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Sujeet K. Sharma
Yogesh K. Dwivedi
Bhimaraya Metri
Banita Lal
Amany Elbanna (Eds.)

Transfer, Diffusion and Adoption of Next-Generation Digital Technologies

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Editors

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Editors
Sujeet K. Sharma
IIM Nagpur
Nagpur, India

Bhimaraya Metri
IIM Nagpur
Nagpur, India

Amany Elbanna
Royal Holloway, University of London
Egham, UK

Yogesh K. Dwivedi
Swansea University
Swansea, UK

Banita Lal
University of Bradford
Bradford, UK

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Preface

A new generation of digital technologies are rapidly proliferating at individual, organizational and societal levels. Most of these next-generation digital technologies have strong inter-connections enabling the production, processing and storage of large amounts of data, creation of new data and data-driven decision making. These technologies invite new assessments and research questions to ensure the delivery of maximum value (tangible and intangible both) at an individual, organizational and societal level while avoiding potential harm and negative unintended consequences on individuals, organizations and society at large.

The IFIP WG8.6 group aims "to foster understanding and improve research in practice, methods, and techniques in the transfer and diffusion of information technology within systems that are developed, and in the development process"[1]. In continuing this mission, we organised the IFIP WG 8.6 Conference on "Transfer, Diffusion and Adoption of Next-Generation Digital Technologies" at Indian Institute of Management Nagpur, India on 15–16 December 2023 as a forum for scholars and practitioners to present their research ideas and findings.

The focus of the conference was on understanding the transfer, diffusion and adoption of next-generation digital technologies and systems e.g., metaverse and augmented/virtual reality, blockchain, fintech, artificial intelligence, conversational AI, LLMs, ChatGPT, internet of things and social media among other prominent digital technologies that are expected to have a significant impact on the future economic development of societies, organizations and individuals. The strong link between technology adoption and socio-economic development in many economies is evident from a review of the role of information technologies, particularly over the last two decades. Recently in Forbes, a popular contributor, Bernard Marr, wrote in 2023 "What we're starting to see with metaverse is that we're ready for a new chapter of the world wide web – a new chapter of the internet … think of it perhaps as an immersive Internet". These above-mentioned next-generation digital technologies have a great potential to contribute to the reformation of organizations and societies and their unintended consequences are yet to surface. In recent years, scholars have shown great interest in understanding how these technologies are introduced, how they are used, and what their effects and potential are on people, societies and businesses.

This conference brought together scholars and practitioners from interdisciplinary fields in order to enrich scholarly reflection on the adoption, use, impact and potential of next-generation digital technologies. The conference mainly focused on papers that addressed questions related to the diffusion and adoption of emerging technologies. Besides, we were also open and committed to the broader theme of IFIP Working Group 8.6. We received 209 papers from academicians and practitioners worldwide. All submissions were double-blind reviewed by at least two reviewers. The reviewing

[1] http://ifipwg86.wikidot.com/about-us.

process resulted in the acceptance of 89 full papers and 23 short papers to present in the conference. The acceptance rate of submitted papers was about 54%. We are grateful to all track chairs who selected reviewers and the large team of reviewers who provided constructive and timely feedback to authors.

We sincerely thank all authors, reviewers, participants, program committee members, track chairs, advisory board, IFIP WG8.6 officials and IIM Nagpur faculty & staff who helped in making this conference a grand success.

December 2023

Sujeet K. Sharma
Yogesh K. Dwivedi
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Contents – Part III

Transfer, Diffusion and Adoption of Next-Generation Digital Technologies

Industry 4.0

Literature Review of Theory-Based Empirical Research Examining Consumers' Adoption of IoT

Salma S. Abed(✉)

Department of Management Information Systems, College of Business, King Abdulaziz University, Rabigh, Saudi Arabia
sabid@kau.edu.sa

Abstract. The Internet of Things (IoT) is an international context that is in the process of massive development. The IoT has initiated new opportunities in the technological context and is one of the most central technological initiatives today. This study conducted a systematic review of the related literature examining theory-based empirical research on IoT adoption by consumers. Forty-three studies were identified between 2011 and 2023 in 20 different countries, mostly Malaysia, Turkey and India. The studies have mostly examined IoT adoption in smart homes, IoT adoption in the retail service industry (consumer shopping), and IoT adoption in healthcare and fitness wearable devices. The main theory that was used to examine the consumer adoption of IoT was the Technology Acceptance Model (TAM). The most examined constructs that were found to be significant in relation to behavioural intention were perceived usefulness, perceived ease of use, and trust. This research provides theoretical implementations for future researchers who are interested in examining the IoT adoption of consumers in different countries and different technological contexts.

Keywords: Literature review · consumer adoption · Interment of things · IoT · TAM · UTAUT · UTAUT2

1 Introduction

The Internet of Things (IoT) refers to all physical objects around the world that are connected to the internet wirelessly while gathering and sharing data. Cheap processors and wireless networks can integrate anything into the IoT. This process changes a normal device into a smart device, adding digital intelligence to the connected devices [18, 42]. Since the 1980s and 1990s, the idea of adding sensors and intelligence to a basic device has been discussed. However, progress has been slow as the technology was not ready at the time. The term Internet of Things (IoT) was created in 1999 by a British technology developer, during a presentation at Procter & Gamble (P&G) [44]. He stated that "The IoT integrates the interconnectedness of human culture 'things' with the interconnectedness of our digital information system 'the internet', That's the IoT" [44]. The goal of the

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IoT is to maximize the outcomes of the internet through continuous connectivity, data sharing, and remote-control ability [1, 16]. It is important, effective, and innovative to enable connectivity for everything, everyone, and everywhere.

The IoT is the new innovative trend in the world of business and technology. Officials are confident that the IoT is one of the central emerging technologies of the present day, like robotics and artificial intelligence [2]. Scholars have stated that among all of today's technology trends, the greatest is the IoT as it is going to cause major changes and provide big opportunities in forthcoming years [2, 4]. [1] stated that "IoT is a fast-growing constellation of Internet-connected sensors attached to a wide variety of things."

A study issued by Forbes Insights surveyed around 500 managers based in the USA, Europe, and the Asia-Pacific, representing different industries. Specifically, 90% of them indicated that IoT will be very significant in their business future. Furthermore, 75 billion devices could be connected to the internet by 2025 [34]. In fact, there are many IoT applications around the world such as in smart cities, smart homes, smart healthcare, smart buildings, smart wearable devices, smart farming, and smart appliances. Starting from enterprise IoT to consumer IoT through to industrial and manufacturing IoT, IoT applications extend into telecommunications, verticals, energy, and more.

The growth of predictions can be found with reference to all IoT acceptance and adoption. Accordingly, a comprehensive review of the literature of IoT adoption will provide a unified perspective of the IoT and assist as a source of the growing body of knowledge. The main goal of the present research was to gather the existing theory-based empirical literature that examined IoT adoption by consumers, in order to develop an understanding of the most examined theories and constructs. The present review has undertaken an analysis of IoT, including the number of theory-based empirical researches according to the published year, the countries that have examined IoT adoption by consumers, the IoT technology context that has been empirically examined in the literature, the examined theories and models of IoT adoption, and the examined constructs found to be significant. The rest of the paper is organized as follows: the systematic literature review approach, results, dissection, and conclusion.

2 Literature Review Approach

This research follows the systematic literature review approach presented by [43, 49] according to the following six steps:

1 Identification and selection of the keywords, and the specification of the combinations of keywords to be used: As the purpose of this study was to undertake a complete search aiming to develop the present literature and knowledge of theory-based empirical research examining the consumer adoption of IoT, a number of keywords were therefore used. These were tech*, technology, adopt*, adoption, "technology adoption", IoT, "Internet of Things", consumer*, customer*, Theory*, Model*, TAM, UTAUT, UTAUT2, "Technology acceptance theories and models".
2 Specific combinations of keywords were selected. After that, a combination of keywords was built up that can help the researcher to focus on the targeted literature of the present study, which were tech* + adopt*, "technology adoption" + IoT, "Internet

Of Things" + consumers* + Theory*, Model*, "Technology acceptance theories and models".

3 Selection of Databases: The researcher started to explore the main research engine databases including Scopus, ScienceDirect, Emerald Insight, Google Scholar, and EBSCO to gather the related articles.
4 Developing the inclusion and exclusion measures: A set of inclusion and exclusion measures was decided upon before starting the search. The inclusion measures were that the study was written in the English language, that the literature was published between 2011 and May 2023, and that they were peer-reviewed articles, conference papers, and theses, specifically theory-based papers discussing the consumers' technology adoption of IoT. The exclusion measures were studies written in other languages, papers published before 2011, and papers examining other aspects of technology adoption.
5 Conducting the search: The search was conducted in Scopus, ScienceDirect, Emerald Insight, Google Scholar, and EBSCO over a period of one month in May 2023. A different sets of keyword combinations were used to search each database.
6 Quality assessment: The abstracts were scanned for quality assessment and the relevant papers selected. All irrelevant papers were extracted based on the exclusion measures. Furthermore, the full papers were reviewed to check the examined theories and models and the significant relationships therein; finally, the writing up of the literature review was performed. The literature review procedure of the present research is presented in Fig. 1.

3 Results

After filtering the identified papers in the literature, 43 studies were identified that empirically examined IoT adoption by consumer segment based on a range of technology adoption theories. These studies were conducted between 2011 and 2023. The identified empirical research was mostly concentrated in 2018, followed by 2017, 2019, 2020, 2021 and 2023. Figure 2 presents the number of theory-based empirical research studies undertaken according to year.

Regarding the countries that examined IoT adoption by consumer, 20 countries have been identified in the literature: Malaysia (14%), Turkey (11%), India (9%), Taiwan (7%), China (7%), USA (7%), Saudi Arabia (5%), Egypt (5%), Thailand (5%), New Zealand (5%), the Netherlands (5%), South Korea (5%), Indonesia (2%), Germany (2%), Tanzania (2%), Poland (2%), Greece (2%), Hong Kong (2%), Pakistan (2%), and Jordan (2%). Figure 3 presents the countries that have examined IoT adoption by consumer.

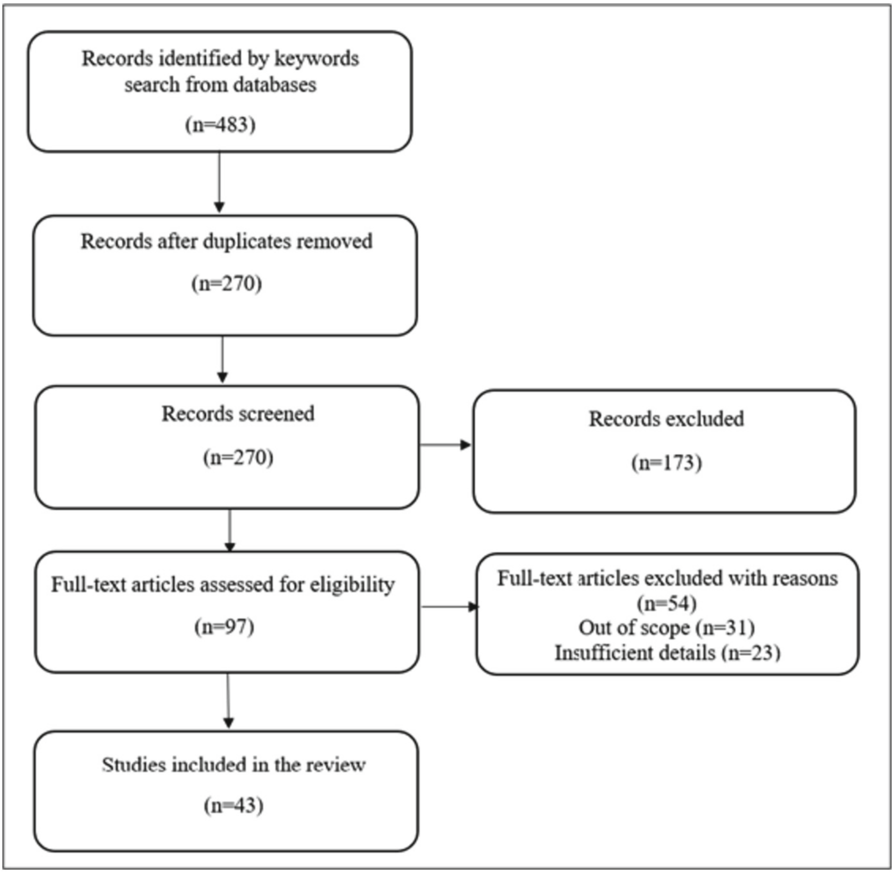

Fig. 1. Literature review procedure conducted

Regarding the IoT major themes that have been empirically examined in the literature, 16 different contexts have been identified: IoT technology adoption, IoT adoption in smart homes, IoT adoption in the retail service industry (consumer shopping), IoT adoption in healthcare and fitness wearable devices, IoT adoption in higher education institutions, IoT services, domestic IoT devices and smart speakers, IoT adoption of products and applications, IoT adoption in smart home energy management and electricity-saving services, IoT adoption resistance, IoT smart home adoption for elderly healthcare, IoT adoption among accounting and finance students, IoT mobile payment adoption, IoT adoption by the consumers of telecommunications companies, IoT adoption by aged consumers, and IoT adoption by generation-Z. Figure 4 presents the cont ext of the IoT technologies empirically examined in the literature.

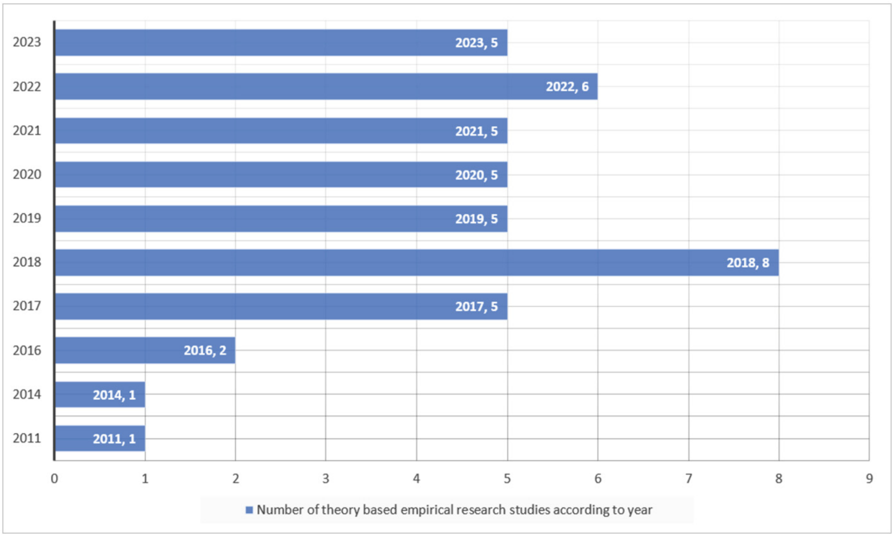

Fig. 2. The number of theory-based empirical research studies by year published

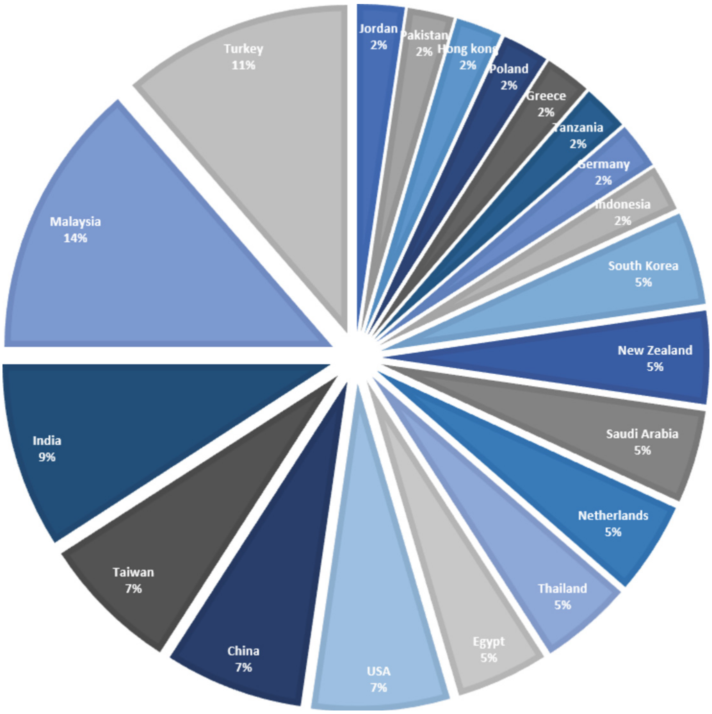

Fig. 3. Countries that examined IoT adoption by consumer segment

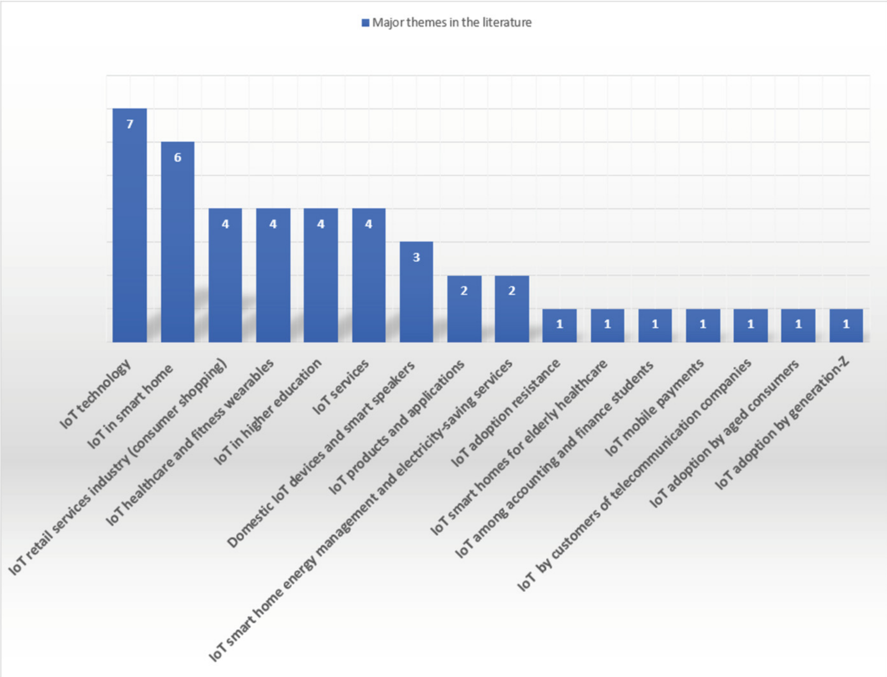

Fig. 4. The IoT major themes that have been empirically examined in the literature

Regarding the technology acceptance theories and models that have been used to examine IoT adoption in the literature, the most examined is the technology acceptance model (TAM) as a single model [3, 5, 10, 13–15, 17, 19]. It was also combined with other theories and models such as TAM and the Diffusion of Innovation Theory (DOI) [26, 48]; as well as TAM, DOI, protection motivation theory (PMT), and privacy calculus theory (PCT) combined [21]. Also, TAM, Theory of Reasoned Action (TRA) [32]; and TAM, TRA, and The Theory of Planned Behavior (TPB) [30]. Other studies examined UTAUT [4;7; 8; 9; 31;35], and UTAUT2 [1; 2; 12; 27; 41]. Table 1 presents the studies that examined the technology acceptance theories and models involved in the adoption of IoT in the literature.

Table 1. The theories and models that examined IoT adoption in the literature

Theory	**References**
TAM	[3, 5, 10, 13–15, 17, 19, 20, 24, 25, 37–39, 45–47]
TAM & DOI	[26, 48]
TAM, DOI, PMT, PCT	[21]
TAM & TRA	[32]
TAM & TRA & TPB	[30]
TAM & GT & ISSM	[23]
TRA & TCV	[22]
TPB & RCT	[40]
TPB & PCT	[6]
TRI	[33]
MATH	[11]
IRT & MDT	[36]
Ram and Sheth's (1989) theoretical framework	[29]
Value-based adoption model (VAM)	[28]
UTAUT	[4, 7–9, 31, 35]
UTAUT2	[1, 2, 12, 27, 41]

TAM: Technology Acceptance Model; DOI: Diffusion of Innovation; PMT: protection motivation theory; PCT: privacy calculus theory; TRA: Theory of respond action; TPB: Theory of planned behavior; GT: gratifications theory; ISSM: information systems success model; TCV: Theory of consumption value; RCT: rational choice theory; MATH: E-Model of Adoption of Technology in Households; TRI: Technology Readiness Index; IRT: Innovation Resistance Theory; MDT: Multidimensional Development Theory; VAM: Value-based adoption model; UTAUT: Unified Theory of Acceptance and Use of Technology; UTAUT2: Unified Theory of Acceptance and Use of Technology 2.

Regarding the most examined constructs associated with behavioural intention (as a dependent variable), a selection was found to be significant. The most examined construct in the literature found to be significant was perceived usefulness (18 times), followed by perceived ease of use (13 times), trust (12 times), performance expectancy (9 times), perceived risk (7 times), social influence (7 times), attitude (7 times), perceived enjoyment (6 times), effort expectancy (6 times). Figure 5 presents the frequency of the examined constructs with behavioural intention found to be significant.

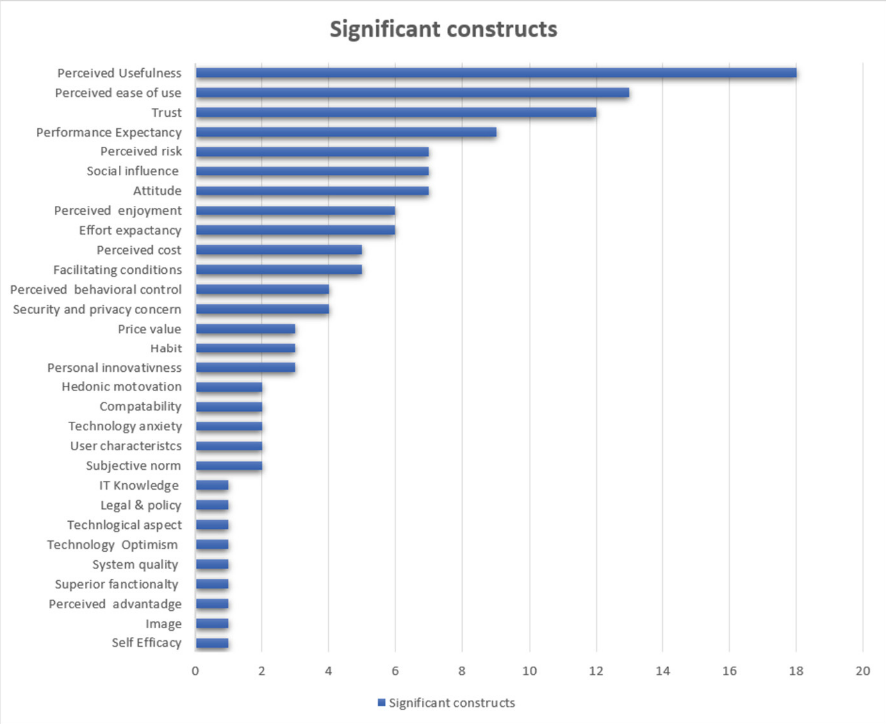

Fig. 5. The examined constructs in relation to behavioural intention that were found to be significant

4 Discussion and Future Research Directions

After presenting the literature review results, the discussion and future research directions are presented in the following points:

1. This study aimed to identify the research that empirically examined IoT adoption by consumers based on technology adoption theories and models. After eliminating the studies that are not in the same context, only 43 papers were identified covering the past 11 years from 2011 to 2023. This number is very limited, especially as IoT is a new and novel technology that is critical to be adopted in consumers' daily lives in different fields and contexts. More theory based empirical research needs to be conducted to examine IoT adoption.
2. Regarding the countries and regions identified in the literature, 16 different countries were examined for IoT adoption by consumers, and most of the studies were conducted in Malaysia, Turkey, India, and Taiwan. Accordingly, this new and important technology that can be used in the daily lives of consumers needs to be examined in other countries and regions.
3. The major themes that have been empirically examined in the literature were IoT technology adoption, IoT adoption in smart homes, IoT adoption in the retail service industry (consumer shopping), IoT adoption in healthcare and fitness wearable

devices, and IoT adoption in higher education institutions. The number of studies examining specific technologies are very limited. Therefore, more forms of IoT technology need to be empirically examined such as, IoT Applications and Services, IoT Communication Technologies, Big Data and IoT, Artificial Intelligence and IoT, IoT and Smart Cities, Blockchain and IoT, as well as IoT Recent Trends.

