consumers. The management of this data involves multiple stakeholders, from online retailers and payment processors to logistics providers and marketing firms, creating a complex web of data flows and interactions that increase the potential for privacy breaches.

Legal regimes across the world have responded to these challenges with various data protection laws, but significant divergences remain in the scope, enforcement, and effectiveness of these rules. The European Union's General Data Protection Regulation (GDPR) is widely regarded as one of the most comprehensive frameworks, enforcing stringent requirements for consent, transparency, data handling, and breach notification. Its extraterritorial reach holds even non-EU companies to high standards if they target or process data from EU residents. Meanwhile, the United States takes a more fragmented approach, combining federal statutes focused on specific sectors with state-level laws such as the California Consumer Privacy Act (CCPA), which grant consumers certain rights over their data. China, with its swiftly developing digital economy, has introduced the Personal Information Protection Law (PIPL), representing an ambitious framework that balances privacy interests with governmental oversight and national security considerations.

However, these distinct regulatory models create challenges for e-commerce enterprises operating globally. The variation in legal obligations often leads to compliance complexity, creating administrative burdens and increasing the risk of inadvertent violations. Companies must invest significant resources to monitor changing legal landscapes and implement measures that satisfy multiple jurisdictions simultaneously. Moreover, enforcement practices differ widely; regulators in some regions prioritize punitive actions, while others emphasize cooperative compliance programs. For consumers, this patchwork system can result in inconsistent levels of data protection and uncertain ability to exercise their rights.

Cross-border data flows add further complications. Data necessary for fulfilling orders, fraud prevention, or marketing is often transferred between countries with differing legal protections, raising questions about jurisdiction and adequacy. Disputes over data transfer adequacy agreements, contractual clauses, and international enforcement mechanisms underscore the difficulty of balancing global commerce with local privacy rights.

Technological innovations continuously reshape the nature of data collection and use in e-commerce. Advances such as artificial intelligence, machine learning, blockchain, and the Internet of Things enable personalized and efficient service delivery but also introduce vulnerabilities and regulatory ambiguities. These emerging technologies challenge policymakers to craft adaptable legal frameworks capable of governing new forms of data processing without stifling innovation.

In addition to legal and technological factors, consumer awareness and behavior play critical roles. Research indicates that consumers in some regions are more informed about their data privacy rights and skeptical of data practices, influencing their engagement with e-commerce platforms. In contrast, users in other regions may lack sufficient understanding or access to redress mechanisms, limiting the practical impact of regulatory protections.

Given these complexities, a rigorous comparative analysis of the legal and regulatory landscape confronting e-commerce data security is essential. This study focuses on three major jurisdictions—the European Union, the United States, and China—selected due to their economic significance, regulatory leadership, and contrasting approaches to data protection. The research seeks to identify common challenges, assess the effectiveness of existing frameworks, and explore opportunities for harmonization and improved consumer protection.

The research questions guiding this study are:
1. What are the primary legal and regulatory challenges faced in securing e-commerce data within the European Union, the United States, and China?
2. How do the substantive provisions and enforcement mechanisms of key regulations differ across these jurisdictions?
3. What regulatory gaps hinder effective protection, especially concerning cross-border data flows and technological developments?
4. How can policymakers and industry stakeholders address these challenges to create more coherent and protective data security regimes?

Addressing these questions is timely, as e-commerce continues to expand and integrate into daily life across the globe. The findings aim to support regulatory bodies, e-commerce businesses, and consumer advocates in navigating the complex data security landscape. Practical policy recommendations will be offered to promote cooperation, compliance, and technological innovation compatible with high privacy standards.

This research adopts qualitative methods, analyzing legal texts, regulatory policies, and expert opinions to provide a nuanced and contextualized understanding of the challenges. The study complements existing quantitative research by giving voice to regulatory practitioners and industry professionals, whose experiences illuminate the operational realities behind statutory texts and enforcement notices.

LITERATURE REVIEW

The literature on e-commerce data protection highlights a dynamic yet fragmented regulatory landscape. The GDPR is widely studied for its comprehensive scope, extraterritorial application, and strict principles governing consent and data minimization (Kuner, 2022). This regulation serves both as a standard bearer and a challenge for global operators seeking compliance.

Studies of U.S. legal approaches show a patchwork system, with federal laws like the Health Insurance Portability and Accountability Act (HIPAA) coexisting with state laws that reflect varying levels of consumer protection (Schwartz & Solove, 2019). The enactment of the CCPA marks a significant development but does not resolve inconsistencies nationwide.

Chinese regulations, including the Personal Information Protection Law (PIPL), mirror many provisions of the GDPR but are situated within a political context emphasizing government control and national security (Chen, 2023).

Cross-border data flow issues emerge prominently in the literature as a critical barrier to harmonizing e-commerce data security. Legal scholars note the difficulty in reconciling differing privacy philosophies and enforcement standards, resulting in regulatory uncertainty (Graham & Goldsmith, 2024).

Prior qualitative research points to challenges in enforcement consistency, consumer awareness, and technological change outpacing regulation. However, comparative qualitative analyses remain limited, especially regarding practitioner and regulator perspectives across the EU, U.S., and China.
Below is a detailed, approximately 1000-word draft literature review on e-commerce data protection regulations focusing on the European Union, United States, and China, integrating comparative insights and referencing key academic themes in the area.

The regulation of e-commerce data protection exists within a complex and evolving legal landscape, characterized by divergence in laws, enforcement mechanisms, and underlying philosophies across jurisdictions. This section critically examines major regulatory frameworks in the European Union (EU), United States (US), and China that govern the security and privacy of consumer data collected and processed in e-commerce contexts. It also explores key challenges posed by cross-border data flows, technological change, and inconsistencies in enforcement.

The European Union's General Data Protection Regulation
The GDPR, implemented in May 2018, represents a landmark in data privacy regulation with its comprehensive and unifying approach across all member states (Kuner, 2022). Establishing a single legal framework for protecting personal data, the GDPR enshrines core principles such as lawfulness, fairness, transparency, purpose limitation, data minimization, and accountability. Its scope extends beyond the EU's geographic borders through extraterritorial provisions, meaning that even companies outside the EU must comply when processing data of EU residents.

Key rights granted to individuals under the GDPR include the right to access their data, rectify inaccuracies, erase data ("right to be forgotten"), restrict processing, and data portability. The regulation also mandates strict conditions for lawful data processing, explicit consent requirements, and imposes obligations on data controllers and processors to implement "privacy by design and by default." Data breaches must be reported to authorities within 72 hours, with heavy administrative fines—up to 4% of global turnover for serious violations—enforced as deterrents.

The GDPR's unified regime has provided clarity and strengthened consumer protection but also presented compliance challenges for multinational e-commerce businesses. Companies must invest heavily in revising data handling practices, updating consent mechanisms, and appointing data protection officers. While academics praise GDPR as a "gold standard" in privacy, it also serves as a benchmark against which other jurisdictions' frameworks are frequently compared.

Unlike the EU's holistic approach, the US lacks a single federal law regulating personal data privacy comprehensively. Instead, it relies on a sectoral regulatory system where individual laws address specific types of data or industries. Notable statutes include the Health Insurance Portability and Accountability Act (HIPAA) for health data, the Gramm-Leach-Bliley Act for financial data, and the Children's Online Privacy Protection Act (COPPA) for children's information.

At the state level, laws vary significantly, although California's Consumer Privacy Act (CCPA), effective from 2020 and enhanced by the California Privacy Rights Act (CPRA) in 2023, provides a relatively strong consumer protection model within the US. The CCPA grants consumers rights to know what personal data is collected, to access it, request deletion, and opt out of its sale. However, it applies only to businesses meeting certain thresholds and to California residents, leaving inconsistent protections for people in other states.

Researchers note that this fragmented regime leads to regulatory complexity for e-commerce firms, which must navigate different state laws alongside federal statutes and sector guidelines (Schwartz & Solove, 2019). The absence of a comprehensive data protection authority contrasts with the EU's formal supervisory bodies, and enforcement often occurs via litigation or Federal Trade

Commission actions rather than proactive regulation. Though the US market values innovation and business freedom, critics argue that consumer privacy remains inadequately protected at a national level.

China's PIPL, effective from November 2021, marked the country's first comprehensive legal framework governing personal data protection, drawing extensively on elements of the GDPR's model while embedding them within China's particular political and social context (Chen, 2023). The PIPL emphasizes state sovereignty and national security, resulting in a centralized approach to enforcement conducted by the Cyberspace Administration of China (CAC).

The law sets out principles including legality, legitimacy, necessity, and good faith in data processing. It mandates obtaining consent, limiting data collection to stated purposes, and protecting sensitive personal information rigorously. Cross-border data transfer is tightly controlled, requiring security assessments and adherence to strict contractual and organizational safeguards. Violations can incur fines up to 5% of annual revenue or 50 million RMB, alongside possible suspension or shutdown of operations.

A key divergence from Western models is the PIPL's prioritization of government oversight. Unlike the GDPR's focus on empowering individual rights, the Chinese regime integrates data privacy with broader state interests, reflecting governance under an authoritarian framework. This alignment creates specific compliance challenges for multinational e-commerce companies operating in China who must reconcile different legislative obligations.

CROSS-BORDER DATA TRANSFER CHALLENGES

As e-commerce fundamentally relies on digital platforms transcending national borders, a dominant theme in the literature revolves around cross-border data flows and their associated legal complexity. Both GDPR and PIPL impose stringent rules on transferring personal data to third countries, contingent on the receiving jurisdiction's data protection adequacy or specific contractual guarantees.

Scholars highlight that these restrictions complicate the operations of international e-commerce platforms, potentially fragmenting global digital markets (Graham & Goldsmith, 2024). The invalidation of the EU-US Privacy Shield framework by the Court of Justice of the European Union in 2020 further exacerbated uncertainties. Companies now rely on mechanisms such as Standard Contractual Clauses while navigating ongoing judicial and regulatory scrutiny.

China's PIPL also enforces data localization rules alongside export controls, with exemptions recently clarified for non-critical and certain e-commerce data. However, compliance costs and operational constraints remain significant.

The difficulty lies in harmonizing protections without creating "data sovereignty" barriers that undermine openness and innovation. Continued legal divergence risks disincentivizing international trade and frustrates consumer protection goals.

Enforcement and Consumer Awareness Issues

Empirical studies and qualitative research indicate that enforcement practices vary widely. The EU's Data Protection Authorities are proactive and well-resourced, capable of large-scale investigations and imposing record fines. The US system's decentralized approach yields variable enforcement depending on litigation trends and agency priorities, often leading to inconsistent deterrence. In China, enforcement is assertive but less transparent, with regulatory decisions influenced by strategic state objectives.

Consumer awareness about data rights and protections emerges as a mixed picture. European consumers generally benefit from significant public information efforts and formal complaint mechanisms. Conversely, in the US and China, awareness tends to be localized and limited, reducing the effective exercise of consumer protections.

Technological Change Outpacing Regulation

Lastly, a key challenge found in all jurisdictions is the rapid pace of technological innovation outstripping legislative updates. The proliferation of artificial intelligence, data analytics, Internet of Things (IoT), and blockchain technologies introduces new data processing modalities, complicating compliance with existing laws crafted for earlier digital realities (Weber, 2020). Policymakers struggle to craft flexible frameworks that can adapt to these developments without stifling beneficial innovation.