4. The technology acceptance theories and models that have been used to examine IoT adoption in the literature are very limited, mostly to TAM, DOI, UTAUT, and UTAUT2. Other technology adoption theories and models need to be examined as well as moving on to combining more than one theory in a single conceptual model. This will provide a clearer view of IoT adoption by consumers.
5. The most examined constructs were perceived usefulness, perceived ease of use, trust, and performance expectancy. The other constructs need to be investigated further to gain a better vision of the most significant factors that affect the consumer intention to adopt IoT technologies.

5 Conclusion

This study has reviewed the literature on theory-based empirical research to examine the consumer adoption of IoT. Forty-three studies were identified between 2011 and conducted in 20 countries, mostly in Malaysia and Turkey. The studies mostly examined IoT technology adoption, IoT adoption in smart homes, IoT adoption in the retail service industry (consumer shopping), IoT adoption in healthcare and fitness wearable devices, and IoT adoption in higher education institutions. The main theory that was used to examine the consumer adoption of IoT was TAM. The most examined constructs that were found to be significant in relation to behavioural intention were perceived usefulness, perceived ease of use, and trust.

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A Conceptual Framework for Achieving Sustainability in Supply Chain Using Industry 4.0 Technologies in Emerging Economies

Vaibhav Sharma[1], Praveen Saraswat[1,2], and Rajeev Agrawal[1](✉)

[1] Malaviya National Institute of Technology, Jaipur 302017, India
ragrawal.mech@mnit.ac.in

[2] Swami Keshvanand Institute of Technology, Management and Gramothan, Jaipur 302017, India

Abstract. Making the supply chain sustainable, practices aim to reduce the hazardous impacts of supply chain activities aimed at global pollution and global warming. However, the literature collected from Google Scholar has discussed how Industry 4.0 (I4.0) technologies can address the issue of sustainability in the supply chain by addressing resource efficiency, transparency, and energy consumption issues. The impact of each technology on sustainability is not discussed well, and how these technologies can be helpful to address sustainability issues in industries. Therefore, to fill this gap, the present paper aims to answer how these technologies can address sustainability issues. In the study, a novel framework is proposed that discusses how each technology of I4.0 can address the various sustainability issues in the supply chain. This study can help emerging economies and a novel contribution to the theory to understand the impact of I4.0 on the sustainable supply chain.

Keywords: Industry 4.0 · Sustainable Supply Chain · Emerging economies

1 Introduction

Sustainable supply chain management (SSCM) integrates the Triple Bottom Line (TBL) viewpoint to manage material, economic, and information flows to prevent negative impacts and create economic, ecological, and social capital [1]. The advent of Industry 4.0 by Germany [2] can create a smooth flow of information and material through the value chains. Different technologies of I4.0, such as the Internet of Things (IoT), Industrial Internet of Things (IIoT), Cyber-Physical Systems (CPS), Big Data Analytics/Artificial Intelligence (AI), Blockchain, Cloud Computing, Cognitive computing, Autonomous systems, Digital twin, Augmented Reality/Virtual Reality and Horizontal and Vertical integration make the machines capable of making autonomous decisions and enhancing the supply chain drivers (Facilities, Inventory, Transportation, Information, Sourcing, and Pricing) to increase the visibility and transparency on one hand and increasing the performance and deal with disruptions and mitigate the risks on the

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other hand. The need for attaining sustainability is essential for the survival of mankind [3]. The three sustainability pillars (Economic, Social, and Environmental) are the key concepts to achieve sustainability [4]. The various functions involved in supplying raw materials sourcing and finished goods delivery to the customers positively impact society and people to achieve economic benefits [1]. Supply chain sustainability can be achieved by analyzing the social responsibility not only of the OEMs (Original Equipment Manufacturers) but also of suppliers by prioritizing the usage of renewable energy, recyclable materials, and circular products [5]. To achieve two major goals, visibility, and required ROI (Return on Investment), the importance of Sustainability with I4.0 is a well-established answer.

The study has five parts. Section 1 introduces. Section 2 reviews relevant literature. Section 3 discusses framework development based on review. Section 4 suggests ways organizations can overcome I4.0 technology implementation challenges. Section 5 concludes and suggests further research.

2 Literature Review

We reviewed the articles concerning industry 4.0 enhancing sustainability in supply chains of emerging economies by searching in Google Scholar. Sustainability is the need for manufacturing organizations to prevent themselves from huge financial losses, and various I4.0 technologies such as the Internet of Things, Big data analytics, Blockchain, Machine learning, etc. [6] can contribute to attaining sustainability in developing economies [7]. Various challenges, such as Organizational, Technological, Strategic, Legal, and ethical issues, must be addressed [8]. Including sustainability in supply chains requires organization-friendly Government policies, Collaboration, and transparency among the different supply chain stakeholders [9]. In emerging economies, SMEs (Small and Medium-sized Enterprises) are the most vulnerable sectors to adopt I4.0 technologies as they lack motivation from partners and customers [10]. Adopting I4.0 improves operational performance and competency of supply chains, although intrinsic and extrinsic factors negatively affect digitalization [11]. As discussed in [12], I4.0 technologies can help to play a significant role in reducing emissions and production for achieving sustainability in supply chains [8], whereas [13] presented in the context of MSMEs (Micro, Small and Medium Enterprises) the barriers to sustainability using I4.0, and supply chain and environmental related enablers were also presented.

2.1 Internet of Things (IoT)

The IoT in a different component of supply chains can be RFID (Radio Frequency Identification) based transportation that increases supply chain visibility and improves efficiency [14]. The benefits of the adoption of IoT in the supply chain can relate to finding enough data for real-time data management to proceed with Business Intelligence improvement, and the major challenge is a diminished understanding of the IoT benefits [15]. Other issues include framework preparedness, market and property motivations, technical capacity criteria, and policy resources [16].

2.2 Blockchain

Blockchain technology can act as a sustainability driver for the supply chain by reducing product recall, creating an accurate carbon footprint for a carbon tax, incentivizing recycling behavior, and reducing emission fraud [17]. Developed countries dominate the Blockchain-SCM understanding, so there is an immense opportunity for developing a maturity model for emerging economies [18]. But characteristics of Blockchain technologies: low-cost Blockchain deployment, low cost and rapid diffusion of IoT, and use of the mobile phone can act to enforce sustainability standards and remove institutional cost-benefit analysis power distribution challenges [19].

2.3 The Cloud

The cloud database can potentially increase the accuracy and real-time management of information, helping the stakeholders identify the problems that are creating environmental footprint performance across the supply chain [20]. Various green SCM practices, such as green purchasing, manufacturing, ecological design, and training, positively impact environmental performance; green manufacturing and green design positively impact economic performance [21]. On the other hand, green purchasing and training have a non-significant impact on economic performance, and the initial cost of implementing green supply SCM practices is high. However, digital technologies (IoT) are still being studied [21, 22].

2.4 AR/VR in SSCM

All the past research done on AR/VR (Augmented Reality/ Virtual Reality) in operations in Supply Chain Management (SCM) [23] is theoretical. The analysis of challenges and barriers for a deeper understanding of the implementation of AR/VR in Sustainable supply chains through data is still desired [23]. AR/VR technology can increase visibility in terms of the real-time look of manufacturing facilities, distribution centers, etc., improve customer order receiving, delivery of orders becoming efficient, and no late delivery, transparency by providing exact information on packaging and its content and security of the package to deliver after the customer recognition [24].

2.5 Big Data

For supply chains to become sustainable, Big data tools such as data processing, analytics, reporting, etc., can help organizations take corrective actions in the operations, transparency, and risk mitigation in the manufacturing supply chains [25]. Big data analytics can help emerging economies collect data and analyze data to disseminate the knowledge obtained to achieve sustainability in the supply chains [26].

2.6 AI

The AI technology can improve the supply chain resilience and supply chain performance [27]. Sharma et al. [28] suggested that AI has the potential to revolutionize different sectors of the economy, like healthcare, manufacturing, education, and agriculture. Increasing operational efficiency and reducing costs are important for enhancing decision-making. This can be achieved through inventory optimization, route optimization, demand forecasting, and quality control.

3 Emerging Economies and Challenges

Technologies pose challenges such as skill development of users and habituating the users to increase the efficiency of the supply chain by the mutual trust between the organization and employees. These are the challenges for various industries such as (Plastic, Paper, Cement, Automobile, Chemical, Electronics, Pharmaceutical) [12].

3.1 Sustainability of the Previous Steps

3.1.1 Infrastructure Challenges

Firstly, emerging economies have a long way to go to implement the I4.0 technologies as it depends crucially on the Fiscal and Monetary policies to address the crisis they have encountered during COVID-19. For that, structural reforms are required to enhance the institutional capacity. Secondly, the policies that are adopted to date are required to prove their credibility so that the economies can be alleviated to become the developed ones under the umbrella of macroeconomic policies. However, infrastructure development in emerging economies can be challenging due to a lack of funding and resources and difficulties with regulatory hurdles [8, 11, 16]. Private-public partnerships, foreign investment, and international aid are some ways to finance infrastructure development in emerging economies.

3.1.2 Macroeconomic Stability

Issues include commodity exports, money inflows and outflows, and institutional and regulatory capability. Macroeconomic stability boosts investment, poverty reduction, and living standards. Monetary and fiscal policies encouraging sustainable economic development, low inflation, and a stable exchange rate can enhance macroeconomic stability [10, 11]. They can also execute structural reforms to boost economic efficiency, decrease corruption, strengthen governance and regulation, and boost human capital investment. International organizations and wealthier nations can provide technical and financial aid to emerging economies.

3.1.3 Population Size

Organizations and governments need to consider the potential impact of population growth on resource availability and environmental degradation to manage supply chains sustainably in emerging economies. This may involve implementing sustainable sourcing practices, reducing waste and emissions in supply chain activities, and investing in renewable energy and resource-efficient technologies [12]. Additionally, the distribution of population within the emerging economy and how it affects the transportation and distribution of goods as the dispersed population can increase the complexity and cost of logistics. In contrast, a concentrated population can lead to increased urbanization, and associated environmental challenges, such as air and water pollution, are to be considered.

3.1.4 Ease of Doing Business

A favorable business environment, with clear and streamlined regulations, efficient bureaucratic processes, and a stable political climate, can encourage investment, improve supply chain efficiency, and promote sustainable business practices [8, 29]. On the other hand, a challenging business environment, with complex regulations, corruption, and political instability, can lead to higher costs, supply chain disruptions, and a reduced focus on sustainability. In such cases, companies may be more likely to engage in unsustainable practices, such as environmental degradation and labor exploitation, to maintain profitability.

4 Framework for the Integration of I4.0 Technologies to Achieve Sustainability

As shown in Fig. 1, emerging economies face policy-binding and financial adjustment issues hindering I4.0 technology implementation in SSCM. So, this study combines the different challenges from the literature review of emerging economies and their ability to implement I4.0 technologies. It also presents the advantages and drawbacks of I4.0 technologies, combining SSCM targets and sustainability pillars, as discussed in Sect. 2.

4.1 I4.0 Technologies for Achieving Sustainability in Supply Chains

Technologies can help to reduce waste in supply chains, optimize supply chain operations, and increase efficiency and productivity, which can reduce costs and the carbon footprint. For example, the use of Big Data and AI can provide insight into the improvement in the reduction of supply chain emissions. Circular business models can be developed according to the conditions of a particular emerging economy. The other technology is Blockchain, which can increase transparency and traceability throughout the supply chain and manage disruptions and supply chain efficiency (Fig. 1). It can reduce intermediaries, increasing the speed of supply chains' activities. This can help companies to identify and address the sustainability challenges at the Triple Bottom Line (TBL).

4.2 Supply Chain Sustainability Targets

IoT, AI, and robotics are some technologies that can play a crucial role in sustainability. IoT sensors and predictive maintenance can reduce carbon emissions. Blockchain can help in the ethical sourcing of materials. AI algorithms can help in diversifying suppliers and increase resiliency in the supply chain, as well as manage production processes at the operational level. Technology access, skilled workforce, data privacy, and motivation of local suppliers to get integrated into mainstream technologies are challenges.

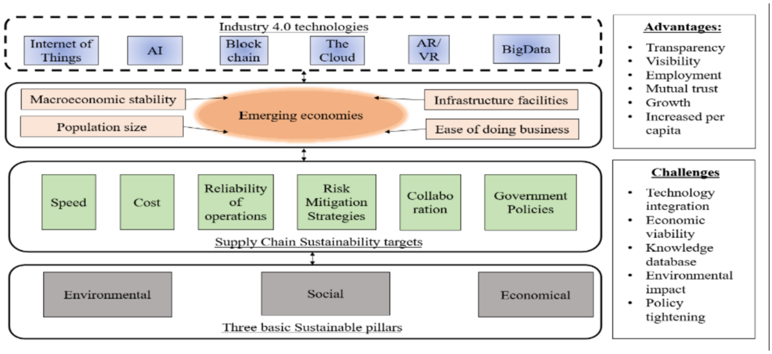

Fig. 1. Framework for achieving sustainability in the I4.0 era for emerging economies.

5 Practical Implication

The literature evaluation suggests training workers and managers and collaborating with research institutions to utilize I4.0 technologies in supply chain activities. Emerging economies aim for supply chain sustainability within their state's constraints and rules. I4.0 technologies will boost per capita income, operations transparency, supply chain visibility, mutual trust, country, organization, and stakeholder growth. Technology integration in their supply chain, the economic viability of investing in I4.0 technologies, a knowledge database to produce skilled workers, assessment of environmental impacts of supply chain activities, and strict policy adherence of their states are all necessary to achieve these advantages.

6 Conclusion and Future Implications

This study aims to help emerging economies adopt I4.0 technologies for supply chain sustainability. Population size, macroeconomic stability, infrastructure capabilities, and ease of doing business are the major factors to consider before implanting I4.0 technologies, as well as building on three major sustainability pillars to make the supply chains fast, responsive, reliable, resilient, and collaborative. This model can be extended to conduct a survey with the managers of emerging economies who want to achieve sustainability in their supply chains in a more detailed way, pointing out the main problems they encountered. Also, TOE (Technology Organizational Environment) can be used to further extend and verify the framework.

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Industry 4.0 Implementation: Evidence from Indian Industries

Abhijeet K. Digalwar[1,2](✉), Sudhanshu Ranjan Singh[2], Rishi Pandey[1], and Ankur Sharma[2]

[1] Symbiosis Centre for Management Studies (SCMS) Nagpur, Symbiosis International (Deemed University) SIU, Pune, Maharashtra, India
akd@pilani.bits-pilani.ac.in

[2] Birla Institute of Technology and Science, Pilani, Rajasthan, India

Abstract. The emergence of "Industry 4.0" signifies a new industrial era, where various technologies converge to provide digital solutions. Industry 4.0 (I4.0), encompasses a range of digital technologies that profoundly impact manufacturing businesses. However, there is limited knowledge regarding how businesses utilize these technologies. This paper addresses the pillars of Industry 4.0, a crucial part of the next industrial revolution for Indian manufacturing industries aiming to become competitive smart factories in the global market. A survey of 73 Indian industries assessed their current technologies. Implementation criteria for Industry 4.0 in Indian industries were established based on the survey results. The findings reveal that customer satisfaction and quality are top priorities for Indian industries. While most industries have implemented Industry 3.0 practices, awareness and adoption of I4.0 still pose challenges, particularly for SMEs. This report analyzes the technological status of Indian industries, identifies the gap, and provides a roadmap for adopting Industry 4.0. Bridging this knowledge gap and embracing Industry 4.0 can enhance competitiveness, drive innovation, and meet the evolving demands of the global market. The transition to smart factories powered by Industry 4.0 unlocks new opportunities for India's industrial sector, propelling it towards a prosperous future.

Keywords: Industry 4.0 · Indian Manufacturing industries · smart factory · India

1 Introduction

1.1 Indian Manufacturing Sector

The emergence of new technologies and globalization is having a huge impact on the manufacturing industries around the world (Singh, Garg, and Deshmukh, 2010). The sustainable growth of any nation depends not only on the large-scale industries but also depends upon the small and medium-scale industries which are the major source of employment generation and utilization of indigenously available resources. As ancillary units, SMEs are complementary to large-scale industries by fulfilling primary requirements (Jutla, Bodorik, and Dhaliwal, 2002). Due to their significant contribution to

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Indian GDP and employment, SMEs are vital for the Indian economic structure and are considered the backbone of the economy. In developing countries, such as India, the public and private sectors clearly distinguish the significance of SMEs for their impact on employment, development, social cohesion, innovation, and economic growth (Singh, Garg, and Deshmukh, 2008).

With a mission and vision to have the exponential growth of the Indian economy, the Indian government has designed *"Make-in-India"* and *"Digital India"* programs to renovate India into an international manufacturing hub of goods ranging from software to cars, paper to power and submarines to satellite and a lot more (Salcedo, 2018). The government has set a target for 2025 to upsurge the share from 16% to 25% by manufacturing sector hence expecting to be the fifth largest manufacturing country in the world (PWC, 2017). The swift expansion and exposure of the internet and information in industries have generated new opportunities for the way products are designed, manufactured, and sold. SMEs must adopt new technology and practices to ensure sustainability over the long term if they want to compete in national and international marketplaces. SMEs are trying to update their business strategy to cope with the increased demand for customized products by actively adopting new technologies (Sharma and Bhagwat, 2006).

Manufacturing is the main focus of this industrial revolution. This sector plays a significant role in sustaining the progression of the economy and is considered a force multiplier, i.e. return on investment is fourfold GDP growth (Narkhede, 2017).

1.2 Industry 4.0

Every industrial revolution can be considered an era of transformation. The world we experience today is an outcome of three major industrial revolutions. At the end of the 18th century, Great Britain started the first industrial revolution, which was characterized by mechanization which made possible by steam and waterpower. The second industrial revolution originated in the United States, driven by assembly lines and electrification of industrial units which led to mass production (Bortolini et al. 2017). A new era of automated and improved production was made possible thanks to the third industrial revolution by identifying the use of electronics and IT in industrial processes (Ghobakhloo, 2018; Erol et al., 2016). The current industrial revolution is in full swing with production monitoring and automation by intertwining operation technology (OT) with information technology (IT). This digitization enables the integration of system and processes across industries so called industry 4.0 where product controls their manufacturing processes. Table 1 depicts the advancement and characteristics of industrial revolutions.

Customer Demand is very dynamic in nature. The customer of the 21st century demands the products that are best in the segment, and economical. As different needs and technologies arise, the industrial work system needs to be changed. With the increasing demand for customized products with a shorter development cycle of industry 3.0 mass production system is not the best choice economically (Schuh et al., 2014). The transition from a true physical system to a virtual system is now causing a paradigm shift in the entire production ecosystem with technological advancements happening at a fast pace. Various pillars or key technologies of Industry 4.0 is shown in Fig. 1.

Table 1. Milestones of the industrial revolution (source-DFKI 2011)

Industrial Revolutions	Year	Type of production	Key Technologies	References
Industry 1.0	End of the 18th century	Craft and Job shop production,	Mechanization using steam power	Lukac (2016)
Industry 2.0	Start of the 20th century	Mass-Production, Assembly lines	Electrification of factories	Deloitte Insights (2018)
Industry 3.0	End of the 20th century	Mass Production assisted by Automation	Robots, Computers, CNC, PLC	Schumacher, Erol and Sihn (2016)
Industry 4.0	Current Trend…	Mass customization	CPS, IoT, connected factories, smart products, Big data analysis	Kagermann et al. (2013)

Manufacturing and other industries are transitioning to Industry 4.0, which is information-internet driven. Products, machines, and people work together to create a dynamic, self-organizing networked system. It symbolizes a paradigm change from centralized to decentralized production, meaning that machines now communicate with the product to tell them exactly what to do rather than just processing it (Weyer et al., 2015).

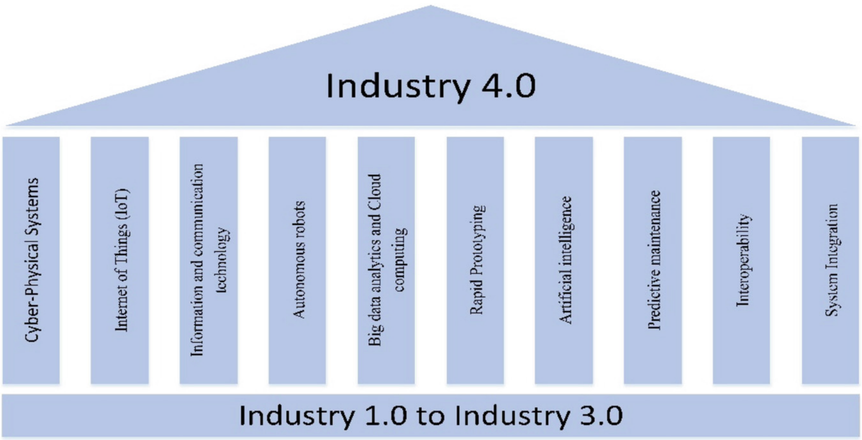

Fig. 1. Pillars (Key Technologies) of Industry 4.0

2 Literature Survey

The German government launched an endeavor to digitize the manufacturing sector in 2011 at the Hannover exhibition as a part of the "high tech strategy 2020 action plan" (Weyer et al., 2015) which sparked the fourth industrial revolution's emergence. Other economies are also facing a similar transition and coined different terms for similar development e.g., in China "made in china2025" (Qin, Liu, and Grosvenor, 2016) "Internet+", Industrial internet in the USA "Making 4.0 by European Union, and "Make in India" by Indian Government (PWC, 2017). Industry 4.0 is the intelligent fusion of the physical and digital worlds using a cyber-physical system in industrial processes by which a self-governing, self-managing network can be established between human, machine, and products (Balasingham, 2016). Despite great interest in Industry 4.0, there is no formally accepted definition for it. Industry 4.0 fundamentally indicates the technologies related to the industrial manufacturing process. Industry 4.0 focus on both hard and soft technologies, which must be advanced to improve productivity. The first paper on industry 4.0 was published in 2011 by (Kagermann et al., 2013) and molded the groundwork for industry 4.0 (Stock and Seliger, 2016). According to Jian Qin et al. (Qin, Liu, and Grosvenor, 2016) there is a basic unanimity among all researchers that the industrial revolution requires a long period to get fully developed and cover the aspects of product, customer, business, and factory. While one part of the researchers' claims that industry 4.0 coins out from the German philosophy for productivity and future growth in manufacturing enterprises and the other part argues that small and medium-scale industries cannot overcome significant obstacles (Balasingham, 2016). Recent literature on industry 4.0 provides the following obstacles to implementing industry 4.0: Resource scarcity (Schroeder, 2015), lack of knowledge management systems (Uden and He, 2017), high implementation cost (Kamigaki, 2017), lack of IT infrastructure (Yan, Zhang and Vasilakos, 2014), Employment disturbance (Frey and Osborne, 2017), lack of reference architecture (Müller, Kiel and Voigt, 2018) and many more. Despite many challenges, industry 4.0 has many Benefits: increased flexibility (Hofmann and Rüsch, 2017) (Deloitte Insights, 2018), mass customization (Deloitte Insights, 2018), increased speed (Davies, 2015), improved productivity (Deloitte Insights, 2018), better quality. After analyzing the benefits and challenges, it can be summarized that there is a mixed approach of the researchers and policymakers toward implementing industry 4.0 practices. Lack of reliable information regarding the fourth industrial revolution will impact industries. Table 2 presents the content validity of the tools and techniques of industry 4.0 as described by different authors.

According to literature and a recent poll conducted in Germany and India, industry 4.0 knowledge is still low, particularly among small and medium-sized businesses. On the other hand, IT giants are well primed and becoming a helping hand to SMEs in developing the base for Industry 4.0 implementation.

Table 2. Pillars of Industry 4.0 emphasized by selected authors

Authors	1	2	3	4	5	6	7	8	9	10	11	12	13
Deloitte Insights (2018)	✔	✔	✔	✔	✔			✔		✔			✔
Balasingham (2016)	✔		✔	✔	✔	✔			✔	✔			✔
Rüttimann and Stöckli (2016)	✔	✔	✔	✔	✔	✔	✔		✔		✔		
Leitão, Colombo and Karnouskos (2016)	✔	✔	✔	✔	✔		✔	✔					
Schuh et al. (2015)	✔		✔	✔		✔					✔	✔	
Schumacher, Erol and Sihn (2016)	✔	✔		✔		✔				✔			✔
Kagermann et al. (2013)	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Qin, Liu and Grosvenor (2016)	✔	✔	✔	✔		✔		✔		✔		✔	
Pereira and Romero (2017)	✔	✔	✔	✔		✔		✔	✔	✔			✔
Trentesaux and Rault (2017)	✔	✔	✔	✔	✔		✔	✔	✔				
Stock and Seliger (2016)	✔	✔	✔	✔								✔	✔
Chen (2017)	✔	✔		✔	✔	✔		✔					✔
Lukac (2016)	✔	✔	✔		✔		✔	✔		✔		✔	✔
Kayabay and Akyol (2016)	✔	✔			✔		✔		✔				
Lin et al. (2018)	✔	✔		✔		✔	✔	✔	✔			✔	

Note- 1: Cyber-physical systems 2: Internet of things 3: Information and communication technology 4: Industrial robots 5: Big data analytics and Cloud computing 6: 3D printing 7: Artificial intelligence 8: Virtual reality 9: Predictive maintenance 10: Interoperability 11: Learning factories 12: Enterprise resource planning (ERP) 13: Systems integration

3 Research Methodology

3.1 Industry Database Creation

The paper represents the outcome of the questionnaire survey. The aim was to analyze the readiness of the Indian industries on the trend of industry 4.0. It mainly means whether Indian industries are interested in the 4th industrial revolution and whether they are ready for adoption. An examination has been conducted in Indian SMEs Practicing Industry 4.0 tools and techniques. Prior to the examination, a database of 200 Indian SMEs was created relevant to four selected sectors, from all over the country.

The questionnaire survey was divided into four blocks, namely:

- Importance given by a company to the competitive priority
- Current advanced manufacturing practices followed
- Degree of investment in Industry 4.0 practices
- Employee willingness for the transformation to the fourth industrial revolution

Based on the operations and product. According to the MSME (Ministry of MSME - Government of India, 2018), four industries—automotive, machinery, electronics, and process—can be used to categorize SMEs in India.

This study attempts to evaluate Industry 4.0's current state in the automotive, manufacturing, process, and electronic industries. Figure 2 illustrates the methodology that has been followed to carry out the study.

3.2 Design of Questionnaire and Data Collection

A five-point Likert scale was used to develop the Structured questionnaire to assess the current technological proficiencies in Indian manufacturing industries. In this examination to seek information on industry 4.0 practices a questionnaire investigation approach has been deployed and the identification of current manufacturing practices is related to industry 4.0. To carry out the examination appropriately, an industry 4.0 questionnaire has been formed by executing a thorough literature review. The questionnaire has been pretested before the final form was shared with leading industry practitioners of 170 industries of four sectors (i.e., Automobile, process, electronics, and machinery). Finally, a total of 73 valid responses were received. The response rate is 42.94%.

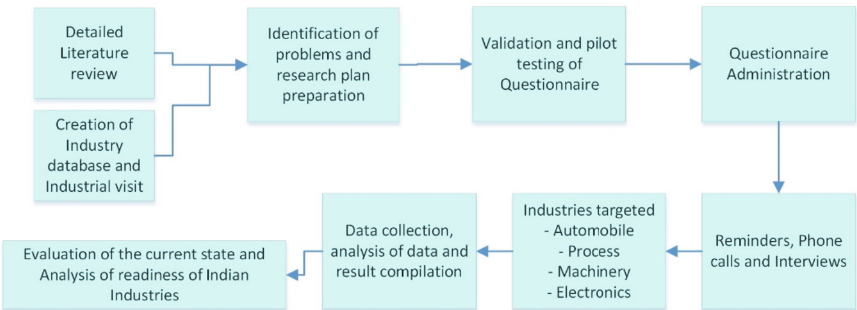

Fig. 2. Research methodology

The scale's internal reliability is evaluated using the inter-item analysis method. Each scale's Cronbach's Alpha is calculated in accordance with an empirical study performed by Flynn (Benoit, 1990) and (Malhotra, 1998). According to Table 4, each scale's Cronbach's Alpha value is greater than 0.6, which validates the empirical study (Nunnally, 1979). Sector-wise distribution of 73 respondents is shown in Table 3.

Table 3. Sector-wise Distribution of 73 respondents

Industry sector	Number of respondents	Percentage (%)
Automobile (Auto Ancillary)	23	31.50
Machinery	18	24.65
Process	16	21.91
Electronics	16	21.91
Total	**73**	**100**

Table 4. Cronbach's Alpha for the scale used

Cronbach's Alpha					
Scales used	Automobile (n = 23)	Process (n = 16)	Electronic (n = 16)	Machinery (n = 18)	Overall (n = 73)
Competitive priorities	.612	.608	.558	.760	.634
Current AMTs	.689	.804	.603	.857	.738
Industry 4.0 practices	.741	.814	.629	.846	.757
Industry 4.0 implementation	.830	.746	.811	.913	.825
Employee willingness Potential	.757	.661	.824	.873	.778

4 Measures

4.1 Competitive Priorities

Respondents are asked to rate the importance of six competitive priorities on a five-point Likert scale: flexibility, innovation, cost, time to market, quality, and customer satisfaction. The descriptive data (Mean and Standard deviation) for the aforementioned six competitive priorities are provided in Table 5. Customer satisfaction is seen as the top priority for Indian SMEs in terms of competitiveness, followed by quality, cost, time to market, and flexibility. The automotive, process, electronics, and manufacturing industries all place similar focus on these areas.

Between competing priorities, SPSS also calculates Pearson's correlation coefficient (2-tailed) which is shown in Table 6. The association is seen to be significant and positive at both the 0.05 (*) and 0.01 (**) levels. At a significance level of 0.05*, the strongest correlation (0.576**) is found between CP5 (Quality) and CP6 (Customer Satisfaction). It is true because the best quality products are key to customer satisfaction. The lowest correlation (0.232*.) is between CP1 (flexibility) and CP5 (quality) at a significance level of 0.01**. This is also true in many cases because if the system is too flexible, then quality cannot be consistent. Quality is always achieved through stability and consistency.

Table 5. Mean and standard deviation for Competitive Priorities

Competitive priorities	Automobile (n = 23)		Process (n = 16)		Electronics (n = 16)		Machinery (n = 18)		Overall (n = 73)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CP1	3.94	.198	3.63	.306	3.75	.131	3.82	.456	3.78	0.141
CP2	3.16	.125	3.06	.198	3.50	.230	3.60	.326	3.33	0.083
CP3	4.30	.257	4.10	.172	3.94	.274	4.08	.358	4.10	0.076
CP4	4.19	.345	4.01	.166	3.69	.493	3.90	.440	3.94	0.143
CP5	4.43	.103	4.21	.319	4.13	.301	4.16	.439	4.23	0.139
CP6	4.57	.270	4.43	.201	4.44	.212	4.37	.514	4.45	0.146

Note: CP1-Flexibility, CP2-innovation, CP3-Cost, CP4-Time to market, CP5-Quality, CP6-Customer satisfaction

Table 6. Pearson correlation for competitive priorities

Correlations[c]							
		CP1	CP2	CP3	CP4	CP5	CP6
CP1	Pearson Correlation	1	.039	.110	.172	.232*	.304**
	Sig. (2-tailed)		.743	.353	.145	.048	.009
CP2	Pearson Correlation	.039	1	.193	.335**	.040	.208
	Sig. (2-tailed)	.743		.102	.004	.735	.077
CP3	Pearson Correlation	.110	.193	1	.001	.148	.047
	Sig. (2-tailed)	.353	.102		.990	.211	.695
CP4	Pearson Correlation	.172	.335**	.001	1	.276*	.263*
	Sig. (2-tailed)	.145	.004	.990		.018	.025
CP5	Pearson Correlation	.232*	.040	.148	.276*	1	.576**
	Sig. (2-tailed)	.048	.735	.211	.018		.000
CP6	Pearson Correlation	.304**	.208	.047	.263*	.576**	1
	Sig. (2-tailed)	.009	.077	.695	.025	.000	

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed)
[c]List wise N = 73

4.2 Current Level of Advanced Manufacturing Techniques

Respondents were asked to rate how much advanced manufacturing technology is currently being employed in their sector. This is the initial stage in implementing industry 4.0 because no industry can use industry 4.0 tools without first understanding its current state. For this eight AMTs are identified which were the result of 3rd industrial revolution i.e., Computer Numeric Control (CNC), Computer Added Designing and Drafting (CADD), Robots, Flexible Manufacturing Systems (FMS), Enterprise Resource Planning (ERP) and Automatic Material Handling System (AMHS). Then a five-point Likert Scale is used to indicate the current use of these five AMTs (1-Not in use and 5-High in Use). From the initial statistical analysis of AMTs it is observed that SMEs of automobile companies are highly utilizing AMTs in India followed by the electronics, machinery, and process sector. For the automobile and machinery sector, the overall mean is highest for CNC followed by Robots, ERP, CAD, and FMS. The lowest mean is for AMHS which shows that Indian automobile and machinery sectors are not investing in this area and Material is being transferred from one place to another manually. For process, sector, and electronics sector highest mean is for ERP followed by CAD, CNC, and robots.

The Pearson's correlation (2-tailed) is calculated for advanced manufacturing techniques at a significance level of 0.05 (*) and 0.01 (**). At a significance level of 0.05* highest correlation (0.540**) is observed between AMT5 (CNC) and AMT6 (FMS). It is true because CNC machines are the main part of flexible manufacturing systems and the lowest correlation (0.318*) is observed between AMT1 (AMHS) and AMT2 (ERP).

4.3 Industry 4.0 Practices

On a five-point Likert scale with 1-No investment and 5-High investment, respondents were asked to indicate the level of investment in Industry 4.0 techniques, including CPS, IoT, Big data and Cloud computing, ICT, Artificial intelligence, and 3D printing. The Mean and standard deviation for Industry 4.0 practices data shows that Indian firms are investing more on fast prototyping and cyber-physical systems (CPS) before moving on to the Internet of Things (IoT). The least mean is observed for artificial intelligence. Since this term is new for most industries so there's a risk in investing in this direction.

The Pearson's correlation (2-tailed) for Industry 4.0 Practices at a significance level of 0.05 (*) and 0.01 (**) depicts at a significance level of 0.05* highest correlation (0.701**) between I4 (CPS) and I5 (IoT) and the lowest positive correlation (0.421**) is between I1 (Big data and Cloud computing) and I6 (Artificial intelligence).

4.4 Industry 4.0 Implementation Steps

Respondents were asked to describe how Industry 4.0 is currently being implemented in their organization. By these questions, we can analyze at what pace Indian industries are implementing industry 4.0. On a five-point Likert scale, respondents are asked to rate eight implementation milestones. Implementation steps are Technology assessment, Return on investment, Planning phase, Collaboration with leading I4.0 companies, Development and implementation, and post-implement evaluation. It is observed that Technology assessment is the most important implementation step followed by Return-on-investment analysis. The least important is given to development and implementation and post-implement evaluation.it is observed that Most of the Indian industries are collaborating with leading industries of the world to assess the requirement to implement industry 4.0.

The Pearson's correlation (2-tailed) for Industry 4.0 Implementation steps is calculated at a significance level of 0.05 (*) and 0.01 (**). At a significance level of 0.05* highest correlation (0.719**) is observed between IS2 (Return on investment) and IS3 (Planning phase). It is true because the return on investment plays an important role in planning to implement new technology. The lowest positive correlation (0.311**) is between IS5 (Development and implementation) and IS6 (Post-implement evaluation).

4.5 Employee Willingness

The present study asked respondents/organizations/Employees to indicate their willingness to adapt to Industry 4.0 i.e., Management commitment towards Industry 4.0, Awareness of I4.0 at the top management level, Awareness of I4.0 at the middle management level, Awareness of I4.0 at the worker level, Employee retention rate, Attitude towards conversion to I4.0 on a five-point Likert scale. The descriptive statistics (Mean and Standard deviation) of the above six Employee willingness potential demonstrates that awareness of industry 4.0 at the top management level is high. CEO and the General Managers of Indian SMEs are well-known with this industrial revolution. Awareness of Industry 4.0 at the worker level is the lowest. It is true because generally, workers are less aware of global technical changes. Still, we have found some awareness. In Indian industries, the attitude towards conversion to Industry 4.0 is also low because it will affect the jobs by automating manual laborious tasks.

Potentials for Employee Willingness are estimated using Pearson's correlation coefficient (2-tailed). The association is seen to be significant and positive at both the 0.05 (*) and 0.01 (**) levels. At a significance level of 0.05* highest correlation (0.702**) is observed between EW3 (Awareness of I4.0 at middle management level) and EW4 (Awareness of I4.0 at worker level) and the lowest correlation (0.123*) is between EW1 (Employee retention rate) and EW2 (Awareness of I4.0 on top management level).

5 Conclusion

Despite the increasing trend in Industry 4.0, there are still only a few Indian industries that are effectively trying to adopt it. According to a survey report, customer satisfaction is given the highest importance by Indian industries, while flexibility and innovation are given the lowest priority. Flexibility should be the competitive priority that can be achieved by implementing Industry 4.0. This reflects the fact that Indian industries are not utilizing the available advanced manufacturing systems. There is a need to change the traditional manufacturing system in order to bring flexibility and agility and provide customers with what they want in a very short time.

However, merely deciding to adopt Industry 4.0 does not guarantee success. Effective implementation is also necessary. From the above analysis, it is evident that Indian enterprises are attempting to adopt Industry 4.0 technology, but the achievement criteria need to be improved. There is a diversity of needs and requirements among customers and industries in every country, which depends on demographic conditions, resource availability, economic conditions, and government policies. Therefore, Indian industries should adopt Industry 4.0 after customizing it according to their specific requirements and the availability of resources.

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Internet of Things and Sustainability: A Literature Review

Khusboo Gupta(✉), Arpan Kumar Kar, and M. P. Gupta

Department of Management Studies, IIT Delhi, New Delhi, India
khusboo.gupta2712@gmail.com

Abstract. The purpose of this study is to review the literature of Internet of things research in the sustainability domain. We used keyword co-occurrence analysis to identify the newly emerging areas keeping 'internet of things' and 'sustainability' as central themes. The findings indicate energy management, smart cities, industry 4.0, artificial intelligence, smart water management, supply chain management, smart farming, and digital transformation as key emerging areas. Further, we found a strong connection between energy efficiency, IoT, and AI research. The study also highlights the usage of emerging technologies like blockchain, machine learning, digital twins, cyber-physical system, etc. contributing towards the sustainable development goals.

Keywords: internet of things · IoT · sustainability · energy efficiency · artificial intelligence

1 Introduction

The internet era began in the 1990s when the role of the internet was primarily to connect people through PCs and was referred to as the internet of people [1]. Within a short span of internet coming into existence came the internet of things. The term includes two words 'internet' and 'things' meaning things or objects that can be connected using the internet. The Internet of things is an integral part of human life and plays a significant role in improving the quality of life [2]. The role of IoT has been documented to be increasing very fast across pervasive applications involving individual usage contexts and organizational usage contexts.

If we look around within both industrial and personal usage spaces, we use a lot of IoT components such as sensing, analytics and visualization tools [3]. In the year 2021, the valuation of IoT market stood at USD 384.70 billion [4] and the market is expected to keep growing. However, the environmental aspect of IoT needs to be addressed. With industry 4.0, the technology has been condemned for causing environmental degradation [5]. It is important to work towards responsible digitalization and contribute to reducing e-waste [6]. The e-waste generated by IoT is not decomposable and holds hazardous materials alarming a critical concern about environmental sustainability [7]. The current study is an attempt to understand IoT research in sustainability domain. In this paper, we address the following research questions:

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a. What is the trend of using IoT for sustainability in scientific literature?
b. How is the nomological network for scientific literature in IoT for Sustainability?
c. Which are the major sponsoring research agencies that support collaborative research in this space?
d. What are the main discussions surrounding IoT for sustainability?

While studies have increased in this space, there is a need to synthesize the literature so that stakeholders can have a better overview of the existing state, particularly if one is venturing into this space of action research. In this study, Sect. 2 presents the methodology, Sect. 3 outlines the findings of the study followed by discussion in Sect. 4. And lastly, the conclusion in Sect. 5.

2 Methodology

Our study is the intersection of engineering and social sciences. Hence, we used the Scopus database as it is one of the largest databases for engineering and social science-focused focused literature [8]. The rigorous acceptance process ensures high-quality articles are indexed and makes it one of the most reliable databases. A keyword search was conducted on Scopus database using two keywords 'internet of things' and 'sustainability' with 'AND' operator in 'Article title, Abstract, Keywords' field. We extracted the data on 2nd November 2022. The search query displayed 2076 results, and we further narrowed down our search by filtering 'Document Type' to 'Article' and the query ended up with 949 articles. We used keyword co-occurrence analysis technique of bibliometric analysis to analyze the articles. In this analysis, keywords used by authors are extracted and network visualization map is created to identify the key trends in publications. Using Vos Viewer, we further created network visualization and density visualization map. Further, we also examined the major funding research agencies by creating collaboration networks among institutions using Vos Viewer.

3 Findings

This section has been divided into three sections: Overview of publication per year, nomological network of publications and major contributions related to sustainability in internet of things research.

A. Overview of Publication per Year: As we chose no start date, 2003 marks the first and only one publication. After an 8-year gap the second article was published. The perspective on sustainability may differ across disciplines [9]. While the initial year articles focused on creating a sustainable model for IoT usage, the idea of sustainability shifted to the environmental aspect in later years. The search resulted in 949 articles of which 97% of articles have been published after 2015. The drastic shift towards sustainability can be attributed to the United Nations declaring 17 Sustainability Goals for 2030 Sustainable Development Agenda on 1st January 2016 [10]. The number of publications increased significantly from 2019 to 2022, indicating the high incorporation of sustainability element in IoT research (Fig. 1).

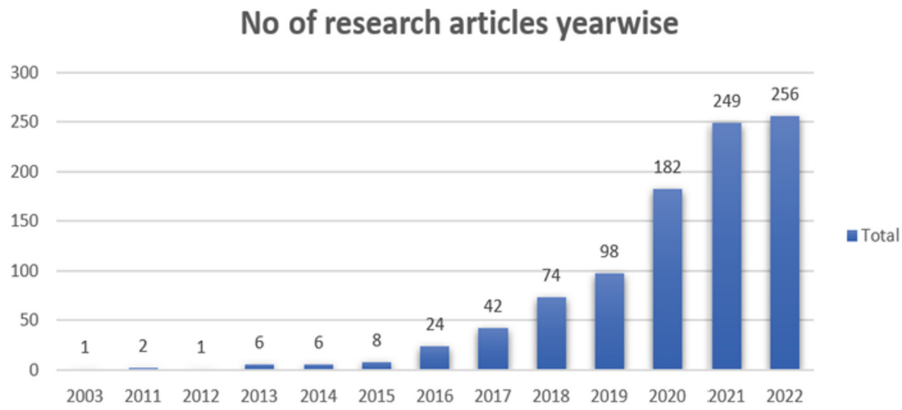

Fig. 1. Distribution of selected articles.

A look at the growth trajectory indicates that increasingly there is stronger focus on the use and applications of internet of things for achieving sustainable development. Increasingly focus on sustainability has been seen across studies working in the space of IoT, which may be accounted due to agendas set by Sustainable Development Goals of the United Nations or Climate Change Conferences of the United Nations.

B. Nomological Network of Publications: A nomological network is a visual representation of a study's concepts (constructs), their observable manifestations, and the connections among them [11]. A nomological network of publication helps to identify patterns and relationships amongst various keywords. We conducted keyword co-occurrence analysis. The frequency of a term's appearance in selected articles is indicated by the size of the nodes; the larger the node, the more frequently the keyword appears in those articles. The link between nodes denotes the similarity of keywords occurring in selected articles, while the closeness of nodes reflects the level of similarity; the closer the nodes, the more similar the keywords [12].

With the help of network diagrams around keywords (Fig. 2) we aim to understand what key new areas are emerging, keeping the internet of things and sustainability as the central theme. The surrounding clusters around the central theme in the network map gives us an idea about emerging disciplines [13]. In the era of digitalization, the internet of things technologies plays a crucial role.

Using network diagram analysis and simple manual interpretations we identified 8 emerging areas namely energy management, smart cities, industry 4.0, artificial intelligence, smart water management, supply chain management, smart farming, and digital transformation. Interestingly these themes are interconnected with each other. The application of Artificial intelligence and machine learning helps in understanding big data generated using IoT technologies, which further contributes to taking decisions on resources management. While IoT data generated can be used to take decisions on judicious utilization of resources, it also consumes energy. Thus, if we look closely in the knowledge map, we find linkage with energy harvesting and energy efficiency. There is emphasis on renewable energy sources too. The greater the circle, the greater number of times the keyword has been used in the literature. In the Fig. 2, we can locate energy efficiency, energy harvesting, renewable energy and environmental sustainability. This clearly indicates the dominance of energy management research in IoT literature in the sustainability domain.