Gaps in Comparative Qualitative Research

Despite the importance of these topics, the literature reveals a comparative qualitative research gap examining how regulatory frameworks operate across jurisdictions from the perspective of practitioners and regulators. Most research has focused on doctrinal analyses or policy proposals, with less attention to real-world compliance challenges or enforcement dynamics in multinational e-commerce contexts.

This study seeks to fill this gap by exploring these dimensions in detail, thereby contributing to scholarly understanding and policymaker insight.

METHODOLOGY

This study employs a qualitative comparative design involving detailed documentary analysis combined with semi-structured interviews. Legal statutes, regulatory guidelines, enforcement records, and academic literature were systematically reviewed. Key documents included the GDPR, CCPA, and PIPL along with associated commentaries and rulings.

Interviews were conducted with twelve experts, including data privacy lawyers, compliance officers working with e-commerce platforms, and regulators involved in policy implementation across the studied jurisdictions. Participants were selected using purposive sampling to ensure representation of diverse professional viewpoints.

Data were analyzed thematically. Transcripts were coded iteratively to identify recurring patterns and jurisdiction-specific challenges. Analytical rigor was maintained through triangulation—cross-verifying data from different sources—and reflexivity was exercised to account for researcher bias.

Ethical protocols were observed strictly. Informed consent was obtained, confidentiality assured, and all data anonymized.

FINDINGS

Compliance Fragmentation

The divergence of regulatory regimes has created a landscape of compliance fragmentation.
In the EU, the GDPR mandates proactive accountability, including the appointment of data protection officers for certain firms, mandatory data protection impact assessments, and detailed consent management systems. While these mechanisms have significantly enhanced rights protection, they impose disproportionate burdens on small and medium-sized enterprises (SMEs). This issue is frequently noted as a barrier to entry in e-commerce markets, as compliance costs divert resources from innovation and growth.

By contrast, the US adopts a sectoral and state-driven model. Federal statutes such as the Health Insurance Portability and Accountability Act (HIPAA) and the Gramm-Leach-Bliley Act (GLBA) provide strict provisions for healthcare and financial sectors respectively, while the California Consumer Privacy Act (CCPA) and subsequent California Privacy Rights Act (CPRA) extend more general protections. The absence of a unified federal law produces a patchwork in which compliance requirements vary substantially between jurisdictions. This inconsistency complicates operations for firms engaged in nationwide commerce, creating barriers similar in severity to those faced under the EU's system, though for different reasons.

China's PIPL sets out extensive obligations covering consent, sensitive data handling, and localisation requirements. However, its application is complicated by opacity in state enforcement practices. Businesses frequently report uncertainty regarding how regulators interpret or apply these provisions. In environments where political considerations guide enforcement priorities, foreign firms may adopt a risk-averse stance, limiting their scope of operations.

Thus, across all three jurisdictions, the fragmentation of compliance generates substantial operational inefficiencies. For global e-commerce companies, the necessity to reconcile conflicting frameworks undermines legal certainty and increases costs, ultimately limiting consumer choice and market dynamism.

Enforcement Variation

Equally significant are the disparities in enforcement across jurisdictions.

The EU has developed highly active supervisory authorities, such as the Irish Data Protection Commission and the French Commission Nationale de l'Informatique et des Libertés (CNIL), which wield broad investigative and punitive powers. The imposition of record fines against multinational corporations demonstrates both the seriousness and credibility of enforcement. The availability of judicial review and complaint procedures ensures that enforcement decisions are subject to rule-of-law guarantees.

Conversely, the US relies more heavily on litigation, private actions, and settlements to achieve accountability. While high-profile cases occasionally generate meaningful change, systemic enforcement is less assured. The Federal Trade Commission (FTC) plays a key role but lacks the capacity and statutory powers to mirror the broad oversight of its European counterparts.

In China, enforcement is driven primarily by state-led investigations, often linked to national security and public order considerations. Judicial transparency is comparatively limited, and the application of sanctions may appear inconsistent to outside observers. This combination of strict formal rules with discretionary enforcement produces heightened uncertainty for businesses.

The variation in enforcement models underscores the deeper divergence in regulatory philosophies: The EU privileges individual rights, the US emphasises a litigation-based consumer protection ethos, and China prioritises state sovereignty and societal stability.

Data Transfer Restrictions

Cross-border data flows highlight the clash between global commerce and territorially bound regulation.

Under the GDPR, transfers outside the EU are conditioned on adequacy decisions or legal mechanisms such as Standard Contractual Clauses (SCCs). The Court of Justice of the EU's invalidation of the Privacy Shield agreement between the EU and the US in 2020 (Schrems II) destabilised transatlantic transfers, leaving companies uncertain about legality and exposing them to potential liability.

The US itself maintains few restrictions on outbound transfers, yet American businesses remain bound by EU constraints if they wish to process European data. This extraterritorial reach of the GDPR has effectively made European standards global benchmarks for multinational e-commerce companies.

China adopts one of the most restrictive regimes. Data localisation requirements, coupled with the requirement for government approval before cross-border transfers, slow operations and impose high compliance costs. For many firms, these barriers discourage or delay market entry, thereby reshaping global patterns of digital trade.

Together, these restrictions reveal that far from enabling digital globalisation, data laws are increasingly serving as instruments of sovereignty, creating legal borders in an otherwise borderless market.

Consumer Awareness and Empowerment

The success of data protection frameworks depends not only on laws but on the ability of consumers to exercise their rights. Here, jurisdictions diverge sharply.

In the EU, public awareness of rights has increased substantially since the GDPR's introduction. Outreach campaigns, NGO activities, and visible enforcement have empowered individuals to exercise rights such as access, erasure, and portability. Consumer organisations play an active monitoring role, creating a broader culture of data accountability.

In the US, awareness remains limited. The complexity and variation of rights across states deter consistent consumer engagement. More crucially, the prevalence of opt-out rather than opt-in frameworks leaves consumers disadvantaged, as many lack the time or expertise to scrutinise privacy notices.

China formally grants individuals rights under the PIPL; however, awareness and willingness to act upon these rights are limited. Cultural and political contexts also shape public interaction with legal remedies, reducing the role of the individual in enforcement compared with collective state authority.

Without enhanced consumer education, even robust legislative frameworks risk underperforming in practice. This suggests that awareness must be treated not as a by-product of regulation but as a core aspect of regulatory strategy.

Adaptation Challenges in Emerging Technologies

A final challenge is the pace of technological change. Data-driven innovations such as artificial intelligence (AI), blockchain, and decentralised ledger technologies consistently test the boundaries of existing frameworks.

AI systems are capable of generating sensitive inferences from seemingly anonymous data, undermining reliance on traditional concepts of consent. Blockchain technologies pose particular difficulties for the GDPR's "right to be forgotten," given their immutability. In many cases, technical impossibility confronts legal impossibility, leaving regulators and businesses in uncertainty.

The EU has begun addressing these issues through its proposed Artificial Intelligence Act, but gaps remain. The US, absent a comprehensive privacy law, oscillates between self-regulation and sectoral initiatives. China continues to regulate emerging technologies through its broader cybersecurity oversight framework, linking technological risks to questions of national security.

These difficulties highlight the need for regulatory flexibility. Rigid statutes are ill-suited to technologies that evolve faster than legislative cycles. Iterative regulatory models, experimental sandboxes, and adaptive sectoral guidelines may provide more effective solutions.

Balancing Protection and Competition

Beneath these themes lies an enduring dilemma: the tension between protecting data and fostering digital competitiveness. The EU's rights-centric approach provides strong individual protections but raises the burden of compliance and may deter start-ups. The US's market-oriented model fosters innovation but leaves consumers exposed to gaps. China's state-centric approach consolidates control but risks undermining foreign investment and trust.

None of these models achieves an ideal balance. For global e-commerce operators, the resulting asymmetry itself becomes a competitive factor influencing market entry, investment strategies, and consumer trust.

Obstacles to Global Harmonization

Efforts to harmonize global data protection face significant headwinds. Sovereignty, cultural values, and distinct legal traditions shape state approaches, making treaty-based convergence challenging. The EU elevates privacy as a fundamental right; the US approaches data as a consumer and contractual interest; China integrates data into national security. These philosophies are difficult to reconcile.

Nevertheless, incremental pathways remain. Regional schemes such as the Asia-Pacific Economic Cooperation (APEC) Cross-Border Privacy Rules demonstrate partial progress. Model frameworks promoted by organizations such as UNCITRAL and OECD can foster convergence. Importantly, regulatory authorities can align enforcement priorities and share institutional best practices even absent formal treaties.

The Critical Role of Consumer Education

One of the most overlooked aspects across all jurisdictions is the role of consumer education. Without informed consumers, even the strongest frameworks cannot achieve their protections. Public literacy campaigns, integration of data rights into educational curricula, and active collaboration with NGOs could empower individuals to assert rights consistently across contexts.

CONCLUSION

The comparative analysis of data protection frameworks in the European Union, the United States, and China underscores the formidable structural challenges that continue to shape the regulation of e-commerce in the twenty-first century. As digital markets expand, the regulation of personal data has become one of the defining issues of global governance, raising urgent questions of how innovation, competition, and privacy should be held in balance. While significant steps have been taken in all three jurisdictions to advance data protection law, the divergent approaches adopted highlight an environment characterised by uncertainty, complexity, and fragmentation.

At its core, the challenge lies in reconciling the competing demands of data security and market growth. The GDPR epitomises the European commitment to treating privacy as a fundamental right. It creates detailed compliance obligations that significantly alter the organisational practices of businesses within and beyond the EU. The US, by contrast, has long prioritised economic dynamism and technological innovation, resulting in a patchwork framework that emphasises sectoral regulation and relies heavily on litigation for redress. In China, the PIPL represents a firm assertion of state authority over data flows, embedding privacy protections within a broader framework of sovereignty and security. These models reflect not only different legal traditions but different cultural and political philosophies about the role of the state, the rights of individuals, and the value of data in society.

This divergence has produced what may be described as a condition of compliance fragmentation, where multinational e-commerce firms must navigate multiple, often contradictory standards. Compliance costs, legal uncertainty, and operational inefficiencies burden both large and small firms, creating barriers to entry and ultimately limiting consumer choice. Fragmentation is not only an abstract governance challenge: its effects are tangible, affecting how quickly companies can expand into new markets, whether smaller firms can afford compliance, and whether consumers receive consistent levels of protection globally.

The variation in enforcement mechanisms compounds these issues. European supervisory authorities have demonstrated a strong commitment to active oversight, using their powers to impose meaningful sanctions and to shape organisational culture. In the United States, reliance on litigation and settlements produces a more inconsistent model, where major breaches sometimes

result in significant penalties but routine oversight is lacking. By contrast, China enforces its rules primarily through opaque state-led processes, which often intertwine compliance with political and strategic considerations. These enforcement differences illustrate the depth of divergence, extending beyond the letter of the law to the institutional logic underpinning regulation.

A further layer of challenge is posed by **cross-border data transfer restrictions**. While e-commerce is inherently transnational, the laws governing data are rooted in national sovereignty. The EU's adequacy framework is rigorous, requiring either formal determinations or complex contractual agreements such as Standard Contractual Clauses. The US, with comparatively light outbound restrictions, nevertheless finds its firms constrained by EU rules in practice. China's localisation mandates and approval procedures make it one of the most restrictive jurisdictions, positioning data mobility as a matter of state interest. Together, these approaches highlight an emerging paradox: the global digital economy thrives on interconnectedness, yet national policies increasingly erect borders in cyberspace.