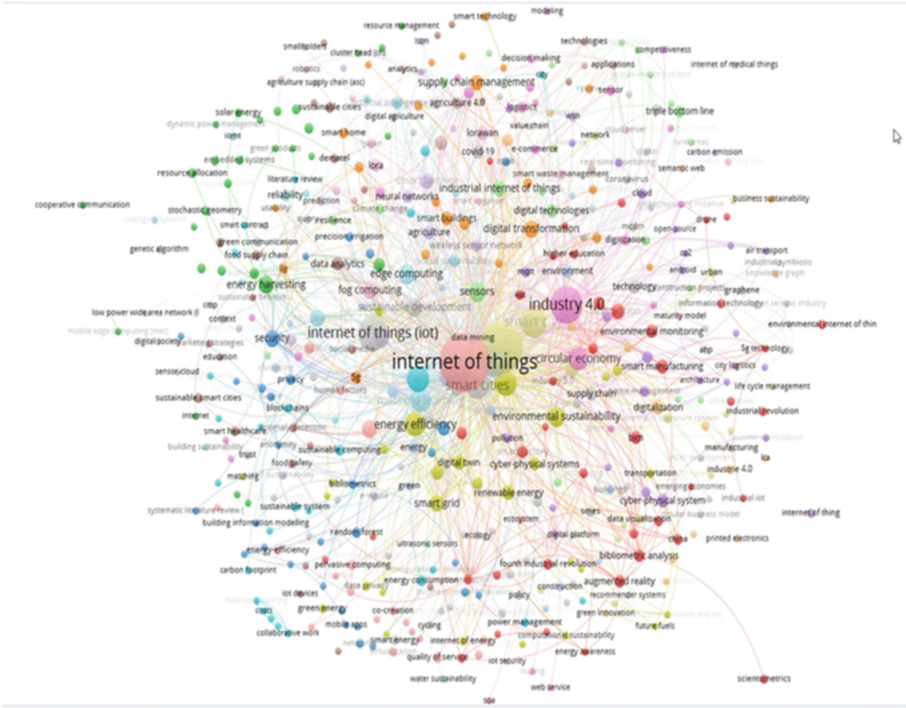

Fig. 2. Knowledge production of IoT research in sustainability based on keyword co-occurrence.

The keyword density visualization map further makes it easier to comprehend the map's general structure highlighting the most crucial areas of research. Further, using density visualization map (Fig. 3), we were able to identify the keywords with higher density. The pure yellow represents the higher density wherein indicating industry 4.0, big data, blockchain, and machine learning strongly being considered in IoT research in sustainability domain. Further, we observe the strong connection between energy efficiency, industry 4.0 and AI research.

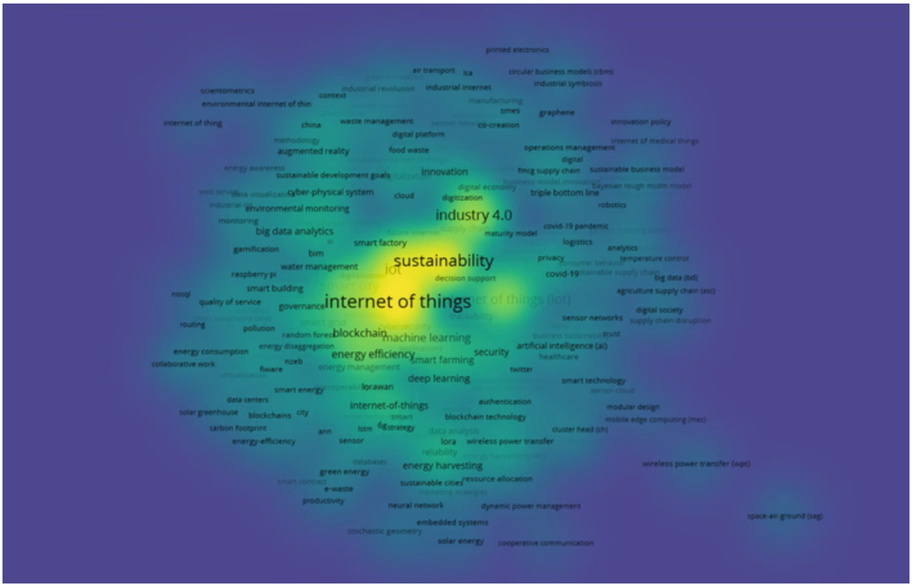

Fig. 3. Density Visualization map of dominant research themes.

We also wanted to know the major funding agencies which were sponsoring research in the space of internet of things and sustainability. Our findings highlighted, majority of the funding agencies are based out of European Union and Eastern Economies. A list of the top funding agencies are listed in Fig. 4 (Table 1).

Table 1. Dominant funding agencies in the space of IoT and Sustainability.

SN	Agency name	Count
1	National Natural Science Foundation of China	45
2	Horizon 2020 Framework Programme	39
3	European Commission	37
4	Fundação para a Ciência e a Tecnologia	24
5	European Regional Development Fund	22
6	National Science Foundation	19
7	Engineering and Physical Sciences Research Council	17
8	National Research Foundation of Korea	17
9	Deanship of Scientific Research, King Saud University	14
10	Conselho Nacional de Desenvolvimento Científico e Tecnológico	12

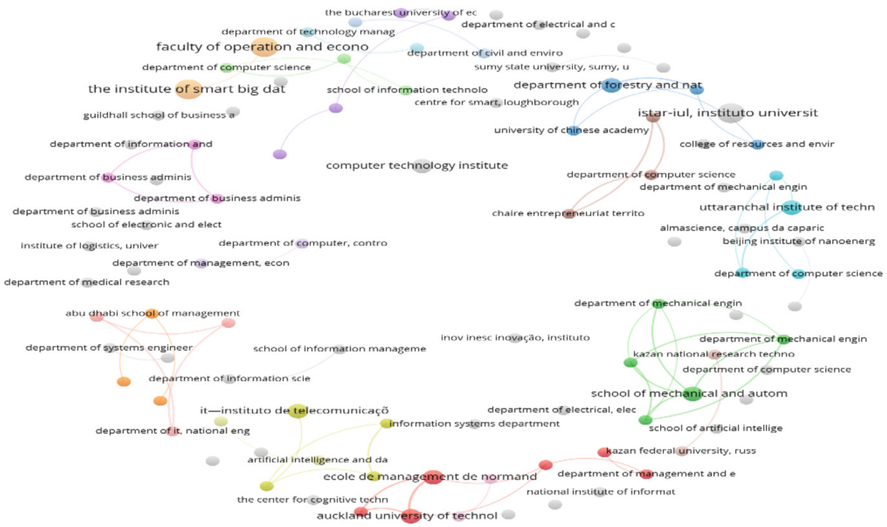

Fig. 4. Collaboration networks among institutions.

The collaboration networks across institutions indicate that there are some collaborations which is happening typically in the European region. However not much of collaborations are witnessed across other countries across continents. This therefore enables us to posit that more research calls which may foster collaboration may be made across economies where participants emerge from different continents and create cross cultural knowledge in this space.

C. Major Thematic Contributions: The existing literature highlights that sector like agriculture, water management, energy management, healthcare, logistics and operations management are using the IoT technologies to achieve their sustainability goals [14–18]. Sustainable smart cities are enabled using IoT technologies [19, 20]. Smart buildings frameworks [21], energy management for smart cities [22], mobility pattern detection system, smart traffic-monitoring deployment [23], are a few IoT use cases for smart cities discussed in the existing literature. Further, IoT literature discusses Smart healthcare for patient monitoring, remote diagnosing [24] with emergence of concept like Internet of Health Things [25, 26]. Nevertheless, the usage of other emerging technologies like blockchain, AI, edge computing, fog computing, big data analytics in these key areas are further amplifying the effectiveness of IoT towards sustainability goals. For instance, mobile crowd sensing provides mobile users to share local knowledge [27] and the data generated being used by AI can be utilized to track sustainability goals. The application of IoT sensor devices for smart farming, seed selection, irrigation, trading of crops [15, 28] in agriculture helps to cope with food scarcity problem and work towards zero hunger SDG goal. Digital twin framework yet another emerging technology in industry 4.0 has use cases in agriculture [18]. Nonetheless, digital twins are being used for designing sustainable workflow and processes for industries and organizations thereby contributing towards minimizing carbon footprints.

The current literature also contributes towards clean water and sanitation, another SDG goal by using IoT devices for blockchain based water management system for irrigation and water supply [18, 29]. The IoT literature also focus extensively on energy harvesting and energy efficiency. Energy harvesting is the small-scale capture of ambient energy for use in wireless devices [30, 31]. IoT devices mostly operate through batteries and thus there is a need for finding alternative sources of renewable energy highlighting the importance of energy harvesting systems for IoT devices [32]. In fact, computational power requires electric power, and to generate electric power, there is need to produce energy [33]. The advancement in IoT has led to exponential growth in data services usage and there is need to make next generation of cloud services to be energy efficient [34, 35]. The integration of IoT with smart energy system with emphasis on renewable resources utilization contributes to achieving sustainable development goal of Affordable and Clean Energy [36]. Environment monitoring IoT is useful as it helps to minimize the adverse impact of organization activities on the environment. Wireless sensor network (WSN) based solutions have been proposed in the literature for water quality, air contamination, radiation emissions and agricultural practices [37–39]. These IoT technologies are classified under Environmental Internet of things [40]. The literature is witnessing trend in IoT as a solution to sustainability.

Moreover, supply chain management becomes more efficient using IoT technologies. For instance, Radio-frequency identification (RFID), one of the components of IoT enables tracking products within supply chain [41]. The application of AI tools improved efficiency of supply chain along with reducing carbon footprints [42]. Nonetheless, the application of digital twin in supply chain has enhanced with the usage of IoT [43]. IoT is used with blockchain for automating smart contracts, improving utilization of existing resources, just in time manufacturing. Besides, the usage of CPS (Cyber Physical System), CPPS, big data enables efficient logistics management [44, 45]. Meanwhile, some researchers have also raised concerns about security and privacy of data collected by IoT devices [46, 47].

4 Discussion

This paper examines the incorporation of IoT in sustainability and how to deploy IoT to contribute positively to this domain. There is an upward trend in the number of publications which signifies the importance of sustainability being acknowledged for IoT research. The discussions around concepts such as Consumer Internet of Things (CIoT) [48–50], Environmental Internet of things [40, 51] Internet Health of things [25] and Internet of Underwater Things (IoUT) [52] are emerging. Keeping in view the climate change issue, it's crucial for scientific literature to address sustainability issues. With digital transformation being a key goal of organizations, the current literature contributes towards achieving the goal with minimal effect on the environment. Interestingly the applicability of IoT devices combined with machine learning and blockchain technologies is creating synergy towards accomplishing sustainability goals [15, 28]. This further highlights the potential of AI, machine learning and blockchain technologies to support sustainability goals. Moreover, emerging technologies like digital twins have huge potential for research. While technology has been argued to be creating environmental degradation, the literature reflects on how the effects can be minimized. The current literature explores various possibilities where applications of IoT can help in controlling environmental damage. The nomological network of publication clearly indicates the applicability of IoT in energy efficiency, smart farming, smart cities, water management along with usage of other technologies like blockchain, machine learning, digital twin, and cyber physical system. Further, there is also need to have strong collaborations for research especially in regions beyond Europe.

5 Conclusion

The current world is acknowledging the shift towards meeting the sustainability which is reflected in the existing literature. There is positive trend of using IoT in sustainability in the current literature. We cannot ignore the environmental implications of technology and the resources required to deploy these technologies. The data collected using IoT devices is beneficial in achieving these sustainability goals. Thus, the need of the hour is to deploy IoT technologies thriving towards overall sustainable development. The stronger collaborations and with institutional help the research in this space will flourish and thus contribute to the mankind. The existing literature highlights that the sustainability is being taken seriously, however there is future scope to explore ways of reducing environmental damage. There is further scope in exploring emerging technologies such as blockchain, artificial intelligence, machine learning, digital twin, cyber physical system etc. along with IoT towards attainment of sustainability goals.

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Smart City as a Mix of Technology, Sustainability and Well-Being: A Myth or Reality?

Anton Manfreda[1](✉) and Tea Mijač[2]

[1] School of Economics and Business, University of Ljubljana, Kardeljeva Ploscad 17, 1000 Ljubljana, Slovenia
anton.manfreda@ef.uni-lj.si

[2] Faculty of Economics, Business and Tourism, University of Split, Cvite Fiskovica 5, 21000 Split, Croatia
tea.mijac@efst.hr

Abstract. Smart city initiatives are often considered as solutions for overcoming several problems that modern cities are facing. Some of these problems refer to rapid urbanization, old infrastructure or the complexity of properly managing new technologies in cities. This complexity becomes even higher with the inclusion of sustainability and well-being. This paper examines the relationship between technology, sustainability, and well-being in the context of the smart city. The research methodology involves merging the IMD Smart City 2023 Index with the Happy City Index 2023 to identify the relation between "smartness" and "happiness". The analysis reveals a correlation between smart city rankings and happiness rankings; however, with an important discrepancy between smart city performance and happiness when observing individual scores. Additionally, an analysis of scientific literature highlights the limited research emphasis on well-being and sustainability. The findings of the paper highlight the importance of further research in understanding the impact of technology on well-being and the need for a holistic approach that combines technology, sustainability, and well-being in the development of smart cities.

Keywords: Smart city · Adoption · Well-being · Smart City Index · Happy City Index · Attitude · Sustainability

1 Introduction

The world is facing with several issues like global warming, overpopulation, resource deficit, resource allocations, uneven economic development and many others. Many of these issues are not new in the contemporary world; however, several of them are becoming more and more difficult to manage. More than 50% of the global population lives in urban areas, and this number is expected to increase by 66% by the year 2050 [1]. Therefore, problems that are arising in large cities need to be prioritized. The

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primary challenge is to preserve the distinctive qualities of metropolitan areas without harming the environment or the standard of living, especially for the forthcoming generations. Therefore, considering the proper development of the technology, with a focus on sustainability and maintaining or even improving the well-being.

Smart cities as drivers of innovation in the digital age can leverage advanced technologies such as the Internet of Things to create sustainable, open and user-driven innovation ecosystems in order to improve environmental and communication technologies and enable community co-creation of innovative living and working situations [2]. The latter may be seen as a definition of smart cities focusing on the use of technology to promote innovation with the goal of improving the community in various areas [3]. The idea of a smart city is positioned on digital transformation, where the importance of adopting information and communication technology is crucial to achieving city smartness [4]. However, smartness as a main goal may not necessarily lead to the improved well-being of individuals or a sustainable future.

The smart city concept may present one of the ways for humanity to tackle these challenges. With the combination of developing technologies and intelligent management, cities can become significantly more efficient for both inhabitants and businesses. However, the success of smart city initiatives heavily depends on many factors that may hinder their development.

To ensure the successful development and implementation of smart city projects, it is vital for policymakers, businesses, and communities to work collaboratively towards a shared vision. This involves identifying and addressing potential obstacles, investing in the necessary infrastructure and resources, and fostering a culture of innovation and experimentation. By doing so, smart cities may harness their full potential to create sustainable, resilient, and prosperous urban environments that can effectively tackle the global challenges of the future.

The latter sounds like a perfect-case scenario, easily written on paper. Yet the reality is different. Cities are facing with the problems of too rapid urbanization, old infrastructure not being able to cope with the speed of urbanization, individuals reluctant to change their habits, managing the complexity of all interlacing technologies and many others.

A smart city relies on citizens assuming a crucial role in identifying innovation and actively gathering and sharing data, rather than solely reacting to provided information. The future hinges on empowered citizens who drive urban change. Thus, the significance of smart citizenship should be underscored. By leveraging technologies that enable self-expression, social interaction, and the sharing of assets and knowledge, smart citizens can become engaged, enthusiastic, and well-informed decision-makers [5].

However, this process is multifaceted, encompassing various aspects including technology adoption, change management, inclusiveness, and well-being, among others. Existing research on smart cities often fails to address many of these interconnected dimensions. Hence, the objective of this paper is to investigate the interplay of technology, sustainability, and well-being in smart cities, considering both the current state in the cities and relevant scientific research. In the first part, the concepts are briefly presented. The second part briefly presents the methodologies followed by the results section. Finally, a concluding remark is outlined.

2 Literature Review

2.1 Sustainability

The concept of sustainability initially focused primarily on environmental challenges, particularly the conservation of limited natural resources. Key considerations included climate change, clean energy, sustainable transport, sustainable consumption and production, conservation and management of natural resources, and public health. Gradually, attention shifted to include social and economic aspects, primarily in relation to demography, migration, global poverty, and sustainable development challenges [6].

When discussing sustainability in relation to organizations, the commonly employed Triple Bottom Line model [7] represents a balance between the environmental, social, and economic pillars. This model remains widely used as it emphasizes the need for socially and environmentally responsible behavior in organizations while also allowing for economic growth [8]. This holistic approach introduces a new concept of organizational sustainability, recognizing that organizations have a changed role in society and must make strategic decisions aligned with their new social context [9].

Cities, despite their unique challenges, are not exempt from the pursuit of sustainability. With urban environments rapidly expanding and over half of the world's population already residing in cities [10], their role in achieving global sustainability is crucial [6]. Digitalization can serve as a tool to foster sustainable development and enhance the quality of life for citizens, provided it offers practical solutions that benefit their daily lives [11]. Digitalization is therefore presenting a opportunity in organizations and society, and the concept of smart cities is just one of them.

2.2 Smart City

The concept of a smart city is a complex phenomenon that has been explored by numerous researchers, yet a unified definition has not been established. The prevailing understanding emphasizes the use of information technology as a fundamental requirement for a smart city, encompassing economic, managerial, and social aspects [12]. Thus, the concept of smart cities encompasses various crucial aspects of contemporary urban life, including smart mobility, smart living, smart environment, smart citizens, smart government, smart economics, smart architecture, and smart technology [13]. While technology plays a promising and valuable role in creating smart cities, its mere implementation alone is insufficient to generate benefits for society.

Smart cities are closely intertwined with the concepts of the Internet of Things and big data, as the availability of automatically collected data opens up new opportunities for developing and managing public information services. Extensive research has already been conducted from a technological perspective [14]; however, there is still a gap in understanding personal considerations and perceptions [13]. Additionally, recent research has focused on conceptualizing smart cities [15, 16], but there is a lack of comprehensive answers regarding the use of digital technologies to support a sustainable future in these cities.

After all, it is important to consider the elements that link technology adoption and personal characteristics [17], as well as to understand how individual behavior can be transformed to align with a more sustainable future-oriented mindset.

The rapid growth of urban areas in recent years has stimulated the adoption of diverse digital technologies within smart cities worldwide [18]. These technological advancements serve as the primary drivers of digital transformation and are important in shaping smart city initiatives [19]. Their integration, coupled with enhanced governance and the human capital of citizens, ensures that smart cities can bring the positive social change for society as a whole [20]. However, the global trends of urbanization and the pressing sustainability concerns pose significant challenges for smart cities [21] potentially affecting the well-being as well. The cities must address the social and environmental sustainability issues confronted by society, including sustainable economic growth, high quality of life, prudent utilization of natural resources, and smart governance [22].

Therefore, several definitions on smart cities can also be categorized as sustainability-oriented definitions and non-sustainability-oriented definitions [23]. An initial sustainability-oriented definition would be that smart cities leverage not only digital technology to improve traditional networks and services for residents and businesses, but go beyond it by reducing pollution and resource use. It implies better urban transit networks, updated water, and waste systems, and more efficient lighting and heating. It also implies a more responsive local government, safer public places, and accommodating an ageing population.

To attain a smart city, there is a need for increased community participation and to use the technology to accomplish positive community impacts. The technologies of a smart city should also raise residents' standard of living overall. Several activities and solutions in smart cities can enhance the quality of life [24]; however, residents need to perceive them as valuable for their quality of life as well.

3 Methodology

The research methodology in this paper consists of three parts. In the first part of the analysis, the IMD Smart City 2023 Index [25] was merged with the Happy City Index 2023 [26]. Cities that appeared in both indices were identified, resulting in a total of 97 cities worldwide for further analysis. SPSS software was used to analyze the relationships between the rankings and the individual scores of the cities in both indices.

The second part aimed to analyze existing papers on the adoption of smart technology, published in peer-reviewed scientific journals. A keyword search was conducted in the Web of Science (WOS) database. The search criteria included relevant words related to smart technology and either acceptance or adoption, appearing in the title, keywords, or abstract. Only research articles or review articles published in English-language journals indexed in SCI, SCI-expanded, or emerging SCI were included. Papers from WOS categories not relevant for our study such as surgery, orthopedics, veterinary science, art, radiology, and similar fields were excluded.

A total of 3,626 papers published between 1995 and 2023 were further analyzed using VOSviewer software and R Studio (biblioshiny tool). A co-occurrence analysis was performed in VOSviewer on 13,514 keywords with a minimum threshold of 50 occurrences. Additionally, a tree analysis was conducted in R Studio using unigram tokenization on the abstracts of the included papers.

In the third part, a web-based questionnaire was developed, focusing on technology interest, sustainability orientation, smart city-related services, and their impact on the quality of life. In the survey 315 millennials from Slovenia participated, and a total of 214 valid responses on all question sets were collected. The demographic characteristics of the respondents are presented below (Table 1).

Table 1. Profile of respondents

		Share
Gender	female	61%
	Male	39%
Education (highest completed)	high school	55%
	undergraduate	37%
	graduate	8%
Type of settlement	City	46%
	suburban settlement	21%
	a smaller compact settlement	26%
	scattered houses or secluded houses	7%

4 Results

4.1 Relation Between the Smart City and the Happiness

The initial analysis focused on examining the correlation between smart city rankings and happiness rankings. The correlation was found to be statistically significant (Pearson correlation 0.695, significant at the 0.01 level). Figure 1 illustrates a scatter plot of the two rankings. It is important to note that the scales on the axes are different due to the inclusion of several cities in both indices, while our analysis only included cities appearing in both indices, maintaining their original ranks. Lower rank numbers indicate better cities, implying that cities in the lower-left corner are considered the best cities from both the smart city and happiness perspectives.

However, as evident from the Fig. 1, there is a considerable dispersion among the cities. The green circles represent cities that perform well or poorly in terms of both indices. Interestingly, there are several cities that excel in terms of smart city ranking but have relatively low happiness rankings. Consequently, instead of solely examining the ranking positions, we conducted a further analysis of the individual scores received by each city in our sample (Fig. 2).

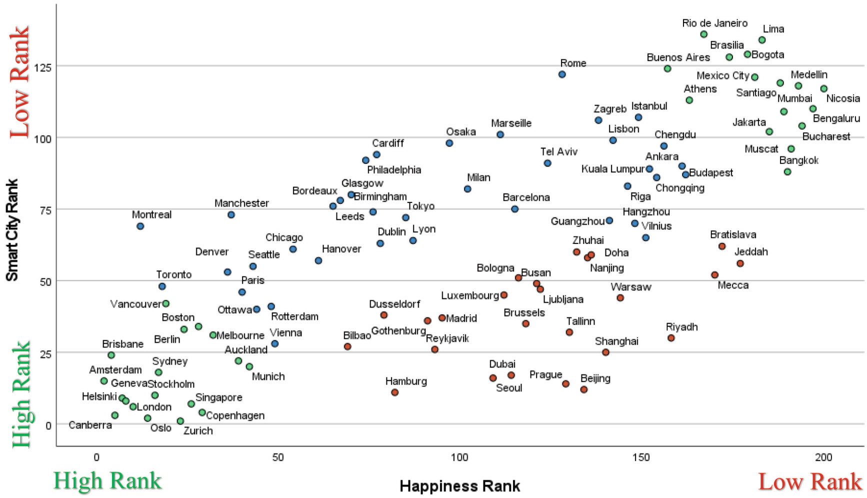

Fig. 1. Relation between smart city rank and happiness rank.

The maximum score for the happiness was 400, while for the smart city score it was 1.00. As a result, cities in the top-right corner of Fig. 2 are considered the best cities from both perspectives. An important observation derived from Fig. 2 is that the majority of cities received commendable scores for the smart city aspect. However, several of these cities performed poorly in terms of happiness.

This observation suggests that solely focusing on increasing smart city scores or enhancing the "smartness" of a city does not necessarily lead to increased happiness within that city. It implies that a holistic approach, considering factors beyond technological advancements, is crucial for achieving overall well-being and happiness in urban environments.

4.2 Bibliographic Analysis of Papers Dealing with Technology Adoption

Given the findings above, we wanted to deeply analyze the scientific literature and the focus of research dealing with smart technology adoption or acceptance. The first observation is that the topic is of interest globally despite some obvious clusters (Fig. 3). After all, it is not surprising due to the similar problems that cities are facing globally.

However, upon conducting a thorough analysis of the abstracts and keywords of the sampled journals within the field, we discovered that scientific papers can be categorized into four major clusters, with well-being being noticeably absent (Fig. 4). The predominant focus of research is primarily centered around (1) the adoption of existing and new technologies and the identification of associated factors, (2) the exploration of underlying technologies and concepts, (3) the consideration of smart technologies as emerging technologies, and (4) the examination of climate change-related issues.

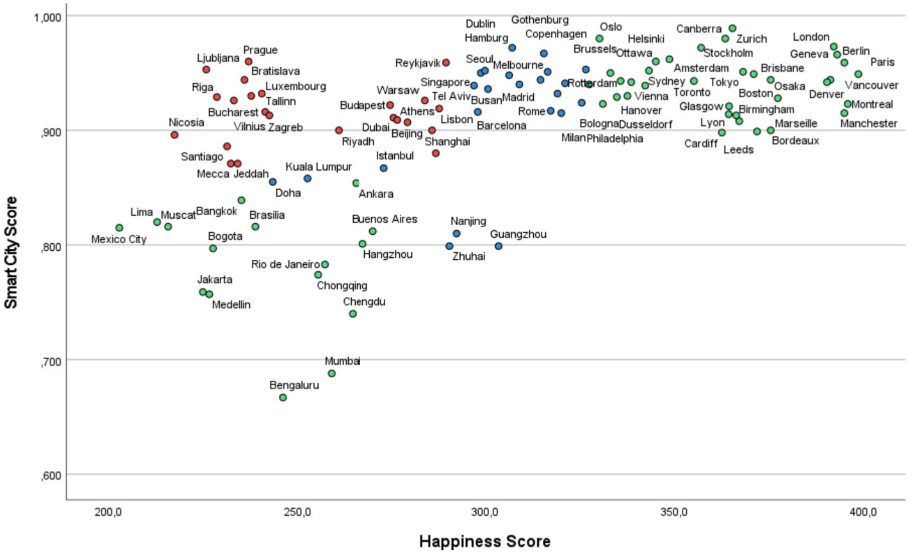

Fig. 2. Relation between smart city score and happiness score.

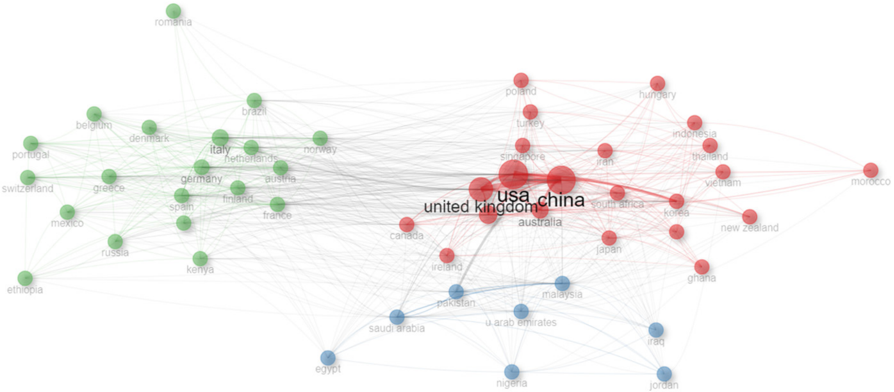

Fig. 3. Collaboration network for smart technology adoption.

Interestingly, the absence of a dedicated cluster for well-being, happiness, or sustainability indicates that the research primarily emphasizes facilitating the adoption process, with less emphasis placed on investigating the impact of smart technology on well-being. There are some rare papers dealing with well-being and smart technology, yet mostly focusing either on older adults only, learning performance or the impact of smart tourism technologies on the well-being of tourists.

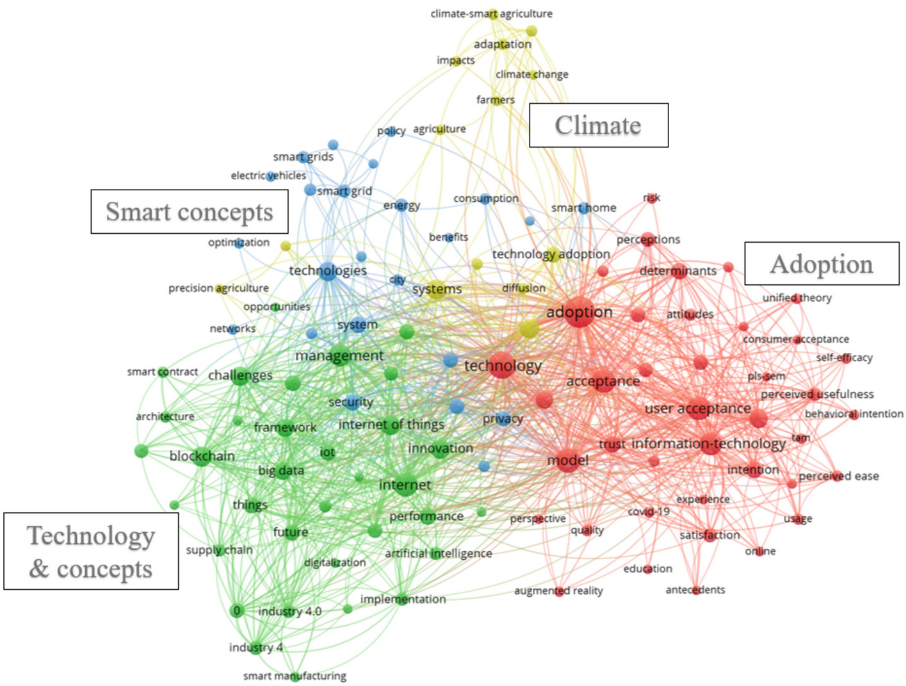

Fig. 4. Co-occurrence analysis of 3,626 papers dealing with technology adoption

We obtain similar findings also by using unigram tokenization on abstracts of included papers (Fig. 5). Again, words such as smart, technology and adoption are understandably prevailing in these studies, while words referring to well-being, happiness or sustainability are not among most common words, signifying that these topics are not a central idea of technology adoption research papers.

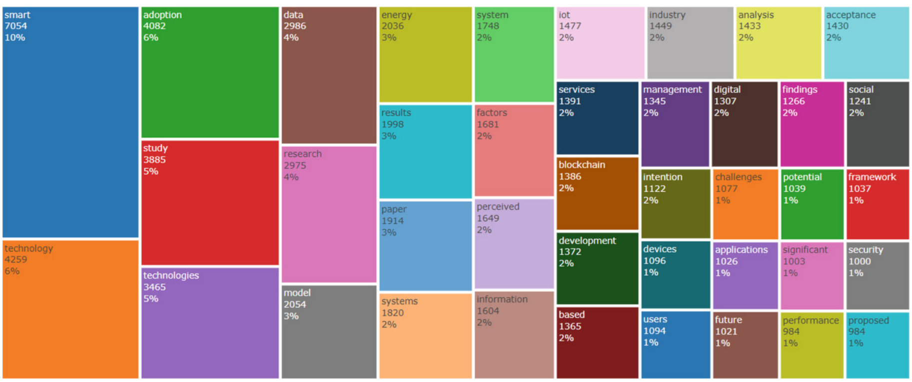

Fig. 5. Tree analysis using unigram tokenization on abstracts of included papers

4.3 Attitude of Millennials Towards Technology and Sustainability

We additionally wanted to examine the attitude of millennials towards the selected topic. Based on the initial data we received it is evident that additional focused research on areas combining technology, sustainability and well-being is needed. Individuals in our sample in the majority do not have any problems with using new technologies and are even not concerned about their future jobs or afraid that in the future they may not be able to follow new technologies.

Sustainability appears to be a high priority for the respondents; however, when examining their specific behaviors (such as choosing a mean of transport or active participation in reducing the negative impact on the environment), a discrepancy between awareness and action emerges. Despite their awareness of sustainability issues, their individual behaviors suggest less sustainable practices. This highlights the importance of bridging the gap between awareness and action to promote more sustainable behaviors among millennials.

Moreover, the respondents generally view smart cities as entities that enhance the quality of life (Table 2). However, they express less preparedness to live in such cities and show some hesitation in contributing to the community by providing the necessary data for the functioning of smart cities. Mostly they are prepared to share the data in case of some return benefit such as a direct reduction in the cost of living.

Table 2. Attitudes of millennials towards technology, sustainability and smart cities

	disagreement				agreement	Mean
	1	2	3	4	5	
I am excited by the possibilities offered by new technologies.	1%	4%	12%	51%	32%	4.1
Caring for the environment is very important to me.	1%	2%	10%	54%	33%	4.2
When choosing a means of transport, its impact on the environment is important to me.	10%	18%	33%	32%	8%	3.1
Smart cities can improve the quality of life.	2%	4%	18%	60%	17%	3.9
I look forward to living in a smart city.	3%	12%	28%	42%	15%	3.5
I would be willing to share a larger amount of my data without the immediate expected mutual benefits.	22%	34%	26%	16%	1%	2.4
I would be willing to share a larger amount of my data if it meant raising the quality of life of the whole community.	7%	18%	22%	44%	9%	3.3

These results highlight the need for further research in this area, particularly in examining the detailed relationship between technology and well-being. After all, a smart city is a complex combination of technologies aimed at creating better living environments for individuals. While individuals show a favorable attitude towards adopting new technologies and believe that smart cities can address various modern problems, they are less prepared to actively contribute to the environment necessary for the successful functioning of such cities. Therefore, additional research considering the elements of happiness, well-being, and sustainability is required to gain a more comprehensive understanding of the relationship between technology and well-being in smart cities.

The limitation of the paper is that only the cities that have the data for both the IMD Smart City 2023 Index and the Happy City Index 2023 were included in the further analysis. Another limitation of the study is that it focused only on papers dealing with technology adoption or acceptance, while the keyword happiness or well-being was not included as the search criteria. However, this was the intention of the research to examine the papers dealing with technology adoption only and to study the focus of these papers. Lastly, in the web-based questionnaire, millennials on the voluntary basis participated not presenting a representative sample of the population.

Future research should be conducted on merging various indices to compare the relation between different categories and subitems within these indices in order to identify additional underlying structures among smartness and happiness. Further, additional research on analyzing relevant papers should be conducted by deeply analyzing the relevancy of each paper for inclusion and using text mining techniques to additionally identify focus areas of these papers. Lastly, a discussion regarding the suitability of existing technology acceptance models and involved factors in order to provide solutions that are leading to sustainability, well-being and happiness should be encouraged. A turbulent environment is already presenting a challenge for existing well-established technology acceptance models in order how to properly address and identify the crucial factors; while sustainability and achieving a state of suitable well-being are presenting additional challenges on how to incorporate these concepts into existing models.

5 Conclusion

Living in a city is becoming increasingly popular as people are attracted to the variety of employment, educational, and recreational opportunities that only diverse urban environments can provide. However, due to the high population density and increased work activity, there are several drawbacks related to pollution, traffic, and public health care problems. The smart city concept may present one of the ways for to tackle these challenges. However, the success of smart city initiatives depends not only on proper technology or technology implementations, but on considering wider complex aspects of intertwining the technology, sustainability and well-being.

This paper examines the smart city concept through the lenses of technology, sustainability, and well-being, considering the current state of cities and a substantial body of scientific literature on technology adoption. The findings highlight the strong need for future research that embraces a holistic perspective and reconsiders existing technology acceptance models to incorporate contemporary issues.

After all, the smart city can be both, a myth and reality. The result mostly depends on the ability to properly manage the technology, sustainability, and well-being. As evidenced in the paper, there are already numerous smart cities around the world facing challenges in achieving happiness and well-being for their inhabitants. Or written differently, there are already too many unhappy, yet smart cities in the world.

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Managerial Competencies for Human Brains and Mechanical Muscles Interplay; A Study of Automotive Industries

Mugdha S. Kulkarni(✉) and Kanchan Patil

Symbiosis Centre for Information Technology (SCIT), Symbiosis International (Deemed) University, Pune, India
{mugdha,kanchan}@scit.edu

Abstract. Industry 5.0 is a complex phenomenon emphasising integrating advanced technologies with human-centric principles to drive innovation and productivity. Industry 5.0 requires extensive technological, managerial and organisational capabilities to create value through the seamless interplay between humans and machines. Personalised, high-quality products are available faster and cheaper when human brains work harmoniously with mechanical muscles. The Cobot-human relationship is symbiotic, strengthening humans and machines to complete production processes.

Considering how human agents will acquire the skills necessary to act autonomously and progress the techno-social revolution in an Industry 5.0 setting is critical. To be human-centric, resilient, and sustainable, industry 5.0 development is from the standpoint of distinct managers' understandings of skills, roles, and responses. Insights from the pertinent academic literature and exploratory qualitative research techniques were used to establish critical managerial competencies for long-term contribution to humanity. Primary data collected through in-depth interviews with managers in 10 different automotive industries were analysed to highlight human-centricity, resilience, and sustainability factors, which can assist automotive industries in propagating Industry 5.0 usage.

This study shall contribute to creating a paradigm shift that requires the management's role to change from profit-centricity to human-centricity, thereby improving productivity.

This study shall contribute to information system research and project management research. This research provides essential insights to business groups, policymakers, academics, and other stakeholders working to build the skills necessary for a sustainable business.

Keywords: Industry 5.0 competencies · human centricity · resilience · sustainability · managerial capabilities · automobile industry

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1 Introduction

The term “Industry 5.0” describes the subsequent stage of industrialisation, which expands on the ideas of “Industry 4.0,” which emphasises automation, connection, and digitalisation. Industry 4.0 strongly emphasises the application of cutting-edge technologies to boost output and efficiency. The EU defines Industry 4.0 is “a vision of an industry that aims beyond efficiency and productivity as the sole goals and reinforces the industry’s role and contribution to society”. It is the 4.0 new industrial revolution focused on Humanism and ethics [1]. It is more phased towards advanced technology. AI-based Robots, IoT, blockchain, smart contracts, etc., add to the efficiency as well as productivity of the organisation. The human-centric motivation, as well as augmented resilience, emphasises sustainability. Even though CSR activities always prevailed, there was a need to prioritise people and the environment over profits, shifting the industry’s emphasis. To establish a more comprehensive viewpoint than Industry 4.0, the concept of Industry 5.0 expands the organisation, becoming more human-centric, resilient, and sustainable as the main foundations of Industry 5.0. The study concludes that developing these managerial competencies is critical for the automotive industry to thrive in the future. A new product’s cost can be estimated using software for manufacturing costing. It automates the costing processes and shortens the time to market new products. Based on the earlier industrial revolutions, when compared to Industry 4.0, which focused on digitising and automating production processes, Industry 5.0 goals to integrate cutting-edge technology with a human-centric strategy. This strategy strongly emphasises the value of social responsibility, resilience, and sustainability [2].

1.1 Research Question

To reflect new thinking and improve performance, changes would follow technological changes in relationships among organizational stakeholders, defined “smart” as the “changes in approaches to work, work cultures, business architecture, premises, decision making, communications, and collaboration”.

1.2 Research Objectives

- Evaluate each manager’s existing competence as a manager in an automotive or -organisation embracing Industry 5.0.
- Identify the critical competencies individual managers need to operate and lead successfully in an Industry 5.0 human-centric, resilient, and sustainable environment.

2 Literature Review

2.1 Manager Competencies to Promote Human-Centricity Values

Organisations can acquire specialised capabilities that prioritise the welfare and empowerment of individuals to adopt human-centric values in Industry 5.0. The human-centric approach “promotes talents, diversity, and empowerment.” [3]. Humans, as a resource, need to focus. Focusing on human resource talent will help to transition into the digital era across many industries, including education, by placing the interpersonal and human components at the centre of our activities [4]. However, the modern digital world emphasises "human-centricity" as a crucial element of the future workplace. They are integrating cyber-physical systems (CPS) into industrial processes.

2.2 Manager Competencies to Promote Strategic Resilience

According to the European Commission, a resilient approach is where companies are agile and flexible and change by adapting to new technology. However, organisations high on flexibility and agility are only sometimes resilient [5]. Effectiveness and profit enlargement are significant factors of the business. The addition of flexibility and adaptability concerning the "lean" version is specifically motivated by the importance of competence. Some anti-fragile organisations learn to foresee, respond and earn systematically from the crisis to guarantee stable and long-lasting performance [6].

2.3 Manager Competencies to Promote Sustainability

An organisation focused on sustainability is fully aware of its responsibilities to various stakeholder groups. Such a company deliberately enhances its social and ecological performance while considering socio-technical concerns. Reconciling divergent and competing requirements within an evolution towards more sustainable business practices might take time [7].

3 Research Methodology

3.1 Qualitative Study

This research used the grounded theory technique to better understand managerial competencies in Industry 5.0. The study also examines the ideas and insights of managers directly involved in providing goods and services related to the automotive sectors in emerging economies.

3.2 Data Collection

After approaching 25 organisations initially, we conducted in-depth interviews with ten managers from 10 automotive industries with headquarters in Pune and the Pimpri-Chinchwad automotive industry belt. Nine in-person interviews and one telephone interview were conducted over three months. The managers we spoke with were knowledgeable about industrial procedures and had over five years of experience.

One is in a leadership position inside the autonomous organisation. The Mahratta Chamber of Commerce, Industries and Agriculture (MCCIA) database, a network and advocacy organisation for Indian businesses in Pune, contained information on the sample of managers. We utilised the following selection criteria to decide which managers would be qualified for this study's interviews: (1) deliver products and services in their respective organisation, (2) have the authority to move company resources as needed, and (3) be responsible for increasing organisation performance. The organisations and people had to remain anonymous due to the sensitive information provided in these interviews. Identifier codes were given to each organisation and its members to achieve this anonymity. Ten individuals across ten organisations were interviewed (Table 1).

Table 1. Anonymised Organisation & Participant Breakdown

Manufacturing Industry code	Individual code	Position	Industry
O1	I1	Managers	Electronics/Electrical
O2	I2	Assistant Manager	Engineering
O3	I3	Managing Director	Aerospace
O4	I4	CEO	Chemical
O5	I5	Technology con-consultant	Automotive
O6	I6	Managing Director	Engineering
O7	I7	Assistant Manager	Automotive
O8	I8	Management consultant	Electronics/Electrical
O9	I9	Managing Director	Automotive
O10	I10	Assistant Manager	Automotive

3.3 Data Analysis and Findings

All of the interviews were recorded and then transcribed verbatim. The coding strategy was used independently by the two researchers who participated in this study to analyse the data. The independent assessments' results helped build the human-centricity, resilience, and sustainability factors. Thematic analysis by NVivo 12 Pro software was used to analyse the transcribed interviews and significant themes related to sustainable development functions like human centricity.

Manager Competencies to Promote Human Centricity

According to Table 2A, out of 10 respondents, six agree that employee empowerment is a significant aspect of human centricity. Industry 5.0 is all about enhancing the digital transformation of enterprises through the effective fusion of people and technology so that they may work more productively together in a secure setting. Even though less than 50% of the respondents agree with diversity and inclusion, a company like Accenture

Table 2. Human Centricity Factors in Industry 5.0 Context

Manager Competencies to promote Human-centricity	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	Total
Employee Empowerment	√		√		√	√		√		√	6
Diversity and Inclusion		√			√		√			√	4
Work-Life Balance	√		√		√	√	√	√	√	√	8
Skill Development and Lifelong Learning	√		√		√	√	√	√	√	√	8
Ethical and Transparent Practices	√		√			√		√			4
Customer-Centric	√			√	√	√	√	√		√	7
Social Responsibility	√		√		√		√		√		5

asserts that organisations use a human-centric approach. The strategy may grow adaptable and resilient in challenging and unpredictable social and economic settings [26]. 80% of the respondents agree that work life is a challenge, and Industry 5.0 will give flexible working arrangements, which are becoming increasingly common in industrialised nations. However, it is unclear how they will affect their health and happiness. Lifelong learning is an important aspect where Companies have been obliged to evolve, embracing continuous learning (lifelong learning) to provide their employees with the training and skills necessary. For the new professional responsibilities to reduce this training gap. As shown in the table, 70% of the respondents agree on ethics and transparency. Industry 5.0 asserts that it will move away from technical productivity methods and towards a more human-centred strategy. Socio-technical interoperability between people and AI systems is a necessary first step.

Manager Competencies to Promote Resilience

Industry 5.0 also emphasises the importance of resilience in disruptions such as natural disasters and pandemics. Developing flexible and adaptable manufacturing processes enables quickly responding to changing conditions. It also involves implementing risk management strategies that can mitigate the impact of disruptions.

According to Table 3, resilient organisations can maintain their enthusiasm under stress, handle disruptive changes, and adapt. They recover quickly after failures. They also conquer significant obstacles without acting dysfunctional or hurting other people. Hence, more than 70% of the respondents agree that strategic thinking, adaptability and flexibility are substantial factors in Industry 5.0. Also, 60% more than half of the respondents agree with Making Decisions in an Uncertain and building stakeholder relations. In our rapidly changing world, organisations frequently face challenging decisions that must be made quickly and effectively. However, risk and uncertainty can significantly affect decisions, which might bother and worry organisations. Examines the challenges of choosing wisely in risky and ambiguous circumstances and provides insightful guidance, including scenario planning and prototyping, communication, and risk management. According to psychological research, organisations with emotional

Table 3. Resilience Factors in Industry 5.0 Context

Manager Competencies for Resiliency	I1	I2	I3	I4	I5	I6	I7	I 8	I9	I10	Total
Strategic Thinking	√									√	8
Adaptability and Flexibility		√	√	√	√	√		√		√	7
Management of Risk	√	√	√			√		√	√	√	7
Making Decisions in an Uncertain		√	√			√		√	√	√	6
Leadership and Emotional Intelligence	√	√	√		√			√	√	√	7
Building strong relationships with stakeholdersers	√	√		√	√	√		√	√	√	8
Continuous Learning and Personal development	√	√	√	√	√	√			√	√	8
Crisis management		√	√		√	√		√	√		6

intelligence may also be crucial in high-stress battle circumstances where cognitive performance is limited. This lack of cognitive function frequently occurs in stressful and high-pressure professional contexts. It is noticed that 80% of the organisations agree that EI is important, and 60% agree that crisis management and the capacity to thrive despite disaster risk. Also, managers can prepare for, deal with, withstand, and recover from disasters. e.g. Covid crisis management with work from home, especially in the manufacturing sector.

Manager Competencies to Promote Sustainability

Sustainability is a vital component of Industry 5.0. The industry aims to decrease carbon footprint and curtail waste through renewable energy sources and sustainable manufacturing practices. It comprises the usage of eco-friendly materials and the implementation of circular economy principles.