Critically, the practical success of any data protection regime depends not only on institutional enforcement but also on consumer awareness and empowerment. Law in isolation cannot safeguard data rights unless individuals are aware of their protections and capable of exercising them. Here, the study revealed stark differences. European consumers, assisted by active outreach and accessible remedies, are more likely to understand and assert their rights. In the US, knowledge gaps remain widespread, compounded by the complexity of overlapping state frameworks and the prevalence of opt-out mechanisms. In China, although formal rights exist, social and political environments may inhibit individuals from pursuing claims or challenging practices. Without informed and empowered consumers, even the most robust legislative designs risk losing efficacy.

The rapid evolution of emerging technologies further complicates the landscape. Artificial intelligence blurs the boundaries of identifiability by extracting sensitive insights from anonymised data, undermining long-standing tools of privacy protection. Blockchain and other decentralised systems highlight the incompatibility of immutable technological design with legal obligations such as erasure. In this respect, all three jurisdictions face parallel difficulties, although their responses differ. The EU is attempting to integrate regulation of AI through complementary legal instruments, while the US oscillates between fragmented sectoral laws and industry self-regulation. China, meanwhile, subsumes technological governance under its integrated cybersecurity framework, in which privacy remains interconnected with broader objectives of public order and state security.

Taken collectively, these findings highlight the central tension between principles and pragmatism. The protection of personal data has emerged as both a moral imperative and a competitive necessity: consumers demand it, yet firms must bear the administrative and financial shortfalls of providing it. Regulatory fragmentation intensifies this tension by ensuring that no jurisdiction offers a perfect model. Each of the three regimes examined here reveals both strengths and weaknesses, suggesting that lessons can be shared, but wholesale harmonisation remains elusive.

The most important insight is that global harmonization remains politically and legally difficult. Divergent constitutional traditions, cultural values, and strategic priorities mean that a single universal framework is unlikely in the near future. At the same time, there is substantial scope for incremental alignment. Sectoral agreements under multilateral organisations, model frameworks propagated by bodies such as UNCITRAL or the OECD, and practical cooperation between national regulators can all contribute to narrowing the gaps. Shared enforcement priorities, the exchange of best practices, and coordinated approaches to major firms could yield meaningful harmonisation at the procedural, if not the doctrinal, level.

Yet perhaps the most transformative outcome could be achieved not by regulators alone but by consumers. As this study emphasises, enhancing consumer education and digital literacy is

essential. Legal protections cannot fulfil their objectives if end-users are unaware of their rights or feel disempowered to enforce them. The promotion of digital literacy campaigns, consumer advocacy mechanisms, and transparent complaint procedures can transform privacy rights from abstract promises into real protections. An empowered consumer population can act as both a counterweight and a partner to regulatory efforts, ensuring accountability from businesses and sustaining pressure for reform.

Looking ahead, the future of e-commerce rests fundamentally upon trust**. Data protection is not merely a technical or legal requirement; it is central to building consumer confidence in the fairness and safety of digital markets. Without such trust, the willingness of consumers to engage in cross-border online commerce will falter, undermining the very foundations of the digital economy. The path forward, therefore, requires a rights-respecting, adaptive, and internationally coordinated regulatory order, coupled with meaningful consumer empowerment.

This study demonstrates that despite notable advances in legislation, **significant disparities in approach and enforcement persist** among leading jurisdictions. International cooperation, adaptable regulation, and consumer education must be seen not as complementary, but as essential pillars of future reform. Continued research is vital, particularly into the implications of emerging technologies and long-term assessments of regulatory effectiveness from the consumer perspective. Only through such efforts can global e-commerce be supported on a foundation of both innovation and protection, ensuring that the benefits of digital commerce are matched by robust safeguards for the individuals whose data sustains it.

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Sustainable HRM: Relevance of People Profit and Planet in Present Scenario

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ABSTRACT

The contemporary business environment is marked by increasing demands for organizations to align economic performance with social and environmental responsibilities. Within this context, Sustainable Human Resource Management (SHRM) has gained prominence as a critical framework that integrates the principles of sustainability into the management of human capital. By embedding the Triple Bottom Line (TBL) dimensions of people, profit, and planet, SHRM redefines organizational success beyond short-term financial outcomes. This study aims to explore the relevance of SHRM in the present scenario by employing Structural Equation Modeling (SEM) to assess the interrelationships among social, economic, and environmental aspects of HRM practices. Data collected from organizational employees and managers will be analysed to validate the conceptual model that links SHRM practices with sustainable organizational outcomes. The findings are expected to highlight how organizations that prioritize employee well-being, profitability, and ecological responsibility create resilient work cultures capable of addressing contemporary challenges such as globalization, climate change, and workforce diversity. The study contributes both theoretically and practically by providing empirical support for the integration of sustainability within HRM and offering guidelines for managers seeking to balance growth with responsibility.

Keywords: Sustainable HRM, Structural Equation Modeling, Triple Bottom Line, People, Profit, Planet, Organizational Sustainability, Employee Well-being

INTRODUCTION

Sustainability has become one of the twenty-first-century concerns. Governments, stakeholders and the general society are increasingly putting pressure on organizations in every industry to stop having a very limited approach to profit maximization and instead to become more socially responsible by implementing strategies that not only conserve the environment, but they also improve social wellbeing. At that, the concept of the Triple Bottom Line (TBL) people, profit, and planet has been accepted as one of the key elements of sustainable business (Elkington, 1997). Human Resource Management (HRM) is one of the many functions in an organization that has a central role to play in the embedding these principles as it directly influences the behaviour of employees, organizational culture, and long-term strategic orientation.

Sustainable HRM (SHRM) is a new and rapidly emerging area of management study. In contrast to the traditional HRM which focuses on efficiency and performance delivery, SHRM is holistic in design incorporating all the financial objectives with ethical labour policies and environmental conservation (Ehnert, 2009). As an example, green recruitment, employee well-being, and environmental awareness training, practices that improve the reputation of organizations, also have a beneficial effect on the employee engagement and commitment. The practices are not a choice in the contemporary world where global inequality, climate change, and changing labour markets are the two primary subjects of conversation and organisational practices have become a necessity to stay in business.

Applicability in the Current Situation

The current situation in the world shows that the implementation of sustainable practices is a burning issue. The COVID-19 outbreak revealed the fragility of the organizations that were preoccupied with their profit-only narrow-mindedness without adequate concern regarding employee health and sustainability. Likewise, the crisis of climate has compelled the companies to rethink their ecological footprint and implement the policies which result in lower energy, waste, and emissions. The organizational environment is also complicated by workforce diversity and globalization, and it needs HR systems that can promote inclusivity, respect human rights, and provide a sense of fairness. SHRM in this environment acts as a guide to overcome such issues by aligning the people and profit and planet aspects into logical organizational practices.

As an example, multinational corporations are turning more and more into the subject of sustainability report, with HR-related indicators, including employee turnover, gender equity, safety at the workplace, and access to training, being considered together with financial and environmental data. Small and medium-sized businesses (SMEs) are not an exception, as they are forced to implement SHRM practices in order to stay competitive and socially responsible. Consequently, the research on SHRM in the given context does not only have academic but practical implications too.

Research Gap and Objectives

Although a number of studies have been done to understand the effectiveness of HRM on the performance of an organization, comparatively few have been carried out empirically to understand the role of SHRM in attaining the sustainability results using a comprehensive model. The available literature is largely theoretical or descriptive as it has not been based on strong statistical confirmations of the interconnection between TBL dimensions and HRM practices. In addition, emerging economies have little evidence to provide, and the conflict between growth and sustainability is particularly high in this case.

This study will aim to fill these gaps through the Structural Equation Modeling (SEM), which is an effective multivariate approach, which allows the researcher to test multifaceted cause-and-effect relationships among latent constructs. The major aims of the study are:

1. To develop a concept of SHRM as an integrative model, which includes people, profit, and planet.
2. To formulate and test a measurement model of SHRM practices with the help of SEM.
3. To investigate the structural relations between SHRM practices and sustainable organizational results.
4. To advise managers and policy makers on how to incorporate sustainability in HRM.

Significance of Using SEM

SEM is the most appropriate method to use in this research paper since it enables the analysis of both direct and indirect relationships of variables, both of which are necessary in considering the complex relationship between people-oriented HR practices, financial performance, and environmental results. The classical regressions are constrained in the manner that they can extend to these multidimensional relationships. In comparison, SEM allows performing measurement validity (via Confirmatory Factor Analysis) and structural hypotheses testing in parallel and thus provides a more comprehensive evaluation.

As an example, employee satisfaction (people dimension) can be directly related to SHRM practices like training, work-life balance programs as well as green HR policies which subsequently impacts on organizational profitability (profit dimension). Simultaneously, the practices can indirectly influence the ecological performance (planet dimension) as well by defining the behaviour of employees related to the sustainable consumption and resource use. To capture such pathways we need an analysis tool such as SEM that will support multiple dependent relationships within a particular model.

Structure of the Paper

The paper is divided into a number of sections. After the introduction, the literature review talks about theoretical foundations of SHRM and the TBL framework, as well as the past empirical research. Section on methodology describes the research design and the sampling strategy and usage of SEM as the method of analysis. The results and data analysis section provides a presentation of the data of the measurement and structural models with special emphasis on the model fit indices and the results of the hypothesis-testing. The discussion puts the findings in perspective to current research and practical application and the conclusion is to give the summation of the contributions and implications and future research directions.

With SHRM being branded a mediator that can be used to offer a transition between conventional HR practices and sustainable development objectives, this research study is relevant to the continuing discussions on how organizations can gain competitiveness and respond to the pressing social and environmental issues.

LITERATURE REVIEW:

1. Theoretical Background

Human Resource Management (HRM) has always been based on organizational performance and efficiency theories. Nevertheless, the increased focus on sustainability demands the introduction of more theoretical approaches. Some of the best applicable ones include the Resource-based View (RBV), the Stakeholder Theory, and the Institutional Theory.

According to the Resource-Based View, organizations obtain competitive advantage as a result of developing valuable, rare, and inimitable resources (Barney, 1991). One of the most important ones in this respect is the human capital (Employees). Sustainable HRM (SHRM) builds on the RBV by focusing on the strategic importance of employees, but it also has a duty to take care of the employees in a manner that acknowledges their well-being and able them to be able to sustain over time.

SHRM can also be viewed through the prism of the Stakeholder Theory (Freeman, 1984). The organizations have a responsibility not only to the shareholders but also to employees, local communities, and environment. HRM practices, in turn, should strike the balance between the interests of various parties such as internal (employees, managers) and external (customers, society, regulators) ones.

Lastly, the Institutional Theory focuses on how norms, regulations, and cultural expectations affect the behaviour of an organization (DiMaggio and Powell, 1983). The trend towards sustainability all over the world, supported by models including the United Nations Sustainable Development Goals (SDGs), institutional pressures organizations to embrace SHRM practices. All these theoretical views justify the inclusion of sustainability perspectives of HRM.