Table 4. Sustainability Factors in Industry 5.0 Context

Manager Competencies for Sustainability	I1	I2	I3	I4	I5	I6	I7	I 8	I9	I10	Total
Environmental Awareness	√		√		√	√		√	√	√	7
Strategic Planning for Sustainability		√			√		√	√		√	5
Sustainable Innovation:	√		√		√		√	√	√		6
Performance Measurement and porting	√		√		√	√		√	√	√	7
Collaboration and Partnerships	√	√	√			√	√	√	√		7
Circular process	√			√	√	√	√	√		√	7
Sustainability values		√	√		√	√	√				5

According to Table 4, 7, out of 10 respondents agree that organisations must emphasise environmentally friendly practices using cutting-edge technology. Manufacturing operations comprehensively apply renewable energy sources—like solar or wind energy. Performance measurement and reporting, where 7 out of the 10 respondents agreed, mentions that Organisations can assure compliance with environmental laws, industry standards, and sustainability frameworks by measuring and reporting on their sustainability performance. Organisations can identify gaps or areas of non-compliance and take corrective measures to align with applicable legislation and standards by routinely monitoring and reporting their sustainability performance. A circular process where Industry 5.0 technology can make manufacturing processes more resource-efficient by increasing product lifespan, decreasing waste, and optimising output. For instance, IoT sensors and data analytics can optimise energy and material to ensure that resources are used effectively throughout the production cycle. Sustainable values out of 10,7 respondents agreed. To share information and best practices values in sustainability, organisations should.

4 Discussion

Industry 5.0, which emphasises human-centricity, strives to establish a harmonious partnership between people and machines in which technology enhances rather than replaces human talents. This method produces superior results in innovation and problem-solving and enhances job satisfaction, engagement, and productivity. The following are the factors that play a significant role in Industry 5.0

4.1 Human Centricity

- **Employee Empowerment:** Organisations ought to promote an atmosphere that gives employees agency and promotes active engagement. Such an environment encourages open communication, involves workers in decision-making, and offers career advancement opportunities. Employees who feel empowered are more driven, engaged, and willing to contribute to the organisation's success [8].
- **Diversity and Inclusion:** Small and medium-sized businesses (Organisations) should appreciate diversity and foster inclusive workplaces that value and respect individual differences. Encouraging diversity in hiring procedures, ensuring every employee has an equal opportunity to succeed, and building an inclusive and respectful workplace atmosphere is vital [9].
- **Work-Life Balance:** The work-life balance entails providing flexible work schedules, encouraging healthy work habits, supplying tools for stress management and preserving one's mental and physical well-being. Supporting work-life balance increases productivity, job satisfaction, and employee satisfaction [10].
- **Skill Development and Lifelong Learning:** Organisations should support lifelong learning and invest in their personnel's ongoing skill development. Staff members learn new skills and information through mentorship programmes, workshops, and training sessions [11].

4.2 Competencies for Resilience

It is adept at organising and leading teams in stressful situations while maintaining composition and making wise choices. They know the significance of effective communication, resource allocation, and quick problem-solving in crises. Strategic thinking.: Resilient organisations can strategise and foresee upcoming difficulties and disruptions. They know the broader market dynamics, technical developments, and new trends that could impact the sector. They can direct the - organisation towards resilience by considering various circumstances and creating proactive measures [12].

Adaptability and Flexibility. Resilient organisations are adaptive and flexible in the face of change. To respond to unforeseen occurrences and changes in the market, they can swiftly modify their plans, procedures, and business practices. They welcome innovation and constantly seek new advancement chances [13].

Management of Risk. Resilient organisations are adept at recognising, evaluating, and controlling risks. They thoroughly know the business's possible hazards and take proactive steps to reduce them. Risk management frameworks, creating backup plans, and ensuring operations continue during a disruption [14].

They are Making Decisions in an Uncertain World. Resilient Organisations are skilled at making defensible choices in complex and challenging circumstances. Before making strategic decisions, they acquire and analyse pertinent data, communicate with stakeholders, and consider various viewpoints. They can make prompt judgements to guide the organisation towards resilience because they can easily take calculated risks [15].

Leadership and Emotional Intelligence. Resilient organisations have excellent leadership and emotional intelligence. Especially in trying circumstances, they can motivate their colleagues and effectively communicate. They are sympathetic to the worries of their employees since they are aware of how emotions affect people. Resilient organisations build a supportive workplace environment that encourages teamwork, trust, and Resilience [16].

They are Building Solid Relationships. Relation with stakeholders and collaborating are two skills resilient organisations possess. They actively interact with vendors, clients, business partners, and other relevant entities to promote cooperation and learning from one another. They use these connections to strengthen their resilience and adjust to shifting market conditions [17].

Continuous Learning and Personal Development. Resilient organisations are often dedicated to their personal growth. They stay current on business trends, technological developments, and resilient best practices. They actively support their team members' progress as professionals by looking for possibilities for professional development [18].

4.3 Ownership of Their Social Duty

This ownership of social duty includes participating in CSR programmes, lending a hand to neighbourhood projects, and considering their activities' social and environmental effects. Organisations can contribute to community development, have experience in sustainability projects, and behave ethically as businesses. By fostering these competencies, organisations can establish a workplace emphasising individuals' well-being, development, and empowerment. As a result, the organisation experiences an uptick in employee happiness, productivity, and overall performance.

Environmental Awareness: Organisations must be well-versed in sustainability- its concepts and ecological challenges. They should be current on environmental laws, new fashions, and sustainable living guidelines. Because of this awareness, they can include environmental factors in decision-making processes, encouraging sustainable practices [19].

Strategic Planning for Sustainability: Organisations must be able to create and practice sustainability strategies consistent with the organisation's objectives and core values. They should consider sustainability's environmental, social, and economic facets when creating long-term strategies. Organisations can direct the organisation towards sustainable practices by establishing and incorporating precise sustainability objectives into the company plan [20].

Environmental Awareness: Effective organisations know the significance of engaging with stakeholders to promote sustainability. They should foster partnerships with suppliers, consumers, employees, communities, and regulatory agencies to identify sustainability goals and work together on sustainability projects. The organisation can reduce their influence on the environment and improve resource efficiency by implementing sustainable procurement procedures, making the most of its energy use, and embracing circular economy ideas [21].

Sustainable Innovation: The organisation may promote innovation for sustainability by developing a culture of creativity and supporting the investigation of sustainable technology and practices [20].

Performance Measurement and Reporting: Organisations should set up systems to track and evaluate the company's sustainability performance. The organisation's dedication to accountability and openness is demonstrated by effectively porting internal and international sustainability performance [22].

Change Management and Employee Engagement: Organisations must have excellent change management abilities to lead sustainability programmes successfully. Employees should be made aware of the value of sustainability, given the opportunity to participate in decision-making, and given training and information on sustainable practices. Organisations may help adopt sustainable behaviours by encouraging employee involvement and developing a sense of purpose [23].

5 Conclusion and Implications of Industry 5.0

Industry 5.0 technology synergy promotes human-centricity, sustainability, and resilience by fusing human and technological strengths. It recognises the value of men in the production process, develops their abilities through interaction with robots, and encourages a positive work atmosphere. It promotes sustainable practices by minimising resource usage and relying on renewable energy sources. Finally, it improves resilience by enabling agile and adaptable production systems and utilising data-driven decision-making. Industry 5.0 provides the way for a more inclusive, sustainable, and resilient future by upholding these ideals [24].

Industry 5.0 helps create a more environmentally friendly and sustainable industrial ecosystem by maximising energy and material utilisation. Industry 5.0 recognises the need for resilient systems that can adjust to and bounce back from setbacks. Industry 5.0 provides real-time data collecting, analysis, and decision-making by fusing technologies like the Internet of Things (IoT) and artificial intelligence (AI). This run time data makes preventive maintenance, predictive analytics, and quick response to unplanned events possible, reducing downtime and enhancing industrial processes' overall resilience. Additionally, Industry 5.0 promotes flexible manufacturing and decentralised production, allowing businesses to respond quickly to shifting consumer needs and supply chain disruptions [25].

Actively seek collaborations and partnerships with external organisations, including NGOs, research institutions, and industry associations. Organisations can learn about new sustainable values, exchange experiences, and use group efforts to address sustainability concerns by joining sustainability networks and projects. Organisations should uphold the highest ethical standards and encourage openness throughout their business operations. Ethics entails acting honestly and responsibly, ensuring workers are treated fairly, and engaging in ethical business practices. Organisations gain the trust of their staff, clients, and stakeholders by acting with integrity and ethics. Organisations should focus on their consumers' demands and preferences when designing products and services to meet their expectations, undertaking market research, actively listening to customer feedback, and constantly updating products based on feedback [26]. Organisations may establish lasting bonds and client loyalty by strongly emphasising customer satisfaction.

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Advanced Manufacturing Technology Implementation in Indian Automotive Industry: An Interactive Qualitative Study

Amruta Patil(✉) and L. Prakash Sai

Department of Management Studies, IIT Madras, Chennai, India
ms21s011@smail.iitm.ac.in, lps@iitm.ac.in

Abstract. The emergence of Advanced Manufacturing Technologies (AMT) revolutionized the industrial landscape through a fusion of technologies (ranging from mechatronics to digital twins) so as to augment go-to-market strategies while reducing costs and increasing productivity. However, the implementation process of these technologies remains relatively unexplored in the technology management domain. To address this gap in research, an exploratory study involving 26 industry experts from the Automotive Industry has been undertaken. The present study aims to investigate the adoption patterns of AMT, specifically in the automotive sector. We employed Interactive Qualitative Analysis to systematically formulate a conceptual framework, classifying factors into drivers and outcomes contributing to successful technology implementation. Primary drivers identified are Competitive Advantage and Alliance Management, while primary outcomes include Return on Investment, Customer Satisfaction, and Project Efficiency. The AMT dimensions considered encompass 3D printing, CNC Machining, Robotics and Automation, Additive Manufacturing, Industry 4.0, and IoT and Smart Manufacturing. This analysis contributes to a deeper understanding of the crucial requirements for effectively implementing Advanced Manufacturing technologies in user industries be it for producing consumer or industrial goods.

Keywords: Advanced Manufacturing Technologies · Technology Implementation · Interactive Qualitative Analysis · Alliance Management · Automotive Industry

1 Introduction

The evolution of AMT in the automotive industry has progressed from the early adoption of CNC machines to the integration of robotics, additive manufacturing, AI, and IoT (Gažová et al., 2022). These technological advancements reshaped manufacturing practices, empowering automotive manufacturers with enhanced productivity, improved quality control, and greater flexibility to meet evolving consumer demands (Stornelli et al., n.d). The industry strategically repositioned to navigate these changes in response to emerging demands. To facilitate this adaptation, stakeholders actively seek to comprehend and embrace novel trends within the industry (Mohlin, 2023). Consequently,

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technology implementation becomes a crucial process that unfolds subsequent to the decision to adopt these new trends.

Although previous studies identified and examined the adoption and absorption of AMT, there remains a significant gap in understanding how implementation unfolds in practice (Singh et al., 2021).

Therefore, as a significant contribution, we propose the development of visual diagrams that depict the primary drivers and outcomes of technology implementation in the automotive industry. Furthermore, we seek a more profound comprehension of these terms by conducting insightful interviews with industry experts, allowing for a more comprehensive exploration of the implementation process. By engaging in this endeavor, we aim to bridge the existing gap in academic literature and contribute to a more nuanced understanding of the complex dynamics of implementing advanced technologies in the automotive industry.

2 Research Background

2.1 AMT Implementation

Given the huge investments of time, money, and effort that go into implementing new technologies, relatively less emphasis has been placed on the implementation stage of technology acquisition (Shaik & Dhir, 2021). Most researchers examined the implementation issues from an organizational perspective, and studies claim a lack of willingness to learn and resistance to adopt the latest technology (Haber & Carmeli, 2023) as a significant barrier to technology implementation. Another heavily researched element in the context of India is capacity utilization (Karadbhajane et al., 2022).

Ghobakhloo et al., 2022 presented a systematic review in the manufacturing sector, which included some vertical integration and intelligent supply chain management. Singh et al. (2021) used quantitative methodology to study the implementation process in India's manufacturing industries. Kaushik & Singh, 2020; Singh et al., 2021; Singh & Gurtu, 2022 studies focus on the motivation that leads to the implementation process and the factors. Still, there is a gap in understanding how these factors are interrelated with each other and the outcomes of the Technology implementation process.

2.2 Automotive Industry

Over the past half-decade, the Indian automotive sector has undergone substantial and multidimensional changes (Adebanjo et al., 2023). These include a notable pivot towards electric mobility (Tarei et al., 2021), a paradigm shift in emission standards to the more stringent BS-VI norms, a burgeoning shared mobility ecosystem altering conventional transportation models, integration of connectivity and autonomous capabilities in vehicles (Maretto et al., 2023), and a redefined consumer landscape marked by digitalization, safety-centric preferences, and the influx of novel market players (Wang et al., 2023). These transformations collectively underscore a trajectory toward sustainable, technologically sophisticated, and consumer-oriented automotive practices (Mustapić et al., 2023). Advanced manufacturing technology encompasses various cutting-edge technologies such as robotics, automation, additive manufacturing, artificial intelligence, and the Internet of Things (IoT) (Frank et al., 2019). These technologies have the potential to revolutionize the automotive industry by improving production processes, reducing costs, enhancing product quality, and enabling customization. Researchers (Laosirihongthong et al., 2003) emphasize that adopting advanced manufacturing technology is critical for Indian automotive manufacturers to stay competitive in the global market.

Studies indicate that implementing AMT in the automotive industry has led to notable improvements in production processes (Tahriri et al., 2022). Robotics and automation have enhanced assembly line efficiency, accuracy, and safety. AI and machine learning algorithms have facilitated predictive maintenance and quality control, reducing downtime and waste (Singh et al., 2021). Furthermore, 3D printing technology has enabled rapid prototyping and customization (Delic & Eyers, 2020), allowing manufacturers to respond quickly to market demands (Hidayatno et al., 2019).

2.3 Automotive Industry in India

Several case studies demonstrate the successful implementation of advanced manufacturing technology in the Indian automotive industry. For instance, by implementing robotics and automation in their manufacturing processes, Tata Motors improved productivity, reduced costs, and enhanced quality. Similarly, Maruti Suzuki India Limited utilized additive manufacturing for prototyping, leading to faster product development cycles. These examples illustrate the positive impact of advanced manufacturing technology on the automotive industry in India.

Recognizing the significance of advanced manufacturing technology, the Indian government introduced various initiatives and policies to promote its adoption in the automotive sector. The "Make in India" campaign aims to boost domestic manufacturing and encourages investments in advanced technologies. Additionally, the National Manufacturing Policy and the Automotive Mission Plan 2026 provide a framework for developing and adopting advanced manufacturing technologies in the automotive industry. These measures strengthen India's position in the global automotive market and drive innovation.

3 Methods

3.1 Interactive Qualitative Analysis

The IQA (Interactive Qualitative Analysis) approach, as advocated by Northcutt and McCoy, emphasizes the essential role of both deduction and induction in the investigation of meaning. This methodology finds its closest counterparts in grounded theory (Glaser & Strauss, n.d) and focus groups (Krueger & Leader, 2002), which are integrated within the IQA protocols (Northcutt & McCoy, 2004). The IQA method has demonstrated its efficacy in diverse fields of study, including gender studies (Jackson & Weimers, n.d), information technology, business management education (Bargate, 2014), and learning (Table 1).

Table 1. Demographics

Category	Description	Percentage
Designation	Manager	30.7
	Deputy Manager/Assistant Manager	46.1
	Senior Engineer	23.1
Work Experience	Less Than 5 Years	34.6
	5–15 Years	57.6
	More than 15 Years	7.6
Gender	Male	80.7
	Female	19.2
Education	Under Graduation	23.1
	Post Graduation	76.9
Work Domain	New Product Development	26.9
	Supply Chain, Procurement, and Operations	30.7
	Design, Testing, Technology Management	19.2
	Cost Engineering	7.6
	Quality Control	15.3

The IQA method's primary objectives are to elucidate a system's components and interrelationships and translate this understanding into practical applications. Adopting a qualitative approach, IQA offers a well-organized, rigorous, and dependable framework for data collection and analysis. The techniques used in this approach draw from total quality management, developed to capture the knowledge of organizational members to address issues and enhance industrial processes. A fundamental premise of IQA is that individuals closest to the phenomenon under study are best suited to interpret the elements and relationships within the system. Unlike many other empirical scientific methods, which often remain relatively silent on the analysis aspect, IQA challenges the traditional notion that participants' role is limited to generating data, with only the researcher being qualified to analyze it (Northcutt & McCoy, 2004).

The end product of an IQA study is a Systems Influence Diagram (SID), which offers a visual representation of the phenomenon based on rigorous and replicable rules. The aim is to achieve complexity, simplicity, comprehensiveness, and interpretability (Northcutt & McCoy, 2004). The resulting SID serves as a mind map of the mental models of a group or an individual regarding the given phenomenon (Bargate, 2014).

What distinguishes IQA from other qualitative inquiry methods is its provision of an audit trail consisting of transparent and traceable procedures, where the constituents themselves, rather than the researcher as an expert, conduct the analysis and interpretation of their data. This approach aims to minimize researcher bias, with the researcher acting primarily as a process facilitator.

3.2 Focus Group and Interviews

During the research design phase of the IQA study, we formulated a research question and identified the experts who had an understanding of the phenomenon being studied. In this case, our research question was: "**What factors influence the successful implementation (adoption) of advanced manufacturing technologies in the Indian automotive industry?"** We approached 26 experts working at higher management in 19 Automotive companies in Chennai, Kolkata, and Bangalore.

We conducted focus group discussions and interviews with the 26 participants to gather data. The focus group discussions followed an IQA protocol aimed at identifying the elements of the system and their relationships based on the constituents' experiences. The facilitator introduced the research question to the participants and then initiated a silent brainstorming session. During this session, participants silently reflected on their experiences and wrote down their thoughts on flashcards, expressing them as words, phrases, or sentences. This activity lasted for approximately 15 min.

The next activity, called inductive coding, involved grouping thoughts with similar meanings. Participants taped their flashcards onto the wall and collaborated to group them based on any criteria, as long as there was a consensus within the group. This process allowed natural clusters to emerge, representing similar meanings shared across the group. The participants spent around 20 min on this activity. Following the inductive coding, the participants engaged in axial coding, which included naming, reorganizing, clarifying, and refining the affinities. Affinities referred to the groups identified in the previous step, representing the elements of the system. The participants spent approximately 15 min naming the affinities (Fig. 1).

After naming the affinities, the participants were instructed to describe each affinity on a sheet of paper, providing examples in their own terms. This activity was performed in small groups of two or three participants and lasted for about 15 min.

The final activity conducted by the focus group was theoretical coding, where participants established perceived relationships among the affinities. An Affinity Relationship Table (ART) was used to capture these relationships through pair-wise comparisons of all the affinities. The participants were instructed to indicate the influence between two affinities by entering the corresponding affinity in the ART. If there was no relationship between the affinities, the cell was left empty. This activity was performed in pairs and took approximately 15 min.

The IQA interview protocol was built upon the affinities identified in the focus group discussions. It consisted of two phases: an open-ended axial interview and a structured theoretical interview. During the open-ended axial interview, participants were introduced to the research question, and each affinity was discussed individually, with participants sharing their experiences related to that affinity and the phenomenon being studied. Following the open-ended interviews, structured theoretical interviews were conducted to explore the relationships between the affinities. Participants were asked to describe the relationships and fill in the ART, following the same coding scheme as in the focus group protocol (Table 2).

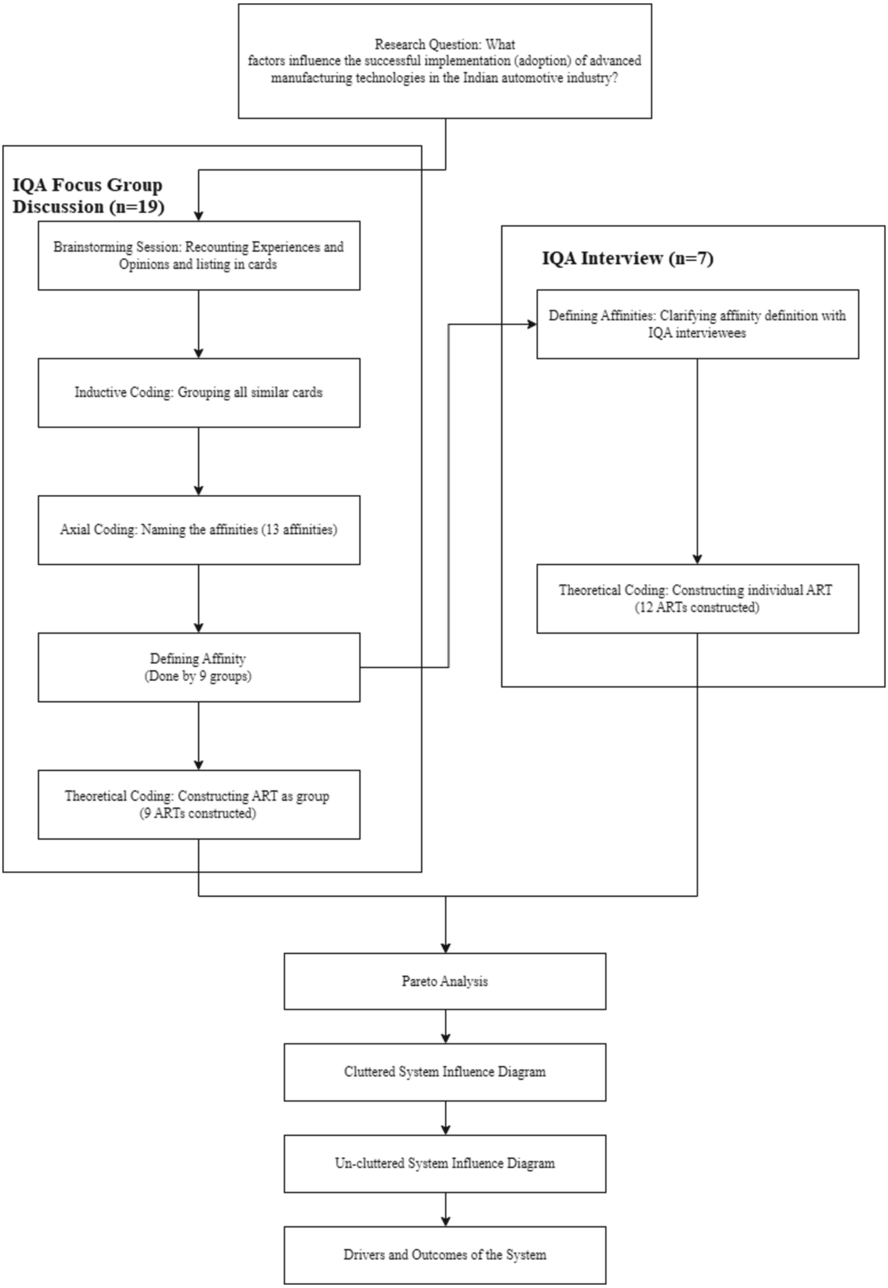

Fig. 1. Process Flow of IQA

Table 2. Inter Relationship Diagram

	1	2	3	4	5	6	7	8	9	10	11	12	13	OUT	IN	Δ
1		↑	↑	↑	↑	↕	←			↑	↑		↕	8	3	5
2	←		←	↑	↑	↑	↑			←	↑	↑	↕	7	4	3
3	←	↑		↑	↑	↑	↑	↑	↑			↑		8	1	7
4	←	←	←		←	←	↑	↑	←		←	↑		3	7	-4
5	←	←	←	↑		←	↑	↑		↑	↑	↑	←	6	5	1
6	↔	←	←	↑	↑		↑	↑			↑	↑	←	7	4	3
7	↑	←	←	←	←	←				←	←	↑	←	2	8	-6
8			←	←	←	←				←	←	↑		1	6	-5
9			←	↑						←			↑	2	2	0
10	←	↑			←		↑	↑	↑		↑	↑	↑	7	2	5
11	←	←		↑	←	←	↑	↑		←		↑	←	4	6	-2
12		←	←	←	←	←	←	←		←	←		←	0	10	-10
13	↔	↔			↑	↑	↑		←	←	↑	↑		7	4	3

3.3 Analysis

The main goal of the analysis phase was to develop a Systems Influence Diagram (SID) that represents the various factors influencing the implementation of AMT in the Automotive Industry. The analysis process in the IQA began with an Affinity Relationship Table (ART), where the relationships were sorted based on their frequency in descending order. The cumulative frequency was then calculated in the same order.