2. Concept of Sustainable HRM

Sustainable HRM is a term that is used to describe how HRM policies and practices can be modified to foster long-term employee growth, organizational prosperity and the welfare of the society (Ehnert, 2009). SHRM focuses on human development in the long term, equality and environmental friendliness unlike traditional HRM, which is criticized as short-term and instrumental approach to employees.

Major dimensions of SHRM are:

1. **Employee Well-being:** Health, safety, work-life balance and growth.
2. **Ethical Practices:** Advancing fairness, inclusion, diversity and respect to labour rights.
3. **Environmental Responsibility**: Green HR practices like eco-friendly recruitment, training sustainability and energy efficient workplace.

4. **Long-term Orientation**: Diving on employee retention and knowledge management as well as intergenerational equity instead of immediate performance measurement**.** Studies indicate that, in many organizations where SHRM is implemented, employee engagement tends to improve, turnover rates decrease, the organization gains a positive reputation, and it becomes more sustainable (Kramar, 2014). Nevertheless, actual application of SHRM differs in different industries and cultural backgrounds where it is necessary that the effectiveness of SHRM is validated by the empirical studies.

3. Triple Bottom Line (TBL) Framework

Triple Bottom Line (TBL) system as developed by Elkington (1997) redefines the organizational achievement by incorporating social (people) and environmental (planet) outcomes along with the financial performance (profit). The TBL is an elaborate framework of measuring sustainability and has gained massive uptake across management research and practice.

- **People Dimension:** Relates to the social accountability of organizations to the employees and the societies. In SHRM, this consists of fair remunerations, staff involvement, workplace diversity, and well-being in general.
- **Profit Dimension**: Although financial viability is a necessity, SHRM focuses on responsible profit-making that does not exploit the employees and does not harm society. Innovation, ethical practices and long-term investments in human capital are a way of obtaining sustainable profitability.
- **Planet Dimension:** We are ecologically responsible, i.e. minimize carbon footprints, protect resources, and green. HRM can achieve this by instilling environmental values in organizational culture in the process of recruitment, training and performance appraisals.

  The TBL model is particularly applicable in the current situation where organizations are being called upon to provide not just with economic value but also social and environmental ones.

4. SHRM and Sustainability Empirical Studies

A number of empirical studies can give us an insight on how SHRM will help to further the objectives of sustainability. Indicatively, Renwick, Redman and Maguire (2013) brought to attention the relevance of Green HRM in instilling environmental values at the HR practices. They claimed that recruiting, training and appraisal systems based on sustainability have the potential to come up with great impact on employee attitude and behavior.

Kramar (2014) performed the literature review on SHRM and came to the conclusion that the implementation of sustainable HR practices in organizations leads to the positive work climate that promotes the improvement of both individual and organizational performance. Likewise, Guerci, Longoni, and Luzzini (2016) noted that sustainability-oriented Hr practices have a positive connection with employee motivation and organizational performance.

The institutional pressures and the necessity to act as a global competitor usually lead to SHRM adoption in emerging economies. Indicatively, Jabbour and Santos (2008) discovered that Brazilian firms that incorporated the concept of green HR were more capable of aligning themselves with the global sustainability standards. It is also noted that SHRM can help in employee retention and employer branding in other industries like IT and manufacturing (e.g., Sharma and Gupta, 2020).

However, in spite of these findings, there is unsatisfactory comprehensive models that empirically prove the relationship of the SHRM practices and TBL outcomes. Most of the studies concentrate on a single aspect (such as environmental sustainability), and it has not explored how people, profit and planet can be integrated to a large extent.

5. Conceptual Model and Hypotheses Development

This paper is based on the literature; it describes a conceptual model connecting SHRM practices and the TBL aspects of sustainability. The model presupposes that the practices of SHRM can affect the well-being of employees, which, in turn, has an impact on financial and environmental performance. To test the model, Structural Equation Modeling (SEM) would be used.

Hypothesis Development:

- **People Dimension**
  - H1: Sustainable HRM practices have a positive effect on the well-being of employees.
  - H2: Organizational commitment and organizational performance have a positive relationship with employee well-being.

- **Profit Dimension**
  - H3: Sustainable HRM practices have a positive effect on financial performance.
  - H4: There is a mediation between SHRM practices and financial performance by employee well-being.

- **Planet Dimension**
  - H5: Green practices in HRM have a positive effect on the environmental responsibility of organizations.
  - H6: The awareness of sustainability by employees mediates the correlation between SHRM practices and ecological outcomes.

Through the hypotheses, the research aims to offer empirical support of the combined role of SHRM in facilitating sustainable organizational performance.

6. SUMMARY OF LITERATURE REVIEW

The review highlights that while the theoretical foundation for SHRM is strong, empirical studies remain fragmented. The integration of the **TBL framework** with **SHRM practices** provides a promising avenue for research, especially when tested through robust analytical methods such as SEM. By addressing this gap, the present study contributes to the advancement of both theory and practice in sustainable management.

Research Methodology

I. Research Design

The research design to be used in this study is quantitative, cross-sectional research to investigate the correlation between Sustainable Human Resource Management (SHRM) practices and organizational sustainability outcomes as the conceptualized Triple Bottom Line (TBL) framework people, profit, and planet. A quantitative design is suitable since the aim of the study is to test the hypotheses and prove a conceptual model with the help of Structural Equation Modeling (SEM), which presupposes the use of numeric data gathered in a fairly large sample.

It is an explanatory research because it aims at not only discovering the immediate impacts of SHRM practices on sustainability changes but also the mediating role of employee well-being and awareness. Through a pool of these attributes, the design gives a holistic insight into how organizations have incorporated sustainability when adopting HRM practices.

II. Population and Sampling

The research will focus on the organisations that are already undertaking sustainability activities, including those with published sustainability reports, corporate Social responsibility (CSR) policies, or those with ISO 14001 certification. This is to facilitate diversity in that both the public and the private sector organizations are incorporated.

The population is made up of employees and managers of mid- to large-sized organizations in industries like information technology, manufacturing and services and where sustainability issues are most evident. Since SEM is not an easy task, the sample size of 300-500 respondents will suffice, as it is a rule of thumb that a minimum of 10 responses is required per estimated parameter (Hair, Black, Babin, and Anderson, 2010).

Sampling method: A purposive sampling method will be used because the study has a specific need of respondents who are in organizations that have implemented sustainability based HRM practices. In organizations, stratified sampling is used to cover managerial and non-managerial personnel within the organizations in order to have a representation of various views.

III. **Data Collection**

The data will be gathered with the help of a structured questionnaire that will be conducted online and on-site. Internet distribution is useful to cover a broader geographic region whereas personal distribution is useful in improving the response rates within the sampled organizations. The questionnaire is pre-tested before it is rolled out with the help of 20 respondents in order to promote clarity, reliability, and content validity. The pilot study will be used to revise items.

The respondents will be given anonymity and confidentiality, and their participation will be voluntary. All the participants are informed, and the data collection is preceded by ethical approval by the relevant institutional review board.

IV. **Measures and Instrumentation**

The questionnaire is based on a number of sections, which are related to the latent constructs of the study. Everything is rated on the five-point Likert scale (1 = strongly disagree to 5 = strongly agree). Constructs and measures of the sample are:

- Sustainable HRM Practices: The question based on the works of Kramar (2014) and Guerci et al. (2016), the questions about green recruitment, training and employee well-being programs, ethical HR policies.
    - Sample question: "The example organization offers training which increases awareness of sustainability."
- **Employee Well-being:** Items are based on prevailing scale on workplace well-being (Warr, 2007).
    - Example item: "My organization provides a healthy balance between work and personal life."
- Organizational Commitment/ Performance (Profit Dimension): based on Meyer and Allen (1991) and Delaney and Huselid (1996).
    - Trial item: In the long term, our HR policies boost productivity and profit.
- Environmental Responsibility (Planet Dimension): Items modified by Jabbour and Santos (2008) and Renwick et al. (2013).
    - Example item: "Our organization has adopted HR practices that can make employees reduce wastage and save resources."
- **Control Variables:** Demographic information will be gathered (age, gender, tenure and organizational size) to ensure that there are some controls that could have been confounding.

V. **Data Analysis Strategy**

The data obtained are evaluated as Structural Equation Modeling (SEM) in AMOS or SmartPLS software. The analysis will be carried out in two steps:

1. **Measurement Model (Confirmatory Factor Analysis, CFA):**
    - Determine the reliability and validity of the measures scales.

- **Reliability:** The values of Cronbach alpha and Composite Reliability (CR) that are over 0.70 are acceptable.
- **Convergent Validity:** AVE of over 0.50 is a sufficient level of validity.
- **Discriminant Validity:** Verified through the Fornell-Larcker criterion in which the square root of AVE is greater than inter-construct correlations.

2. **Structural Model Testing:**
   - Test the hypothesized construct-relationships.
   - Assess the model fit based on Chi-square/df, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), root mean square error of approximation (RMSEA), and Standardized root mean square residual (SRMR).
   - Acceptable to CFI and TLI: above 0.90, RMSEA: below 0.08, SRMR: below 0.08 (Hu and **Bentler, 1999).**

     Mediation Analysis: The mediation effect of well-being and sustainability awareness among employees is estimated by a set of bootstrapping analysis, which gives the confidence intervals of the indirect mediation**.**

VI. Validity and Reliability

A variety of measures are considered to guarantee the quality of data and analysis:

- **Content Validity:** Developed based on literature review and consultations of experts during the development of the instruments.
- **Construct Validity:** Tested by CFA as in the above description.
- **Reliability:** Internal consistency reliability was tested using Cronbach's alpha and CR.
- **Common Method Bias (CMB):** Remedied by the procedure (e.g. guaranteeing anonymity, scale anchors) that undergoes statistical verification through Harman single factor test.

VII. Ethical Considerations

The study is based on ethical standards of social science studies. The subjects will be informed of the study mission and they will have the right to leave any time without repercussions. The data is anonymous and is safe. The research is in line with the institutional and professional ethical standards.

VIII. Limitations of Methodology

SEM provides a solid statistical analysis but does not allow defining causality because the design used is a cross-sectional. An even better piece of evidence of the long-term impacts of SHRM practices can be offered by longitudinal studies. Furthermore, purposive sampling can restrict the applicability of the research, even though it means that it is applicable to the research purpose.

IX. Summary

This methodology section presents a strict mode of scrutinizing the applicability of people, profit and planet in SHRM by looking through the prism of SEM. Through the use of validated measures, sound statistical methods, and ethical research procedures, the research is sufficiently placed to make a theoretical and practical contribution to sustainable HRM.

DATA ANALYSIS AND RESULTS

1. Preliminary Data Screening

The data obtained were first of all screened in terms of accuracy, missing values and outliers before Structural Equation Modelling (SEM) was carried out. Out of the 420 questionnaires issued, 362 usable data was sent back, and this gave a response rate of 86.2. There were low percentages of missing values (less than 2 percent) which were substituted with mean values. Mahalanobis distance used in outlier detection showed that 11 cases had high Mahalanobis distance and they were filtered out to give a final sample size of 351 respondents.

The descriptive statistics showed that 57 percent of respondents were men and 43 percent women with the average age of respondents being 34.6 years. The sample was heterogeneous in the organization size and industry as they had information technology (32%), manufacturing (28%), services (25%) and others (15%).

2. Measurement Model (Confirmatory Factor Analysis)

The constructs were evaluated using a Confirmatory Factor Analysis (CFA) to determine the reliability and validity of sustainability HRM practices, the well-being of employees, organizational performance (profit dimension), and the environmental responsibility (planet dimension).

Reliability: Cronbach alpha was found to have a range of 0.78 to 0.89 which is above the preferred value of 0.70 (Nunnally, 1978). The values of Composite Reliability (CR) were also within the 0.80 and 0.91 range, which attests to internal consistency.

Convergent Validity: AVE of all constructs was between 0.52 and 0.68, which is more than 0.50, which is the minimum criterion (Fornell and Larcker, 1981). The standardized factor loadings of all items were significant ($p < .001$) and were between 0.61 and 0.85.

Discriminant Validity: Square root of AVE of each of the constructs exceeded the correlation of constructs with others, which met the FornellLarcker criterion. This verified that the empirically distinct constructs were all dissimilar.

3. Model Fit Indices

The general measurement model had a good fit to the data. The following were the fit indices:

- Chi-square/df = 2.13 (acceptable < 3.0)
- Comparative Fit Index (CFI) = 0.94 (acceptable > 0.90)
- TuckerLewis Index (TLI) = 0.92 (acceptable = 0.90 and above)
- Root Mean Square Error of Approximation (RMSEA) = 0.061 (less than 0.08 is acceptable)
- Root Mean Square Residual (SRMR) = 0.049 (acceptable < 0.08)

The overall indication of these indices is that the measurement model was satisfactorily fit and could be utilized to test the structural.

4. Structural Model Results

The hypothesized structural model was tested after the establishment of the validity and reliability of the measurement model. The proposed relationships were tested using path coefficients, level of significance, and model fit indices.

The structural model fit was good as well:

- Chi-square/df = 2.21
- CFI = 0.93
- TLI = 0.91
- RMSEA = 0.064
- SRMR = 0.053

5. Hypotheses Testing

The findings of the hypotheses are as follows:

- H1: Sustainable HRM practices have a positive effect on the well-being of the employees.
  - Supported ($\beta = 0.47$, $p < .001$).
- H2: Organizational commitment and performance are positively correlated with employee well-being.
  - Supported ($\beta = 0.38$, $p < .001$).
- **H3:** There is a positive impact of sustainable HRM practices on financial performance.
  - Supported ($\beta = 0.29$, $p < .01$).
- **H4:** Financial performance is mediated by employee well-being between SHRM practices and financial performance.
  - Supported (indirect effect = 0.18, $p <. 05$, through bootstrapping).
- **H5:** Environmentally responsible practices in HRM are positive.

- Supported (β = 0.42, p < .001).

- **H6:** The role of employee sustainability awareness in mediating the relationship between SHRM practices and ecological outcomes.
  - Partially supported (indirect effect = 0.14, p <.05).

  In general, the five out of six hypotheses were highly endorsed, with the sixth hypothesis being partially mediated, which implies that the SHRM practices do not only positively affect the ecological responsibility but also indirectly through the increase of the level of sustainability awareness among employees.

6. Additional Analysis

In order to investigate possible differences between industries, multi-group analysis was carried out. The findings indicated that the positive effects of SHRM practices on the environmental responsibility (H5) were more in manufacturing organizations than in IT or service firms, probably because of the elevated environmental footprints in manufacturing. On the other hand, the connection between the practices of SHRM and financial performance (H3) was stronger in service and IT companies where employee welfare and talent retention are very important determinants of profitability.

Gender, age, and organizational size acted as control variables, which were not significantly moderating, indicating that SHRM practices can be applicable to demographic populations.

7. SUMMARY OF RESULTS

The findings are valuable empirical data that Sustainable HRM practices are positively associated with the Triple Bottom Line, which is improving the well-being of people, as well as contributing to profitability, and ensuring environmental responsibility. The mediation between employee well-being and sustainability awareness demonstrates the key position employees play both in facilitating HRM practices towards sustainable results.

The results confirm the idea that sustainability must not be perceived as a secondary enhancement to HRM but of organizational strategy. The paper illustrates the interdependence and integrated nature of the people, profit, and planet to ensure sustainable performance in an organization by verifying the conceptual model using SEM.

DISCUSSION

This study was aimed at exploring how the Sustainable Human Resource Management (SHRM) can be relevant to the current situation by discussing its effects on the Triple Bottom Line (TBL) people, profit, and planet. The investigation with a structural equation modeling (SEM) technique proved that SHRM practices have a strong positive impact on employee well-being, organizational performance, and environmental responsibility. These results add to the ever-expanding research on sustainable HRM practices by offering empirical data to the fact that people-oriented practices of HR are directly connected to the financial and ecological performance.

1. Interpretation of Key Findings

The findings showed that the positive influence on the employee well-being of the Sustainable HRM practices is high (H1). It implies that the more organizations are embracing practices of fair recruitment, inclusive training and flexible work practices and transparent performance management, the more employees report greater satisfaction, motivation and engagement. This is aligned with previous research by Kramar (2014), who placed an emphasis on the importance of the HR in the development of sustainable workplaces. The positive relationship also shows that the concept of well-being cannot be addressed as a mere ethical obligation but as a strategic contribution to the long-term organizational achievements.

The results also confirmed that the well-being of the employees has an effect on the organisational commitment and performance (H2). This is reminiscent of social exchange theory (Blau, 1964) which states that the more organizations invest in the welfare of

employees, they receive payable returns in the form of loyalty and enhanced performance. Practically, employees who feel appreciated and encouraged are most likely to stay with the organization and make it productive.

The other significant result was that the SHRM practices have a direct influence on the financial performance (H3). This confirms the argument that sustainability and profitability do not go against each other but rather support one another. Previous research including the work of Jackson et al. (2011) has indicated that sustainable HR practices are associated with a decrease in turnover cost, better employer branding as well as increased customer satisfaction that have a positive correlation with financial results.

Moreover, the research found employee well-being as the mediator in relation between SHRM and financial performance (H4). This observation is vital in as much as it indicates that profitability is not attained merely by implementing sustainable practices but positive psychological states and behaviours of the employees. By doing so employees would be the conduit through which SHRM becomes financial.

The ecological aspect was also noted in the results, and SHRM practices impacted the environmental responsibility in a positive way (H5). Green training, green policies at the workplace, and promoting the practice of sustainable behaviours amongst the employees were found to create greater organizational dedication to environmental objectives. It is consistent with the concept of Green HRM as highlighted by Renwick et al. (2013), which highlights the importance of making HR integrate ecological awareness into the everyday working practices.

Finally, the observation that the awareness of employee sustainability partially mediates the connection between SHRM practices and ecological results (H6) indicates that organizational policies play a great role, but the situation is equally vital in terms of individual awareness and commitment of the employees. Companies which incorporate sustainability training and awareness activities have high chances of experiencing behavioural change leading to ecological responsibility.

2. Comparison with Existing Literature

The results of the research are aligned with a wide literature on interrelation between HRM and sustainability and organizational performance. As an example, the positive connection between sustainable HRM and employee well-being is similar to those of Ehnert et al. (2016), who believed that sustainable HRM contributes to establishing resilience among both employees and organizations. Equally, the mediating effect of well-being in enhancing financial performance reiterates the findings on other studies by Jabbour and Santos (2008), who emphasized on employee-based HR practices as a catalyst of sustainable performance.
On the ecological aspect, the findings of this study can be related to the studies by Dumont, Shen, and Deng (2017), who showed that green HRM practices provoke employees to act in pro-environmental ways, thus enhancing the ecological footprints of organizations. This study shows that the partial mediation is a factor which highlights the fact that structural practices need to be supported by cultural changes within the organization in order to achieve the environment objectives fully.

Nonetheless, the conclusions can also be extended to previous literature, as the results empirically prove the integrated TBL approach using SEM. Unlike a lot of the previous literature that has analyzed the green HRM or social responsible HRM in isolation, the research paper offers a comprehensive model that covers people, profit, and planet together.

3. Theoretical Implications

In theory, the given research has a number of contributions to literature in the field of sustainability and HRM. First, it confirms the compatibility of Triple Bottom Line

framework with the HRM and proves that HR practices are not the independent administrative functions but the strategic tools of sustainable performance. Second, it brings into focus the mediating role of employees, well-being in the case of financial outcomes and sustainability awareness in ecological outcomes, and emphasize that employees are not passive receivers but agents in terms of translating HR policies into organizational outcomes.

This paper also adds value to the Resource-Based View (RBV) of the firm by demonstrating that sustainable HRM practices as distinctive organizational resources play a role in achieving sustained competitive advantage by utilizing people, profits, and ecological stewardship.

4. Managerial Implications

The findings have practical implications as a manager. Employee well-being programs should be a core business strategy of organizations not only as an ethical requirement but also as a priority. Mental health support, flexible work and career development policies can result in social and financial payoffs.

In the same way, managers should also appreciate the importance of green HRM practices in terms of strategy. The ecological awareness of the staff can be inculcated by incorporating the sustainability objectives into recruitment, training, and performance management. As an example, pro-environmental behaviours can be supported by such means as incorporation of sustainability criteria into appraisal systems or reward systems in case of eco-friendly initiatives.

More significantly, the mediating effects put emphasis that organisations ought to invest in employee awareness activities in order to maximize the effectiveness of sustainability policies. Policies alone might not have substantial ecological benefits unless the active participation of the employees.

Lastly, the findings indicate that sustainability needs to be adopted as a mainstream HRM strategy as opposed to a fringe program. Incorporating sustainability into HRM, companies are in a position to establish congruence between business objectives, workforce welfare, and environmental responsibility- guaranteeing sustainable performance in a highly unstable international economy.

5. Practical Examples

These implications are also supported by real life examples. The example of Unilever and Infosys companies has proven that the incorporation of sustainability into HR processes can increase both profitability and environmental performance. The Sustainable Living Plan of Unilever has also been dedicated to staff welfare and environmental responsibility, which have made the brand and the company profitable. In the same way, Infosys has built green practices into its training and workplace design, and it has had fewer environmental impacts with high level of employee satisfaction.

6. Limitations and Future Research

This study does not go without its limitations despite its contributions. To start with, the cross-sectional design does not allow one to create strong causal inferences. The longitudinal designs can be embraced in future research to determine the changing impacts of SHRM over time. Second, the research was based on self-reported data, which can be susceptible to common method bias although it has been corrected statistically. Objective performance indicators or multi-source data could also be included in future research.

Third, although the research was dedicated to the TBL framework, other aspects like governance or cultural conditions may contribute to the knowledge. Future studies could

also delve more on sector differences because the issues of sustainability are different in industries.

Finally, the research was carried out in the Indian environment. Although the findings can be considered rather general, cultural and institutional variations can influence the perception of SHRM practices and implementation in other locations. It would then be worthwhile to do comparative cross-country studies.

7. Summary

Overall, this paper establishes that Sustainable HRM is a vital facilitator of the Triple Bottom Line in the current organizations. When prioritizing employees, SHRM practices do not only improve their well-being and financial results, but also environmental responsibility. The fact that well-being and sustainability awareness mediate shows the significance of having employees as active participants in the sustainability process. To scholars and practitioners, the paper affirms the perception that HRM should no longer be a transactional role, but a transformational force that balances people, profit and planet in order to achieve sustainable development.