To identify the optimal relationships, the Pareto principle was applied. This principle suggests that 20% of the relationships account for 80% of the variation in the data. By applying the Pareto principle, dominant relationships were identified and represented in an Interrelationship Diagram (IRD). The IRD is a matrix with rows and columns mapped to the affinities, containing only the dominant relationships.

The analysis was conducted by considering the relationships one by one. For instance, if the relationship was "A influences B," the corresponding cell would have an upward arrow (↑) denoting an "out" relationship. Conversely, if the relationship was "B influences A," the next cell would have a downward arrow (↓) denoting an "in" relationship. For each row, the number of "outs" and "ins" were calculated, and the absolute difference between them was referred to as delta.

The delta values were utilized to classify the affinities within the system. Affinities with positive deltas were considered drivers, those with negative deltas were outcomes, and those with zero deltas, if any, were called pivots. The primary driver was identified as the affinity with zero "ins" or the least number of "ins," while the primary outcome was the affinity with zero "outs" or the least number of "outs."

To construct the Cluttered Systems Influence Diagram (SID), the affinities and their relationships were visually represented. The positioning of affinities in the SID was based on their role as drivers or outcomes. The left side of the SID contained the drivers, starting with the primary driver, while the right side contained the outcomes, ending with the primary outcome. Once the affinities were placed in order, the relationships in the IRD were used to connect them.

However, the cluttered SID often contained redundant links, making it challenging to interpret. To address this issue, redundant links were removed. For example, if A directly influenced C, and A also influenced C through B, the direct link between A and C was eliminated. By removing these redundant links from the cluttered SID, a final simplified representation called the uncluttered SID was prepared.

4 Results

See Fig. 2.

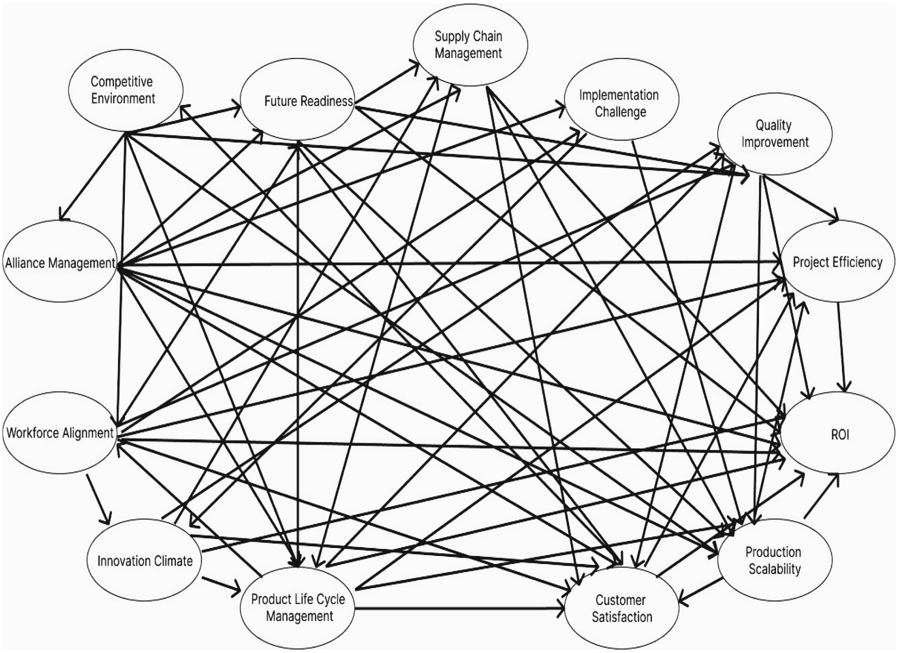

Fig. 2. Cluttered System Influence Diagram

4.1 Competitive Advantage

The pursuit of technological implementation is driven by the necessity to remain competitive both in the Indian and global markets. To gain a competitive advantage, automotive companies must leverage technology to achieve cost leadership and differentiate their products. This necessitates the adoption and implementation of new technologies to address the unique demands of the rapidly growing Indian market.

4.2 Alliance Management

Strategic alliance formation and management have emerged as critical factors for automotive companies seeking to create value and capitalize on their strengths in the ever-evolving market. Collaborations, joint ventures, and alliances are essential for leveraging the capabilities of non-traditional competitors and startups that offer technologically advanced solutions.

Furthermore, collaborating with government bodies, universities, and research organizations can foster innovative alliances, enabling automotive companies to remain at the forefront of technological advancements. Drawing on the historical precedent of alliances with foreign technology giants during India's post-independence period to establish the automotive industry, firms now seek technological partnerships with innovators to sustain their competitive advantage.

Additionally, forming new partnerships for raw material sourcing and component procurement is essential for establishing a resilient and robust supply chain. These partnerships ensure a seamless flow of resources and enhance the overall competitiveness of automotive companies.

4.3 Innovation Culture

The study emphasized the strategic importance of fostering an innovation culture through research and development (R&D). Leaders and executives recognized the need for continuous technological innovation, supported by collaboration, knowledge sharing, and insights from employees at the forefront. Market research and customer-centered feedback were identified as drivers of an innovative culture.

4.4 Product Lifecycle Management

Effective product lifecycle management was deemed necessary for maintaining and increasing market share. Concurrent engineering and better data analysis were highlighted to ensure faster time-to-market, resource utilization, and adherence to circular economy principles. Understanding customer needs and expanding product portfolios were identified as strategies for catering to diverse market segments and driving revenue growth.

4.5 Future Readiness

To address industry uncertainties and disruptions, companies must embrace digitalization, automation, modularity, and mass customization. Predictive maintenance and strategic alliances were highlighted as crucial elements of future readiness. The study emphasized the need for proactive measures in technology adoption and preparedness for market changes.

4.6 Supply Chain Management

Supply Chain Management A robust supply chain, particularly for electric batteries and semiconductors, was identified as vital for successful technology implementation. Challenges related to limited component supply were acknowledged, underscoring the importance of effective supply chain management.

4.7 Quality Improvement

Quality Improvement To meet evolving customer demands and maintain a competitive edge, manufacturers recognized the need for upgrading, digitization, and automation.

4.8 Production Scalability/Flexibility

Capability to efficiently adapt production systems to model variations and volume increases. Flexible and agile production practices have been identified as the most promising approaches to achieve these objectives. Automation is vital to achieving economies of scale and ensuring scalability. Several Indian and global players have announced ambitious goals for EV production, exemplifying the need for scalability, such as BMW's plan to introduce 25 new EV models by 2023 and Ford's target of launching 40 new models by 2022 (Fig. 3).

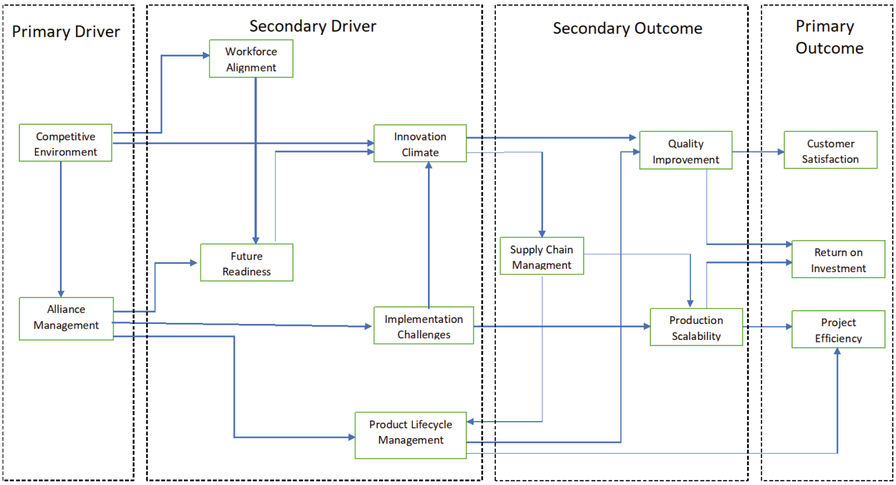

Fig. 3. Uncluttered System Influence Diagram

4.9 Workforce Management

Upskilling and reskilling the existing workforce is crucial to acquiring new skills and knowledge related to emerging technologies. Internal collaborations for innovation and partnerships with educational institutions for research advancements are important strategies for workforce development.

4.10 Implementation Challenges

Implementing new practices in established organizations poses significant challenges. Research initiatives, infrastructure limitations, and skill development for effective utilization of alliances and smooth transitions are key obstacles that need to be addressed along with employee resistance towards change.

4.11 Customer Satisfaction

Enhanced quality and end-to-end product lifecycle management contribute to increased customer satisfaction and positive word-of-mouth publicity. Consumers are driven by improved efficiency, reduced operating costs, and a growing demand for servitization in the automotive industry.

4.12 Project Efficiency/Project Performance

Technology implementation facilitates optimization, transparency, improved communication, and collaboration, resulting in increased project productivity and capacity utilization. Achieving project efficiency is crucial for meeting market demands and being cost efficient.

4.13 Return on Investment

Respondents emphasized the importance of achieving a positive return on investment (ROI) through technology implementation. Given the nascent stage of development in the EV market and uncertainties surrounding its future, companies strive to adopt technology while maintaining price competitiveness and reducing the payback period.

5 Study Implications

5.1 Theoretical Implications

The present study constructed a structured conceptual framework by classifying factors into drivers and outcomes of AMT implementation. This framework provides a comprehensive approach to enrich the literature on AMT implementation.

Furthermore, the paper underscores the pivotal role of alliance management as a critical driver for successful technology implementation, thereby expanding the theoretical understanding of strategic collaborations within technology-intensive sectors. Additionally, it addresses key implementation challenges while highlighting the theoretical significance of cultivating a future-ready mindset. These theoretical insights collectively deepen our understanding of AMT adoption processes, particularly within the unique landscape of the Indian automotive sector, while simultaneously offering broader implications for technology implementation research in the consumer industries.

5.2 Managerial Implications

While challenges in implementation persist, addressing research initiatives, infrastructure limitations, and skill development is imperative for successful integration. Our research aids in comprehending the relationships between dimensions and the appropriate sequence in which stakeholders should comprehend, analyze, and plan while creating a roadmap. It provides practical insights for industry practitioners to navigate the complex and rapidly evolving automotive landscape.

6 Limitations

This research primarily centers on the Indian automotive industry. While this focused approach allows for a thorough examination within a particular setting, it may restrict the applicability of the results to other industries or geographic regions. It's important to acknowledge that the findings of this study might be time-sensitive, given the ever-changing technology landscape and industry dynamics.

A longitudinal perspective could offer valuable insights into how technology implementation and its effects evolve over time. To enhance the comprehensiveness of this research, a comparative analysis could be considered, involving a comparison with other countries and regions, which might yield additional insights.

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Role of Institutional Pressure and Organization Climate in Adoption of Process Innovation for Improving Environmental Performance – A Research on Indian Mining Industry

Lalit Mohan Soni(✉) and Nikunj Kumar Jain

Production and Operations Management, IIM Nagpur, Nagpur, India
ephd22lalit@iimnagpur.ac.in

Abstract. In recent years, the significance of Environmental Performance in attaining organizational performance and sustainable development has been acknowledged. This paper seeks to discover whether and how institutional pressure can stimulate Environmental Performance, and examines how process innovation mediates this relationship, as well as the moderating effect of organizational climate, through amalgamating institutional theory and resource-based view (RBV). The proposed hypotheses are examined using the survey data from 206 firms working in mining industry in India, by partial least squares (PLS) approach. The results suggested that process innovation mediates the positive effects of institutional pressures on environmental performance, which results in improved organizational performance. Additionally, the moderating role of organization climate was also examined. This study provides the first empirical evidence of process innovation's mediatory role between institutional pressures and environmental performance. Furthermore, it deepens our understanding of the contribution of organizational climate to the relationship between institutional pressure and environmental performance, with evidence derived from the mining industry of an emerging economy.

Keywords: Mining · institutional pressures · environmental performance · organizational performance · process innovation · organization climate · PLS

1 Introduction

The mining sector is a significant contributor to a nation's GDP and ensures the availability of essential natural resources for human sustenance. However, while some nations with similar geological settings to India have GDP contributions from the mining sector of over 7%, India's mining sector contributes only about 2.5%. The past few decades have seen tremendous environmental degradation around the world, and India is no exception. The mining industry provided the basis for downstream industries to operate

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and thrive [1]. Mining operations have consistently been of paramount importance to both domestic and international economies due to their indispensability [2]. Although mining industry plays an essential role in propelling the advancement of humanity and the world economy, it has played a significant role in the extensive pollution and ecological destruction that has occurred. Environmental degradation has become a major global challenge, and companies around the world as well as in India have been under pressure to implement green innovation strategies to ensure not only economic success, but also environmental protection [3]. According to [4], organizations can take advantage of the latest technologies like big data and analytics to promote process and product innovation within their enterprise. In a study by [5] specifically on cement industry, it has been observed that In order to achieve improved environmental sustainability, new entrants are introducing environmentally-friendly product innovations targeting niche markets and applications. Green process innovation can be employed to augment the efficacy of environmental management in order to fulfill the demands of environmental conservation [6]. The implementation of innovative solutions can help reduce or even eliminate the expenses associated with complying with environmental regulations, while also providing a competitive edge [7, 8].

Organizations strive to reconcile institutional constraints with the need to meet environmental requirements by deploying new technology and adopting best industry practices [9]. The organizations functioning in the Mining industry must adhere to strict environmental regulations [10, 11]. [12] have encouraged companies in the mining industry to take a more proactive stance on environmental and social matters. The environmental performance is significantly influenced by both environmental management practices and institutional pressures [13, 14]. A study by [15] in the oil and gas sector also found that institutional pressures had a significant impact on economic and environmental performance.

The previous studies and literature review suggests that the dimensions and parameters that drive green innovation through institutional pressure are still largely unclear. To fill this gap, this research combines (institutional theory and resource based view (RBV)) explore whether and how institutional pressure affects environmental performance. Specifically in the mining industry, this research focuses on addressing the following question:

(1) What is the impact of institutional pressure on environmental performance,
(2) How does process innovation mediates the impact of institutional pressure on environmental performance,
(3) How doses organization climate influence the adoption of process innovation and its relationship between institutional pressure and environmental performance

This research makes several contributions to the literature. First, this research examines the mediating effect of process innovation in the connection between institutional pressure and environmental performance, which consequently contributes to organizational performance, hence expanding the discourse on the Porter Hypothesis. Second, by exploring the moderating effect of organizational climate on the response of process innovation to institutional pressure, the research provides a perspective of institutional theory and the Resource-Based View (RBV) offers a novel perspective to the extant literature concerning the preconditions that determines the effectiveness of process innovation when exposed to institutional pressure. Third, this study, conducted in India which is an emerging economy with unique political and economic characteristics and confronting increasing environmental challenges - is of significant importance in terms of verifying the applicability of theories, derived from the Western Context [16].

[17] proposed that the economic standing, nature of mining activities, geological conditions, and size of mining companies are all essential components that dictate the rate of technological adoption within the mining sector for any nation.

2 Literature Review, Theoretical Background and Hypothesis

The past few decades have seen tremendous environmental degradation around the world, and India is no exception. The mining industry provided the basis for downstream industries to operate and thrive [1]. Mining operations have consistently been of paramount importance to both domestic and international economies due to their indispensability. Organizations are required to respond to a host of diverse, external pressures from varied constituencies and stakeholders [18]. The past decade has seen an upsurge in the use of institutional theory within the realm of operations management [19]. According to [20], this theory postulates that external forces act as incentives for firms to enact comparable strategic proceedings. Conversely, institutional theory goes beyond mere economic concerns into the arena of societal reliability for organizations [21]. It can be divided into two distinct sub-theories, a monetary aberration and a sociological variant [22]. Three agents of institution isomorphism can be recognized, namely deterring, coercive, mimetic and normative, a notion forwarded by [23].

2.1 Hypothesis 1: Institutional Pressures are Positively Associated with Environmental Performance

Environmental efficiency can be achieved through reduced resource consumption, decreased waste production, and minimized emissions at the organizational level [24]. Substantial industrial entities in some sectors like large manufacturing and mining, that give rise to ecological degradation are increasingly obliged to reconcile ecological, communal and financial objectives in order to render their operations environmentally viable [10, 11, 25]. The investigation by [26] ascertains that there is an augmented beneficial correlation between the emergent economies and the contemporary acceptance of environmental procedures compared to the more developed economies.

Mandatory disclosure regulations endeavor to stimulate performance enhancement through the inculcation of institutional pressure [18]. Adhering to institutional mandates can yield enhanced fiscal viability for an organization, however, the incorporation of environmental management systems substantially underpinned by institutional and financial parameters has more far-reaching implications for the condition of corporate environmental direction and advancement towards higher levels of ecological sustainability in the corporate world. [27].

Previous studies suggests that institutional pressures like coercive, mimetic, and normative pressures are paramount contributory elements of environmental conduct [14, 26, 28]–[30]. It has additionally been ascertained that coercive, mimetic, and normative pressures notably augment the realization of environmental management accounting, which in effect enhances the environmental execution of the company [14]. A study by [31] posits that an increase in waste reduction assets equips organizations to anticipate and appropriately react to institutional pressures.

This study elucidates the adscititious relationship between institutional pressures and environmental performance within the aegis of the mining sector in developing countries like India.

Environmental stewardship is gaining increasing priority within organizations, and has become a fundamental component of their policy and outlook [32].

2.2 Hypothesis 2: Process Innovation Will Positively Mediate the Relationship Between Institutional Pressures and Environmental Performance

Organizations are driven by institutional pressures to seek environmental practices and innovations in their processes and products [33, 34]. The deployment of innovation affords a chance to revamp the structures of production and services, to refine wares and techniques, and to elevate their global competitive advantage [35]. As per [36], the green product and process innovation have positive effects on environmental performance as well as the organizational performance. [37] studied that green process innovation do not improve the financial performance of the firms in the short term, however positive impacts have been seen in the longer term. Study by [38] reveals that multinational companies do demonstrate a significant degree of environmental innovation, motivated primarily by pressures from both suppliers and customers.

Process innovation assists emerging organizations with contending with long-established companies in the market. Research of [5], particularly in the manufacturing of cement, demonstrates that newly arrived players fill a gap in the market, and facilitate the introduction of ecologically friendly product advances. The specialized market comprehends the fact that new businesses do not strive on the basis of lowest pricing, but instead on the product's environment-friendliness.

The utilisation of green process innovation by organisations has the potential to ameliorate economic productivity, through the diminution of compliance costs and conservation of resources via energy conservation and minimisation of environmental harm [39]. Green process innovation also allows organizations to curtail expenses on dumping of waste deposits and the cost of material inputs [39]. Investment in process innovation can further be advantageous for firms in that it facilitates a decrease in emissions and reducing of waste generated via their business processes, and an enhancement in overall productivity and efficient use of resources [36, 40, 41].

As the international progression of the environmental agenda gathers inertia, organisations are confronted with the challenge of reconciling economic and environmental objectives [42]. A long-standing yet unresolved query is the extent to which institutional pressures are conducive to augmented environmental performance.

It is not feasible to entirely eradicate the diversified ecological repercussions, for example, air, sound, water, contamination, and so forth, from the mining activities; however, their effects can be significantly curbed by streamlining the processes and technologies engaged in the business. This examination aims to establish whether process innovation serves to positively mediate the influence of institutional pressures on environmental performances of mining entities.

2.3 Hypothesis 3: Organization Climate Will Positively Moderates the Relationship Between Institutional Pressures and Process Innovation

The organizational climate is a mutual discernment of the organization's characteristics in regards to policies, practice, procedures, systematizations, and recompenses [43]. Prior research has investigated the influence of organizational climate on sundry facets of organizations, such as knowledge exchange [44], knowledge administration [45], decision making [46], aptitude to change [47], and innovation [48]. Organizations only institute green initiatives or even innovation in the event that they consider this will result in economic returns, process enhancements, and a heightened competitive advantage [49].

This research will examine that how organizational climate of a company moderates the relationship between institutional pressures and process innovation, specifically in mining context.

2.4 Hypothesis 4: Environmental Performance is Positively Associated with Organizational Performance

Environmental performance enhance the company's overall performance [36]. In a study by [50] it is revealed that prioritizing economic performance results in negative environment impact as well as increase in several institutional pressures. [51] elucidated in their findings that the implementation of pollution prevention technologies engenders an increase in manufacturing performance in an organization. [52] demonstrated that the implementation of GSCM strategies had a substantial, beneficial effect on the economic outcomes of a company. [53] postulated that the implementation of EMP contributes to a reduction in expenditure, an augmentation in effectiveness, and a maximization of output. Nevertheless, [54] substantiated that there is no substantial relationship between EMP and the quality or cost performance of an organization. This assessment endeavors to verify if there is a meaningful correlation between the environmental performance of the mining companies and their organizational performance (Fig. 1).

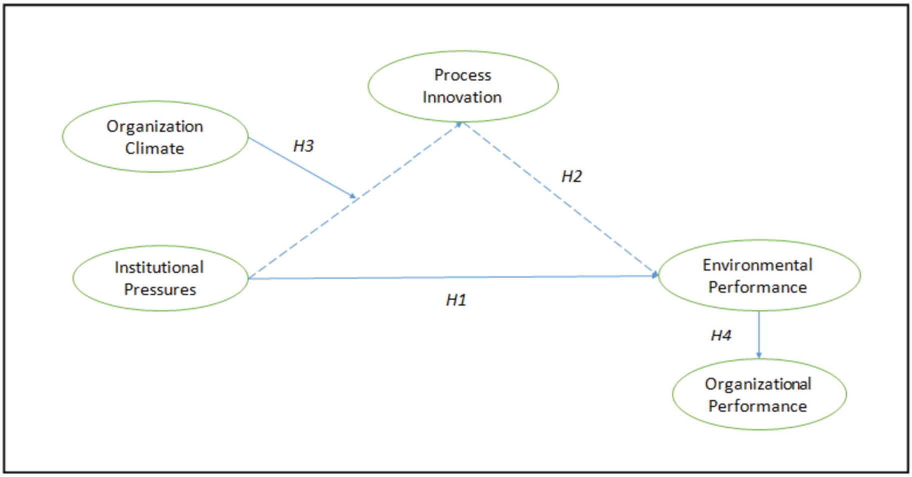

Fig. 1. Conceptual Model with Hypothesis

3 Discussion

The Mining sector contributes significantly to a nation's Gross Domestic Product (GDP) and ensures the availability of material resources essential for the sustenance of human beings. Simultaneously, the activities along the mining value chain have an intense impact on the environment. Consequently, environmental stewardship and execution are necessary components of the overall operations for mining organizations and their progress. The deleterious environmental effects of these operations impose institutional pressures on mining firms. In antithesis, these pressures stemming from the adverse environmental consequence necessitate mining companies to implement supervisory measures and deploy procedures in an effort to mitigate the inimical environmental repercussions arising from mining practices.