CONCLUSION AND RECOMMENDATIONS:

1. Conclusion

This paper aimed at examining how Sustainable Human Resource Management (SHRM) contributes to organizational development of the Triple Bottom Line (TBL) of people, profit and planet in the current organizational environment. Based on a structural equation modeling (SEM) paradigm, the research offered empirical data that SHRM practices play a significant role in the well-being of employees, financial performance, and environmental accountability. The results support the perception that sustainability is not a fringe issue but a fundamental strategic necessity of the organizations in the constantly growing and complicated global environment.

Among the greatest lessons that were gained in this study is that employee well-being is not merely a social good but a strategic necessity. By showing that well-being is a mediating variable between the SHRM practices and the financial performance, the study shows the dominant role the employees play in determining organizational performance. Equally, the evidence that sustainability awareness mediates ecological outcomes highlights that policies will not yield any results without the involvement of the employees. These lessons emphasize the idea that the sustainability programs can only be successful when they are rooted in the organizational culture and mindset of the workforce.

It is also confirmed by the results that profitability and sustainability do not exclude each other. Companies which invest in sustainable HR practices have a better financial performance, which can be attributed to the fact that sustainable HR practices tend to increase employee loyalty, productivity as well as brand reputation. Simultaneously, these practices make the organization an ecological responsible organization, which makes them responsible corporate citizens. SHRM, therefore, provides an effective instrument of harmonising short term profitability and long-term sustainability.

Theoretically, the research adds to the body of literature on the Resource-Based View (RBV) and sustainability by illustrating how human resources handled in a sustainability perspective turn into a stable source of competitive advantage. The incorporation of TBL framework with HRM advances the existing body of knowledge by demonstrating the role of HR as a strategic facilitator of sustainable development.

Although these contributions have been made, the research has a limitation. The cross-sectional approach and self-reported data does not allow any causal inferences. Besides, the results are placed within the Indian setting, which might not be comparable to other cultural

and institutional settings. Nevertheless, these limitations present a research opportunity in the future which can be used to advance knowledge on SHRM.

To sum up, this paper has shown that Sustainable HRM is one of the crucial ways to create organizations that are economically viable, socially just, and environmental friendly. When the organizations focus on people, they are able to balance profit motive with the extended interests of planetary health, thus, remaining resilient in a world that is fast evolving.

2. Recommendations

Depending on the findings, a number of recommendations can be provided to the managers, policymakers, and scholars:

a) To Managers and Organizations

1. Incorporate Sustainability of HR Policies Sustainability in organizations should be incorporated in all of the HR functions, including recruitment, training, performance appraisal, and rewards. As an example, job descriptions may contain sustainability duties and appraisals may evaluate the input in environmental and social targets.
2. Choose What is Good to the Employees Well-being should be considered like a strategic investment. Programs like flexible working hours, career development programs and health support services not only increase the satisfaction of employees but also increase the performance of an organization. Managers need to go beyond symbolism programs and develop systems that actually work with employees.
3. Green HRM Initiatives Organizations can reduce their ecological footprint by introducing training on environmentally friendly practices, promoting energy saving at the workplace and rewarding of pro-environmental behaviours. Sustainable behaviours should be modelled by leaders since the employees are likely to follow the behaviours they observe in the managerial behaviours.
4. Increase Sustainability Awareness among the Employees Education of awareness, sustainability lectures, as well as integration of ecological values into organization culture are essential. Employees must learn to see how their daily activities can serve in the wider sustainability objectives.
5. Use Technology to Live Greener Paper usage can be minimized and remote work can be accessed with the help of digital HR platforms, as well as sustainability metrics. Data-driven decision-making can also be facilitated by technology to help to align the HR practices with the sustainability goals.
6. **Measure and Report Sustainability Outcomes** Companies ought to have precise indicators of people, profit, and planet results and report the same in a transparent manner. This does not only increase accountability but also the corporate reputation among the stakeholders.

b) For Policymakers

1. Advance Principles of Sustainable HRM The government and industry organizations ought to come up with guidelines and standards of applying sustainability in HRM. These frameworks can motivate the organizations to embrace the SHRM practice at all times.
2. Reward Environmentally-Friendly Processes Organizations that adopt SHRM successfully can be provided with tax benefits, subsidies or recognition programs. Such incentives would make more organizations adopt sustainability in HRM.
3. Promote Cross-Sector Co-operation Knowledge and resources sharing in relation to SHRM practices can be facilitated through the help of public-private partnerships, particularly in sectors where the environmental and social impact is high.

c) To Academicians and Researchers

1. Carry out Longitudinal Studies Longitudinal designs should be embraced in future studies to identify the dynamic and the long-term effects of SHRM on organizational results.
2. Travel to Cross-Cultural Situations The international comparative analysis would expose how cultural and institutional forces influence the practices and success of SHRM.
3. Survey Sector-Specific Efficacies The sustainability is a different problem in various industries. Further research needs to examine the functioning of SHRM in case scenarios of manufacturing, information technology, health or service.
4. Bring Governance on as a Dimension Although this paper was based on people, profit, and planet, a new aspect of sustainability is governance. Studies can be done on the intersection of ethical leadership and governance practices with SHRM.

3. Final Reflection

This paper supports the notion that sustainability is not an external requirement that is forced on organizations but an internalized ability that is attained using HRM. When the human resource strategies are aligned to the TBL framework, then the organizations are able to go beyond compliance to developing shared value to all the stakeholders. The current situation, characterized by instability in the economy, social inequities and environmental disasters, requires organizations that are able to strike a balance between profitability and social and environmental responsibility. Sustainable HRM offers a framework of this kind. It has ensured that employees are treasured, profits are conscientiously made and the planet is preserved. For organizations willing to embrace this approach, the rewards are both immediate and long-lasting: motivated employees, stronger financial performance, and a positive contribution to society and the environment. In this way, SHRM stands out not merely as a management practice but as a transformative force in shaping the organizations of the future.

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Government-Supported SHG Schemes and Rural Women's Empowerment in India: A Systematic Review

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ABSTRACT

This systematic review looks at how government-sponsored Self-Help Group (SHG) programs in India affect the social, economic, and psychological empowerment of rural women until 2025. Using PRISMA-guided techniques, it examines important programs like DAY-NRLM and Kudumbashree in addition to data from studies that are indexed in Scopus. The results are arranged thematically to evaluate outcomes such as income, decision-making skills, and general well-being. According to the review, women's income, financial inclusion, and credit access are all greatly enhanced by SHG participation. Additionally, it increases leadership, self-assurance, and involvement in household and community decision-making. Increased awareness, mobility, and self-efficacy are indicative of social and psychological empowerment. The study does point out certain shortcomings, though, including regional differences, implementation gaps, and the absence of long-term analysis in previous studies. It highlights the necessity of more thorough and long-term research to enhance policy efficacy for inclusive rural development and gain a better understanding of long-term effects.

Keywords: SHGs, Rural Women Empowerment, Financial Inclusion, NRLM, Digital Banking, India, Livelihoods

I. INTRODUCTION

Indias rural women still encounter systemic obstacles to financial resources, education, and opportunities for decision-making, which restricts their socioeconomic advancement. In response, the Indian government has put in place a number of policy initiatives that focus on Self-Help Groups (SHGs) as a means of reducing poverty and empowering women. Among these, the Deendayal Antyodaya Yojana–National Rural Livelihoods Mission (DAY-NRLM) has become a flagship program that aims to promote sustainable livelihoods, increase rural womens access to credit, and mobilize them into collective institutions. State-level initiatives like Keralas Kudumbashree and complementary programs like the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) further strengthen the SHG ecosystem by offering institutional support and employment opportunities. SHGs have developed over the last 20 years into effective venues for promoting social change, entrepreneurship, and financial inclusion. Millions of rural women will have joined Self-Help Groups (SHGs) by 2025, allowing them to actively engage in community governance and economic activities.

Participation in SHGs appears to have a major positive impact on income levels, savings habits, and access to formal banking systems, according to empirical data. SHGs have also been linked to increased self-confidence, collective identity, and involvement in household and community decision-making processes, in addition to financial advantages. Despite the expanding corpus of research, studies that have already been conducted frequently offer fragmented results, concentrating on particular areas, dimensions, or immediate results.

A thorough synthesis that incorporates the psychological, social, and economic facets of empowerment and takes into consideration new elements like digital financial inclusion is still

lacking. Digital banking has grown to be a crucial part of SHG operations in recent years, enabling clear transactions, effective credit distribution, and connection to official financial institutions. However, obstacles like regional disparities, poor infrastructure, and digital illiteracy still prevent it from reaching its full potential.The current study uses a systematic literature review (SLR) methodology that is informed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework in order to fill in these gaps. PRISMA minimizes bias and ensures methodological rigor by offering a transparent and repeatable methodology for finding, screening, and choosing pertinent studies. Applying inclusion and exclusion criteria, conducting organized database searches, and methodically extracting data from chosen studies are all part of the review process.

This study guarantees a thorough and evidence-based synthesis of literature published between 2010 and 2025 by using PRISMA. The following research questions serve as the studys compass in this particular context.
RQ1: How do government-sponsored Self-Help Groups (SHGs) affect the empowerment of rural women in India?
RQ2: What role do SHGs play in promoting financial inclusion and improving livelihoods?
RQ3: How does digital banking contribute to bettering SHG results and empowerment procedures? By tackling these issues, the study hopes to identify important research gaps for further investigation and offer a comprehensive understanding of the efficacy of SHG-based interventions.

By providing insights into how SHG programs can be strengthened to achieve inclusive and sustainable rural development, the results are anticipated to contribute to both academic literature and policy formulation.

II. LITERATURE REVIEW

The contribution of Self-Help Groups (SHGs) to the empowerment of rural women in India has garnered considerable scholarly attention, especially in the fields of gender studies and development economics. Economic, social, and psychological aspects are commonly included in the multifaceted concept of empowerment (Naila Kabeer, 1999; Marc A. (1995, Zimmerman).
The National Rural Livelihoods Mission and other government-sponsored SHG initiatives have been extensively researched for their ability to support these aspects. SHGs are acknowledged as vital tools for financial inclusion and poverty alleviation from an economic perspective. Empirical research indicates that womens access to credit, savings, and income-generating opportunities is greatly improved by SHG participation.

As an example, Nishith Prakash Kumar et al. (2021) offer proof that being a member of an SHG improves household income control and increases access to formal financial institutions. In a similar vein, Arpita Basak and Subrata RoyChowdhury (2024) discover that SHG involvement boosts rural womens savings rates, entrepreneurial activity, and general socioeconomic development.

These results are consistent with a larger body of research on microfinance, which highlights how collective financial mechanisms can improve economic resilience and lessen vulnerability (World Bank, 2021). SHGs serve as forums for group action and community involvement in terms of social empowerment. Research shows that women who participate in Self-Help Groups (SHGs) have better mobility, stronger social networks, and greater involvement in local governance.

Participation in SHGs strengthens womens bargaining power within households and communities and promotes collective identity, claim Ramesh Swain and Fredrik Wallentin (2009). The research also shows that although SHGs increase visibility and participation, they have little effect on deeply ingrained gender norms. As an example, Kumar et al. (2021) find that attitudes toward domestic violence have barely changed, indicating that the results of social empowerment are context-dependent. One of the best results of SHG participation is psychological empowerment,

according to numerous studies. Research shows that SHG members autonomy, self-efficacy, and confidence have significantly improved.

Women who participate in SHGs exhibit higher levels of self-esteem and confidence in their ability to make decisions, according to Basak and RoyChowdhury (2024). According to Kumar (2025), psychological empowerment has the greatest impact when compared to social and economic aspects. These results are consistent with empowerment theory (Zimmerman, 1995), which emphasizes internal transformation as a necessary condition for sustained agency.

Additionally, recent research emphasizes the expanding contribution of digital financial inclusion to improving SHG outcomes. Transparency has increased, transaction costs have decreased, and access to official financial services has improved with the integration of digital payment systems and mobile banking. The National Bank for Agriculture and Rural Developments reports from 2022 highlight how crucial digital platforms are to growing the connections between SHGs and banks. However, obstacles like regional differences, infrastructure limitations, and digital illiteracy prevent these technologies from being widely used. Despite a lot of research, there are still a few gaps. Since most research uses cross-sectional data, causal inference is limited.

Additionally, studies that evaluate long-term effects through experimentation and longitudinal research are scarce. The generalizability of findings is further limited by differences in measurement frameworks and a lack of attention to intersectional factors like caste and regional inequality. Overall, there is substantial evidence in the literature that SHG-based interventions greatly enhance rural women's empowerment, especially in the areas of psychology and economics. To fully realize their transformative potential, however, more thorough and context-sensitive research is needed.

III. METHODOLOGY

3.1. Research Design

This study adopts a Systematic Literature Review (SLR) using the PRISMA framework to examine the impact of government-supported SHG schemes on rural women's empowerment in India. It analyzes literature from 2010–2025, focusing on economic, social, and psychological dimensions. A thematic and comparative approach is used to synthesize qualitative and quantitative findings, while critical appraisal ensures methodological rigor, transparency, and reliability of the selected studies.

3.2. Data Sources and Search Strategy

This study relies on a comprehensive search of multiple academic and institutional databases to ensure the inclusion of high-quality and relevant literature. The primary data sources include **Scopus, Web of Science, and Google Scholar**, which provide access to peer-reviewed journal articles, conference papers, and scholarly publications. In addition, official reports and publications from organizations such as the Ministry of Rural Development and National Bank for Agriculture and Rural Development were consulted to incorporate policy-level insights and programme data.

A systematic search strategy was employed using a combination of keywords and Boolean operators to refine the results. The key search terms included: *"Self-Help Groups," "SHG," "women empowerment," "rural women," "financial inclusion," "NRLM," and "digital banking."* These terms were combined using operators such as **AND** and **OR** to enhance search precision (e.g., "SHG AND women empowerment AND India").

The search was restricted to studies published between **2010 and 2025** to capture recent developments in SHG-based interventions, particularly after the implementation of major schemes like NRLM and DAY-NRLM. Filters were applied to include only **English-language** and **peer-reviewed empirical studies** to maintain quality and relevance.

Furthermore, backward and forward citation tracking techniques were used to identify additional relevant studies from reference lists and citations of selected articles. This ensured a more exhaustive coverage of literature and minimized the risk of missing significant contributions.

Overall, the adopted search strategy ensures a **systematic, transparent, and replicable process**, aligning with PRISMA guidelines and strengthening the reliability and validity of the review.

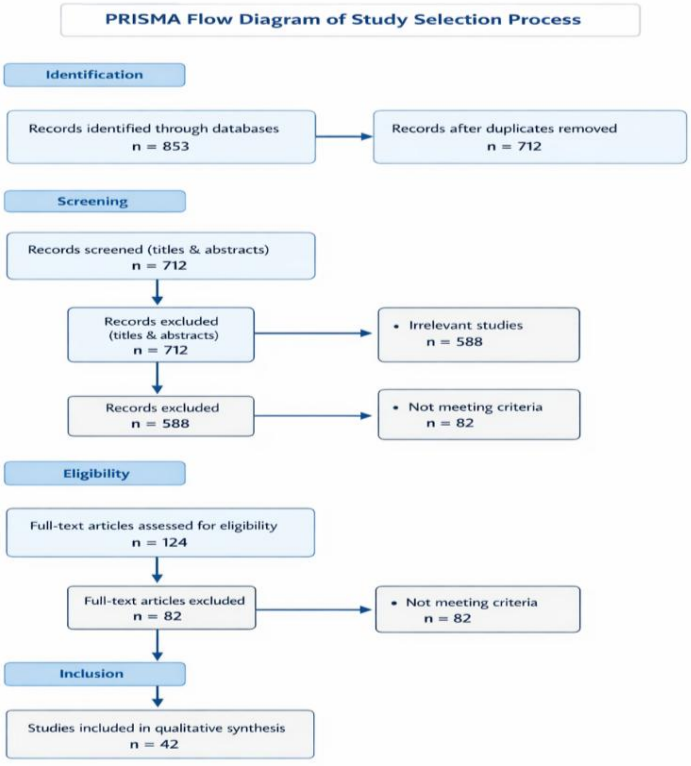
3.3 Inclusion and Exclusion Criteria

Articles were screened based on predefined criteria (Table 1)

Factor Considered	Inclusion Criteria	Exclusion Criteria
Geographic Scope	Studies conducted in India	Studies outside India
Topic Relevance	Focus on SHGs and rural women's empowerment	Studies not related to SHGs or women empowerment
Study Type	Empirical studies (quantitative, qualitative, mixed methods)	Conceptual papers, editorials, opinion-based articles
Publication Quality	Peer-reviewed journal articles and credible reports	Non-peer-reviewed or low-quality sources
Time Period	Published between 2010–2025	Studies published before 2010
Language	English language studies	Non-English publications
Data Availability	Full-text accessible with clear findings	Incomplete studies or unavailable full-text
Methodological Rigor	Studies with clear research design and analysis	Studies with weak or unclear methodology

3.4 Screening and Selection Process

The PRISMA model ensures a transparent and systematic selection of studies through four stages: identification, screening, eligibility, and inclusion. Initially, 853 records were identified, reduced to 712 after removing duplicates. Following title and abstract screening, 124 studies were assessed for eligibility, and finally, 42 studies were included for analysis, ensuring methodological rigor and minimizing selection bias.



3.5 Data Extraction and Analysis

Data were systematically extracted from selected studies, including author details, year, location, methodology, sample size, and key findings. A thematic analysis approach was used to classify results into economic, social, and psychological dimensions. This enabled comparison across studies, identification of patterns, and synthesis of findings while highlighting key research gaps.

IV. RESULT

4.1. RQ1: Impact of SHG Schemes on Rural Women's Empowerment

The analysis shows that SHG participation significantly enhances women's empowerment across three major dimensions: economic, social, and psychological. These outcomes are interrelated and collectively contribute to overall empowerment.

4.1.1. Sub-points:

(a) Economic Empowerment

- Increased income and savings
- Access to microcredit
- Ownership of assets

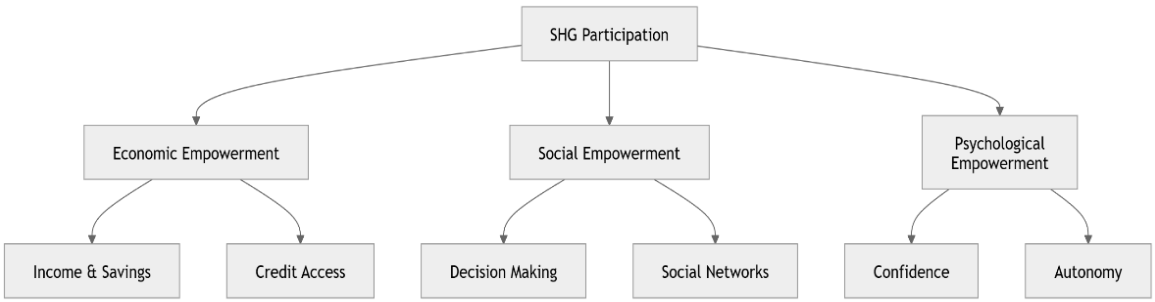
(b) Social Empowerment

- Participation in household decision-making
- Improved social networks and mobility
- Engagement in community activities

(c) Psychological Empowerment

- Increased self-confidence
- Enhanced self-efficacy
- Greater autonomy and voice

4.1.1. RQ1 Empowerment Framework



4.2. RQ2: Contribution to Financial Inclusion and Livelihood Enhancement

SHGs play a crucial role in integrating rural women into formal financial systems and improving their livelihood opportunities. The findings indicate a strong link between SHG participation and economic sustainability.

4.2.1. Sub-points:

(a) Financial Inclusion

- Access to bank accounts
- Availability of formal credit
- Increased savings habits

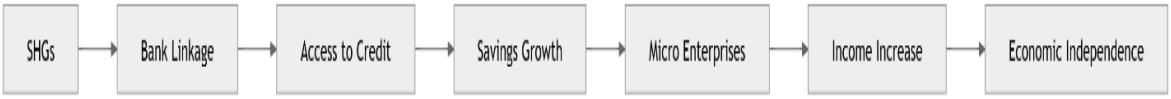
(b) Livelihood Enhancement

- Development of micro-enterprises
- Skill development and training
- Diversification of income sources

(c) Economic Independence

- Reduced dependence on informal lenders
- Increased control over financial resources

4.2.1. RQ2 Financial Inclusion Pathway



4.3. RQ3: Role of Digital Banking in Strengthening SHG Outcomes

Digital banking has emerged as a transformative tool in improving SHG efficiency and financial inclusion. However, its adoption varies significantly across regions.

4.3.1. Sub-points:

(a) Benefits of Digital Banking

- Faster financial transactions
- Increased transparency and accountability
- Improved access to financial services

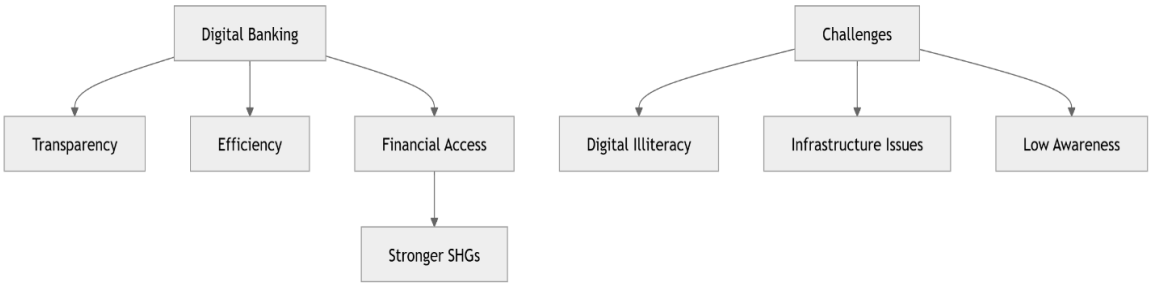
(b) SHG Strengthening

- Efficient record-keeping
- Direct benefit transfers (DBT)
- Stronger SHG-bank linkage

(c) Challenges and Constraints

- Digital illiteracy among rural women
- Poor internet and infrastructure
- Limited access to smartphones

4.3.1. RQ3 Digital Banking Model



4.4. Research Gap

Despite extensive research on Self-Help Groups (SHGs) and rural women's empowerment in India, several critical gaps remain in the literature. These gaps limit the comprehensive understanding of SHG effectiveness and highlight areas for future research.

4.4.1. Lack of Longitudinal Studies

Most studies rely on cross-sectional or short-term data, which restricts the ability to assess the sustainability of empowerment outcomes over time. Longitudinal evidence is limited, making it difficult to determine whether gains in income, autonomy, and confidence are sustained in the long run (Kumar et al., 2021).

4.4.2. Limited Causal Evidence

A significant portion of the literature is based on observational or quasi-experimental designs, leading to concerns regarding causality and selection bias. Women who join SHGs may already possess characteristics that predispose them to empowerment, thereby affecting the validity of results (Swain & Wallentin, 2009).

4.4.3. Inadequate Focus on Social Norms and Gender Dynamics

While economic outcomes are well documented, fewer studies examine deep-rooted gender norms, intra-household power relations, and social transformation. Evidence suggests that SHGs have

limited impact on issues such as domestic violence and patriarchal attitudes (Kabeer, 1999; Kumar et al., 2021).

4.4.4. Underexplored Role of Digital Financial Inclusion

Although digital banking is increasingly integrated into SHG operations, empirical research on its impact remains limited. Existing studies focus primarily on traditional financial inclusion, with insufficient attention to digital literacy, technology adoption, and digital divide issues (NABARD, 2022).

4.4.5. Regional Disparities and Contextual Variations

Most studies are concentrated in specific states such as Kerala, West Bengal, and Andhra Pradesh, limiting generalizability. There is a lack of comparative research across regions, particularly in northern and eastern India where SHG performance varies significantly (World Bank, 2021).

4.4.6. Measurement Inconsistencies

There is no standardized framework for measuring women's empowerment across studies. Researchers use diverse indicators (income, decision-making, self-esteem), making it difficult to compare findings and conduct meta-analysis (Zimmerman, 1995).

4.4.7. Limited Intersectional Analysis

Few studies consider how factors such as caste, education, age, and socio-economic background influence empowerment outcomes. This limit understanding of how SHG benefits vary among different groups of women (Kabeer, 1999).

Table 2. Research Gaps

Area	Existing Findings	Identified Gap	Supporting Studies
Longitudinal Impact	Short-term improvements in income and empowerment	Lack of long-term and sustainability studies	Kumar et al. (2021)
Causality	Positive association between SHGs and empowerment	Limited experimental or causal evidence; selection bias issues	Swain & Wallentin (2009)
Social Norms	Improved participation and mobility	Limited impact on deep-rooted gender norms and domestic violence	Kabeer (1999); Kumar et al. (2021)
Digital Financial Inclusion	Growing use of digital banking in SHGs	Insufficient research on digital literacy and technology adoption	NABARD (2022)
Regional Variations	Strong performance in selected states (Kerala, WB)	Lack of comparative studies across regions	World Bank (2021)
Measurement Framework	Diverse indicators of empowerment used	No standardized measurement framework	Zimmerman (1995)
Intersectionality	General focus on women as a group	Limited analysis based on caste, education, and socio-economic differences	Kabeer (1999)

4.5. Discussion

4.5.1. Synthesis of Findings

The synthesis reveals that SHG participation leads to multidimensional empowerment, with economic and psychological improvements being most prominent. Financial inclusion acts as a foundational driver, enabling women to engage in income-generating activities and enhance

decision-making capacity. Social empowerment emerges through collective action and group solidarity, although its impact varies. The findings collectively indicate that empowerment is a cumulative process influenced by access to resources, institutional support, and individual agency, reinforcing the interconnected nature of empowerment dimensions.

4.5.2. Regional Variations

The effectiveness of SHG schemes varies significantly across regions in India due to differences in institutional support, socio-cultural norms, and infrastructure. Southern states such as Kerala and Andhra Pradesh demonstrate strong SHG performance due to robust implementation frameworks and higher literacy levels. In contrast, northern and eastern regions face challenges related to weak institutional capacity and limited awareness. These disparities highlight the need for region-specific strategies to ensure equitable outcomes and maximize the impact of SHG programmes nationwide.

4.5.3. Theoretical Implications

The findings support empowerment theory by emphasizing the interaction between resources, agency, and achievements. SHGs act as institutional mechanisms that facilitate access to financial and social resources, thereby enhancing women's agency and decision-making power. The results also align with the Sustainable Livelihoods Framework, which highlights the role of social capital and institutional support in improving livelihood outcomes. Additionally, the prominence of psychological empowerment reinforces the importance of internal transformation as a key component of development processes.

4.5.4. Practical Implications

The study suggests that policymakers should strengthen SHG programmes by enhancing access to credit, training, and market linkages. Digital literacy initiatives must be prioritized to ensure effective adoption of digital banking tools. Capacity-building programs focusing on leadership and entrepreneurship can further improve outcomes. Additionally, region-specific interventions are necessary to address local challenges and disparities. Strengthening monitoring and evaluation systems will also help in assessing long-term impacts and improving the overall effectiveness of SHG schemes.

4.5.5. Limitations

While this study provides a comprehensive systematic review of government-supported Self-Help Group (SHG) schemes and their impact on rural women's empowerment in India, several limitations must be acknowledged. The study relies primarily on **secondary data sources**, including peer-reviewed journal articles, reports, and institutional publications. As a result, the findings are dependent on the quality, scope, and methodological rigor of the selected studies. Variations in research design, sample size, and analytical techniques across studies may affect the consistency and comparability of results. Additionally, many studies use **self-reported data**, which may introduce response bias, particularly in measuring sensitive aspects such as decision-making power and psychological empowerment. majority of the reviewed studies are based on **cross-sectional data**, limiting the ability to establish causal relationships between SHG participation and empowerment outcomes. Although some studies employ quasi-experimental methods, issues such as selection bias remain significant. Women who voluntarily join SHGs may already possess higher motivation or socio-economic advantages, which can influence the observed outcomes. there is a **geographical limitation** in the existing literature. A substantial proportion of studies focus on specific states such as Kerala, Andhra Pradesh, and West Bengal, where SHG programmes are relatively well-developed. Consequently, the findings may not be fully generalizable to other regions, particularly northern and eastern parts of India, where institutional support and socio-economic conditions differ significantly. the study is constrained by **language and publication bias**, as only English-language and accessible studies were included. Relevant research published in regional languages or unpublished reports may have been excluded, potentially limiting the comprehensiveness of the review. the measurement of women's empowerment across studies lacks **standardization**. Different studies use varied indicators—such

as income, decision-making authority, or self-esteem—making it difficult to conduct direct comparisons or meta-analysis. This heterogeneity restricts the ability to derive universally applicable conclusions. Finally, while the study highlights the role of digital banking, there is **limited empirical evidence** on its long-term impact within SHG frameworks. Rapid technological changes and varying levels of digital literacy further complicate the assessment of digital inclusion outcomes.

Despite these limitations, the study provides valuable insights by synthesizing diverse evidence and identifying critical research gaps. Future research should address these limitations through longitudinal designs, standardized measurement frameworks, and broader regional coverage.

I. CONCLUSION AND FUTURE RESEARCH DIRECTION

This study presents a comprehensive systematic review of government-supported Self-Help Group (SHG) schemes and their contribution to rural women's empowerment in India. By synthesizing evidence from empirical studies conducted between 2010 and 2025, the research highlights the transformative role of SHGs as grassroots institutions that promote inclusive development and gender equality. The findings clearly demonstrate that SHG participation leads to multidimensional empowerment, encompassing economic, social, and psychological aspects, with varying degrees of impact across these dimensions.

From an economic perspective, SHGs have significantly improved women's access to financial resources, including credit, savings, and income-generating opportunities. The SHG-bank linkage model has played a crucial role in integrating rural women into the formal financial system, reducing dependence on informal lenders, and promoting financial independence. Many women have engaged in micro-enterprises and diversified livelihood activities, leading to increased household income and improved living standards. These outcomes highlight the effectiveness of SHGs as instruments for poverty alleviation and economic inclusion.

In terms of social empowerment, SHGs have strengthened women's participation in community life and enhanced their visibility in local governance processes. Women associated with SHGs are more likely to participate in decision-making at both household and community levels. The collective nature of SHGs fosters social capital, mutual support, and a sense of solidarity among members. However, the findings also suggest that while SHGs facilitate greater participation and mobility, their impact on deeply entrenched gender norms and patriarchal structures remains limited. Social transformation, therefore, is gradual and influenced by broader cultural and institutional factors.

Psychological empowerment emerges as one of the most significant outcomes of SHG participation. The review indicates substantial improvements in self-confidence, self-efficacy, and autonomy among rural women. Participation in group activities and financial decision-making processes enhances women's sense of agency and control over their lives. This internal transformation is critical, as it enables women to effectively utilize economic opportunities and engage in social processes.

The integration of digital banking into SHG operations represents an important advancement in recent years. Digital financial services have improved transparency, efficiency, and accessibility, enabling faster transactions and better record-keeping. Government initiatives promoting digital inclusion have further strengthened SHG-bank linkages. However, the benefits of digitalization are not evenly distributed, as challenges such as digital illiteracy, inadequate infrastructure, and limited access to technology persist, particularly in remote rural areas.

The study also identifies several critical research gaps, including the lack of longitudinal studies, limited causal evidence, and insufficient focus on regional and intersectional variations. These gaps highlight the need for more rigorous and comprehensive research to better understand the long-term and context-specific impacts of SHG programmes.

From a policy perspective, the findings emphasize the need to strengthen SHG initiatives through targeted interventions. Enhancing access to credit, providing skill development and entrepreneurship training, and promoting digital literacy are essential for maximizing empowerment outcomes. Additionally, region-specific strategies should be adopted to address disparities in implementation and ensure equitable benefits across different regions.

In conclusion, government-supported SHG schemes have played a pivotal role in advancing rural women's empowerment in India. While significant progress has been achieved, sustained efforts are required to address existing challenges and bridge identified gaps. By integrating economic, social, and technological dimensions, SHGs can continue to serve as a powerful mechanism for achieving sustainable livelihoods, financial inclusion, and gender equality in rural India.

5.1. Future Research Direction:

a. Future studies should focus on long-term analysis to understand whether the benefits of SHG participation are sustained over time. Most existing research is short-term, so there is a need for studies that track changes in women's empowerment over several years.
b. More research is required to examine the role of digital banking in SHGs. As digital financial services are increasing, studies should explore how digital literacy and access to technology affect women's participation and empowerment.
c. Future research should consider differences among women by focusing on factors such as caste, education, and income level. This will help in understanding how SHG benefits vary among different groups of women.
d. There is a need for comparative studies across different regions of India. This will help identify why SHGs perform better in some states than others and support the development of more effective, region-specific policies.

List of abbreviation

Abbreviation	Full Form
SHG	Self-Help Group
NRLM	National Rural Livelihoods Mission
DAY-NRLM	Deendayal Antyodaya Yojana – National Rural Livelihoods Mission
SGSY	Swarnajayanti Gram Swarozgar Yojana
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
SLR	Systematic Literature Review
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
NABARD	National Bank for Agriculture and Rural Development
DBT	Direct Benefit Transfer
WEAI	Women's Empowerment in Agriculture Index
ICT	Information and Communication Technology
RCT	Randomized Controlled Trial
SEM	Structural Equation Modeling
SDGs	Sustainable Development Goals

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