The previous literatures have substantiated the notion that enhancement of the environmental performance of companies across numerous industrial sectors, such as manufacturing, can culminate in organizational performance, which has been investigated through the present research in the mining industries. Process innovation implementation can be leveraged to selectively amplify environmental performance and, consequently, the overall performance of organizations.

The current study draws upon institutional theory and resource based view RBV theory to study the influence of process innovation towards environmental and organizational performance of the mining companies. Further the study also analyzes the role of organization climate between institutional pressures and process innovation. The results supports the mediating effect of process innovation for environmental performance. The study also supports the moderating role of organizational climate towards process innovation.

4 Implication, Limitation and Conclusion

The precipitous decrement in commodity prices, scarcity in the availability of proficient personnel in outlying development entities, and questions concerning health, safety and environment are obligating mining companies to seek imaginative and cost-effective methods of elevating proficiency whilst deepening throughput and conforming to the most stringent health, safety & environment criterion at the premises. Therefore, it is indispensable to reassess and transform various of the established procedures in the mining course of action in order to effect revolution through the process of modernization. The findings of current research shows that organization climate can influence the process innovation which further contributes to the enhancement of environmental performance.

The present research yields that the organizational climate has the potential to be conducive to the process of innovation, which can then engender a rise in the ecological efficiency. Such findings can be instrumental for policy-makers and personnel of companies in establishing a climate that might foster creative thinking, the development and implementation of innovative processes. Embracing the institutional stresses as an opportunity to innovate and elevate the environmental performance through process innovation can expedite the improvement of organizational performance.

Our study has few limitations, like, the study is based on firms in an emerging market, India; therefore, subsequent experiments may evaluate this model in firms in developed nations. The current research work has tested the process innovation as mediator to environmental performance; similarly the mediation role of product innovation can also be tested in the same testing. Case-based analyses can likewise serve to corroborate the results of this analysis.

We can conclude that, this probably the first academic study in India to empirically examine the role of institutional pressures and environmental performance on organizational performance of mining organization where process innovation also plays an important mediating role. The study also reveals that organization climate can also plays vital role in process innovation and improving overall performance. Academic scholars may feel encouraged to investigate further into these topics from different theoretical lens as well as in other industry contexts. The industry professionals can leverage the findings of the study in improvising the organizational performances of their mining operations and companies.

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Digital Twin for Industrial Applications – A Literature Review

Rashmi Pant Joshi(✉), Surbhi Gulati, and Arpan Kumar Kar

Department of Management Studies, IIT Delhi, New Delhi, India
rashmi4pg@gmail.com

Abstract. The development of technology such as big data, internet of things, cloud, 5G, artificial intelligence plays a significant impact on industries. This promotes the integration of physical and digital worlds and led to the growth of Digital Twins. Digital Twin is the virtual representation of the physical entity that spans its lifecycle, performs simulations and helps in decision making. In this paper, we will study the applications of digital twins in various industries. A systematic literature review is conducted by analyzing the literature from 2017 to 2023. The findings are the applications of digital twins in various industries like agricultural, healthcare, smart cities, automotive, infrastructure, energy and transport. The article concludes by highlighting the conclusions and challenges of the technology. Our study offers insights into how Digital Twin technology plays vital role in shaping various industries and challenges that must be overcome for their widespread adoption.

Keywords: Digital twins · Literature review · Industry applications

1 Introduction

In every facet of the industry, big data, the internet of things (IoT), artificial intelligence, 5G, edge computing, etc., are developing expeditiously and have shown significant potential. These technologies have led to the growth in integrating the physical and digital worlds. This integration led to the emergence of Digital Twins. Digital Twins (DT) are virtual representations of real-world physical assets, processes, and systems that thoroughly monitor their life cycle [1]. The main components of digital twins are a physical entity, a virtual representation of an asset in virtual space, and the connection link between real and virtual space. The concept of DT was first proposed by Professor Michael Grieves when he defined it as an object including a virtual information model and data [2]. Later in 2016, John Vickers jointly proposed the "Digital Twin" [3]. DT is one of the ways to understand the interconnection and transmission of information between physical and virtual space [2]. The virtual models are used for design engineering, product simulation, etc., helping improve customer satisfaction and product/process experience & also fostering innovation towards better solutions. Moreover, the entire lifecycle of the physical object can be imitated through functions like state prediction and decision optimization performed by DT technology [4].

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With computer-aided software & tools, a physical entity is first digitally documented. Using sensors/innovative components, data in real-time is then collected & uploaded to the cloud platforms and further used in big data analytics for simulation and analysis on the virtual counterpart. The more integrated the software is with the physical entity the more utility can be explored. As technology grows, DT will get more and more integrated. E.g., the DT of a vehicle can predict its performance & suggest ways for improvement in design for the manufacturers as well as operational performance for the customers. The real-world data gives insights into weaker points of design. By running what-if scenarios, modeling & simulation, we can better design the final product and improve cycle times & efficiency. The virtual representation can reduce the risk of operation & generate substantial improvements. By optimizing operation, total energy consumption can be minimized for operation/scheduling processes [5].

The DT technology can integrate physical and digital entities by coupling physical entities with their virtual DT. It enables us to get the benefits of both-way transfer of data/information. It is an enhanced replication rather than just a digital clone. An identical Space vehicle was built by NASA for Apollo 13 Program in the 1970s to find out solutions to problems faced by the astronauts [6]. Not being just a simulation, the DT function with updated data through the product life cycle of the physical object and help in monitoring assets in real-time by capturing their current state (age, activity levels, etc.), which can be analyzed for predicting any future uncertain failure of the physical asset, for proactive maintenance.

DT has emerged as a new solution provider to the problems faced by many industries. Thus, DT is applied to several industries and leading organizations, including NASA, Siemens, US Airforce, General Electric, Oracle, SAP, and Altair. Every industry defines its different characteristics for DT in terms of the applications, services, composition for usage methods, and model strategies.

Applications of DT can offer practical solutions to specific challenges faced by each industry. It is important to identify issues unique to each industry and demonstrate the solutions by DT. For instance, in the healthcare industry, DT as technology can be used to improve medical research. Moreover, in the agricultural sector, DT can be used for crop management and enhance production. Thus, it may lead to many potential theoretical consequences for policy and legislation Thus by identifying potential regulatory difficulties or possibilities related to Digital Twins in particular industries, the study may potentially have academic consequences for policy and legislation. Moreover, DT can be helpful in the decision-making process applicable to critical sectors regarding accuracy and efficiency. The study can assist organizations and professionals as they use insights to enhance their operations and gain competitive advantage by acquiring industry practices. Further, our study can contribute by expanding our understanding of the applications of DT technology in different industries and influence future research by identifying knowledge gaps and providing suggestions for further explorations.

Therefore, the paper intends to answer the following research objective:

RQ: How are Digital Twin technologies used in different industries?

The rest of this paper is as follows: Sect. 2 presents the methodology, as we have conducted a systematic literature review to study the applications of DT. Section 3 presents the findings from the literature. Section 4 draws some important conclusions about this review study on the use of DT in various industries.

2 Methodology

To study the applications of DT in industries, a Systematic Literature Review (SLR) process has been followed. Studies [7–13] were considered for developing the review protocol. For undertaking the review, the Scopus database was used to find applicable studies published from 2017 to 2023. Scopus database is the most popular and extensive database for Systematic Literature Review (SLR), focusing on scientific literature for engineering and management [7]. Further, Scopus provides possibilities to users for advanced research for relevant literature. Thus, we used the Scopus database for our research. A search was performed using the string "Digital Twin" in Scopus. It gave 3151 results from journals, books, and conference proceedings, of which only 1496 results from the last 7 years were shortlisted in first run. Further, only 232 articles, with an ABDC index rating of A and above & published in reputed publications, were shortlisted from above results. The list was then exported into a.csv file and was further refined based on the title & abstract, if both mentioned the keyword "Digital Twin," and it led to further shortlisting of 118 papers. These articles were then read and shortlisted based on the relevance of the abstract and were selected only if the articles supplied relevant information about the research question and lastly in order of relevance of abstract, about 22 papers in different domains were selected. In our study, we used SLR to analyze the application and characteristics of DT in various industries, followed by other studies to study the application of technologies in industries.

3 Findings

The major characteristics of DT are the physical entity, virtual entity; physical and virtual environment; state of the two entities; the twinning process, its rate; physical-to-virtual twinning and reverse, and physical and virtual processes [14]. Between the physical and virtual states, there are cycles of the bidirectional flow of data from physical to virtual entity and flow of information & processes from virtual entity to physical one.

A DT environment is a virtual representation of the actual environment in which the physical product exists. It enables virtual techniques such as modeling, simulation, and evaluation to check and assess various scenarios before implementing the physical twin. The core concept envisages a system that couples physical and virtual counterparts helping to use the benefits of virtual and physical environments for the entire system. This process also enables a data-driven and knowledgeable approach to monitor and manage improvement during the product life cycle effectively.

Industry-wide, there have been many practical applications of DT. E.g., GE has developed DT of its jet engines, windfarms, pumps, compressors, etc. & saved more than a billion USD through real-time monitoring. Chevron deploys DT in its oil fields to predict maintenance problems. By connecting sensors to high-value equipment, it is expecting savings of millions of dollars/year. McLaren employs DT in its Formula 1 race car. It uses 300 sensors to generate about 150 GB of data over a race weekend, and

50 engineers review the data & monitor performance. Boeing uses DT to design planes. Simulations are run to predict airplane components' performance over the product's lifecycle. Siemens employs DT to produce industrial computer-control systems and design, test & simulate factory control units in its health business.

In the case of GridCo in Norway, the goals of creating a DT of the power transmission network were to increase efficiency through analytical support and automation, automating the decision support system, and increasing the uptime through faster repair of faults in the infrastructure. To enable the simulation of grid changes before implementation following phases were implemented:

Phase 1: A pilot was developed on a first set of fictitious test data reflecting the grid network.

Phase 2: After a thorough risk assessment of IT security and data sharing as per Norwegian Acts & Regulations, about 3% of the actual grid network was simulated using anonymized & scrambled data with hourly data updates.

Phase 3: The project was now user driven & on real-time data. The supervision was transferred and moved to GridCo's premises, and the scale & scope of data were expanded to the entire grid network without risking exposure of sensitive power system information.

Thus, GridCo realized the strategic value of DT. It enabled it to start future-oriented grid changes and exploit and share data more efficiently. A similar approach can be used in any industrial application sector with SCADA supervision. e.g., it can be used in energy-generating plants like thermal, hydroelectric, and wind plants [15] for use in decision support systems.

A brief on the applications & capabilities of DTs for some major sectors and use cases is given below:

3.1 Agriculture

Agriculture uses 69% of all freshwater worldwide. The challenge is to increase production by 50% from 2012 to 2050 & reduce water consumption. The DT of a smart irrigation system and an application scenario are presented [16]. The system's physical components, like sensors and actuators, relate to their virtual representations. The system has an IOT platform & an event simulation model in Siemens Plant Simulation software. IoT devices aggregate & process soil, weather & crop data to calculate daily irrigation prescriptions. Communication between the platform & simulation model is real-time. An application scenario evaluates system behavior and different irrigation strategies. The benefit is to evaluate the IoT platform, irrigation system, strategies, and current farm practices. Farmers can use it to evaluate system behavior before implementing it & also, and they can allow it to work automatically. The system can improve farm operations & reduce water usage by allowing farmers to gather soil, weather & crop information and evaluate multiple irrigation strategies.

DT in this sector is in the early stages of development [17]. The benefits include reduced cost, efficient management of processes, avoidance of catastrophe, help in decision making, and positive economic impact. It will also help to check and control the irrigation system.

3.2 Healthcare

In healthcare, considerable progress has been made in creating DTs of patients and medical devices. The development of DTs holds great promise for the personalization of medical care for individuals based on their distinctive genes, anatomy, behavior, and many other characteristics. There exist many experimental models based on this technology that use data in real-time of the patient and suggest lifestyle modifications, and treatment, and check the response to the treatment for any changes in solutions [18]. With the use of this technology, the patient can receive a correct diagnosis and treatment, tailored to their needs. The use of technology is also evident in research in the fields of pharmaceuticals and personalized medicine [19]. Physicians can better personalize therapeutic pathways and use less invasive intervention techniques with the help of DTs that incorporate machine and deep learning models and virtual and augmented reality models. As healthcare resources are tightly budgeted, technology like DTs might save millions by predicting results and preventing unnecessary surgery.

DT in the healthcare industry is a step closer to providing personalized medication. Other potential application areas are disease modeling, medical device development, digital therapeutics, advanced understanding of the human body, and optimizing hospital operations. This would enable healthcare providers to use digital care-backed treatments. This would also allow patients to get personalized treatment. For a healthcare institution to have functional DTs, it must be equipped with technology and experienced personnel. Connected infrastructure, data scientists, modeling/analytics technology, data quality, and data privacy are needed for DT technology to evolve further in the system.

Different solutions have been developed to increase life expectancy for the elderly while reducing costs [20]. Using IoT, DT & Blockchain, physical activity monitoring is carried out for the elderly. The elder's physical movements are analyzed to detect irregular physical events in real-time accurately. The proposed framework can keep data secured by applying the security highlights of blockchain. The outcomes have shown the effectiveness of DT with smart healthcare solutions and effective medical services by bringing patients and medical care experts together. Irregular event recognition, model training, testing & cost measurement are used to see system performance.

3.3 Smart Cities

Urban industry needs secure, sustainable cities. Also, improved planning & optimized asset management is needed. The basis for future design, development, and widespread adoption of urban DTs has been proven [21]. It will be helpful for urban management stakeholders. Existing initiatives were mapped about applications, inputs, processing & outputs. Also, the requirements and a basic structure of a city DT were defined.

E.g., in India, Andhra Pradesh is developing a DT of a brand-new city. Designed by architects Foster and Partners, Amaravati has ambitions to become one the most digitally advanced cities globally, with development planning and operations all running on a single platform. Genesys International, a pioneer in survey mapping and 3D contents, and Esri India Technologies Limited, a Geographic Information System (GIS) software & solutions provider, have announced an alliance for work on the software issues. Genesys has strong capabilities in collecting and processing 3D LiDAR data, and Esri technology is most suited for 3D modeling and creation of DTs.

In December 2021, Genesys International launched a PAN India program to make a DT of urban India. The program, which will encompass accurate 3D data for the top 100 cities in India, will lead to the first-time creation of this kind of highly accurate geometrical data. Esri India will become an enabler in this process by providing the most suitable, stable technology platform for 3D modeling, data analysis, and solutions development to help stakeholders solve problems and provide better services to the citizens. This collaboration will enable high-definition mapping of Indian cities for better planning and governance. The GIS-enabled DT will support smart cities across segments, including urban development, planning, governance, disaster management, utilities, etc. DTs are important for government programs like Gati Shakti and Smart Cities, as they help in better designs, cost management, multi-agency coordination, and cutting down project timelines. The technology can help the administration in better decision-making about city planning and operations, which could further lead to sustainable cities and improved urban management [22]. DT can simultaneously imitate multiple systems and process information for large datasets for enhanced city planning and control. Moreover, data facilitation also increases citizen engagement and contribution to urban planning [23].

3.4 Energy

Owing to tighter regulations on emissions, climate change-driven sustainable demands, and technological advancements in energy generation through New and Renewable Energy generation, there is more and more pressure for the physical & digital worlds to come closer. Energy utilities are adopting and using the DT technology to simulate real-life scenarios to prepare for the contingencies and gain insights by exploiting the technological capabilities. The DT technology offers these users agility, resilience, and a competitive edge.

Utility companies must use real-time data generated through continuously measuring sensors to replicate complex physical infrastructure to predict and improve their planning & operations. Whether it is the remote operation of transmission grid assets, or real-time monitoring of the power system equipment health for predictive and prescriptive analytics, access to the huge volume of real-time data of the physical infrastructure has helped in planning, design, and real-time operation.

In India, the Grid Controller of India Limited (Grid-operator) does real-time data monitoring of the health of the national power grid in real-time by the continuous sensor/meter measurements to predict & improve planning, operations & performance. The real-time system parameters provide reliable, up-to-date information and give insights to plan for real-time asset outage management and improve operations effectively. National-level transmission assets are monitored in the Load Dispatch Centers. It helps in real-time decision-making, ensures the continuity of normal operations, and avoids catastrophic power failure situations.

Power Grid Corporation of India Limited (POWERGRID), through its NTAMC (National Transmission Asset Management Centre) and RTAMCs (Regional Transmission Asset Management Centres), has set up centralized monitoring and remote operation of 271 Extra High Voltage (EHV) substations geographically spread PAN India, as of April 2023. The advantages of using DTs for planning and operation in the power sector are effective planning and better design of assets, constant optimization in operations, and preventive maintenance for a longer asset lifespan.

For future digitization of the Indian Grid, a bidirectional communication network is to be created with data flowing through the communication network of the grid using 5G. The EV (Electric Vehicle) chargers, customer meters, and smart homes would all be able to communicate with the DISCOM control center and power market. The benefits would be the identification of defects, predictive maintenance, outage management, etc. In addition, satellite technology would be used for communication between substations & load dispatch centers. Weather forecasts would also be useful for planning operations. In China, Dynamic Security Assessment (DSA) has been conducted online in the power despatch control centers since 2016 [24] at regular 15-min intervals.

In the future, the utilities in the energy sector in India are looking forward to doing simulations to predict performance before assets are deployed physically and during their lifespan. For each of the Lacs of Interstate transmission equipment in number, in real-time, there are about 30–40 data points to be collected and transferred for further processing. The simulations take the real-time data input from the sensor devices to enhance real-time monitoring for normal operation, outage management, preventive maintenance, and remote operation whenever needed for enhancing the overall performance and availability or uptime of the assets in the grid. The increase in revenue is dependent on the availability of assets. The main benefits are effective planning, improved design, continual optimization, and preventive maintenance. Also, the way forward is up-skilling /training of people to use the technology for a sustainable future.

3.5 Automotive

One of the most significant applications of DT technology in the automotive industry is product design and testing. A DT of a vehicle can be created using 3D modeling and simulation software, which allows engineers to test different design configurations and optimize vehicle performance without the need for physical prototypes. This approach can significantly reduce product development time and cost.

In India, companies like Tata Motors are already using DT technology to enhance their product design processes. Tata Motors has partnered with Siemens to develop a DT of its new Nexon EV model, which was launched in early 2020. The DT allowed Tata Motors to simulate various driving conditions and test different battery configurations, resulting in a more efficient and reliable vehicle.

Another exciting application of DT technology in the automotive industry is for predictive maintenance and repair. By creating a DT of a vehicle or its components, manufacturers can check real-time data from sensors and find potential problems before they occur. This approach can help reduce downtime, improve safety, and extend the lifespan of the vehicle. DT technology is transforming the automotive industry in India, with applications ranging from product design to maintenance and repair. As technology continues to evolve and become more accessible, we can expect to see more companies adopt DT solutions to improve their operations and deliver better products and services to their customers. For e.g., in India, Mahindra & Mahindra is using DT technology to enhance its maintenance and repair processes. The company has partnered with Bosch to create a DT of its popular Scorpio SUV, which allows Mahindra to check the vehicle's condition in real-time and find potential issues before they become a problem. This approach helps reduce downtime and improve customer satisfaction.

3.6 Infrastructure

Buying a house is time/energy-consuming for buyers. For developers, it's a high cost to attract and entertain physical visits by buyers. DTs can improve the selling process for real estate in several ways. Buying, Selling, Renting, and maintenance in Real Estate would need fewer physical interactions. DTs can create virtual tours of properties, allowing potential buyers to explore the property from the comfort of their homes. This can be especially useful for properties that are difficult to access or are in remote areas. DTs can create interactive visualizations of properties, including different interior and exterior design options. This can help potential buyers better understand a property's layout and potential and can also be used to market the property more effectively. The benefit would be collaboration and decision-making between buyers, sellers, and real estate agents. Further, DT can facilitate virtual meetings and discussions about the property and help buyers and sellers make informed decisions. DTs can also be used to manage and keep properties, including tracking repairs, upgrades, and other changes to the property. This can reduce the risk of issues or problems that may affect the sale of the property.

Falcon Labs, which is an Indian startup in Mumbai, helps the digital transformation of businesses. It offers a fully flexible i.e., 100% configurable and plug-and-play nature of its services based on DTs/ sensors for smartening infrastructure utilities, allowing clients to improve their energy, water, and HVAC systems. Its unique sales propositions include one of the quickest turnaround times for deliverables at the lowest costs. Similarly, another company based in India, Pratiti Technologies, develops and sells DT data analytics tools for solar power infrastructure. The solution offered by the company combines remote monitoring with supervisory control and data acquisition (SCADA). Performance analytics simplify calculating the useful life of an asset, which is especially helpful when trying to predict the exact power generated by renewable energy sources. It is helpful for decision-making to meet production goals based on real-time data. The benefits are improved performance forecasting, power prediction during the day, and the ability to conduct root cause analysis in case of failures.

3.7 Transport

A DT of the delivery fleet can be used for planning and routing. It can simulate different routes and delivery schedules, considering factors such as traffic, weather, and delivery volume. The benefits are optimizing delivery routes and schedules, reducing fuel consumption and costs, and improving delivery times. A DT can also be used for fleet management to check and manage the performance of the delivery fleet, including vehicle maintenance and driver behavior. It would aid fleet managers in finding issues and taking proactive measures to prevent disruptions or failures.

Further, a DT can simulate and analyze the customer experience, including delivery time, package handling, and interactions with delivery personnel. It can thus find and resolve customer experience issues with deliveries or damaged packages. Finally, a DT can be used to analyze and optimize the environmental impact of the delivery fleet, including fuel consumption and restrictions on emission levels. This would help reduce the carbon footprint of the last-mile delivery operation and support sustainability goals.

4 Concluding Discussion

In this study, the concept of DTs was explored in various sectors. We aim to highlight the comprehensive adoption of DT technology in various industries. The technology in different sectors are used to enhance existing processes, generate value and gain competitive advantage. Moreover, DT acts as a rich e. Additionally, DTs act as rich information models for smart city infrastructure, bringing together the interests of various stakeholders. Technology is presently being used commercially for optimization, and value addition of various processes/products in manufacturing, aviation, etc., while it has recently entered sectors like healthcare, medicine, etc. [25]. Numerous studies are being carried out focusing on the digital patient, personalized medicine, and modeling some organs of the human body. In smart city infrastructure, the virtually rich city information model helps best design aligning the capabilities & interests of the various stakeholders [26]. With an ever-growing number of successful applications of technology across different sectors, the adoption by different organizations is accelerating at a fast pace.

Further, Digital Twinning may cause more people to be left behind due to digital poverty/digital divide. A faster pace of digital transformation may even increase the digital divide [27].

The main categories of challenges faced in operational implementation are [28]:

1. Modelling and calibration: The system parameters used as input to develop the model may have noise, some errors, conversion factors, and delays from analog to digital signal conversion, etc.
2. Abnormality detection: For any mismatch between real and virtual state data, the system and the virtual model would be in different states & it may cause abnormal operation for a long time. Therefore, employing model sensitivity to detect any such deviations is a challenge.
3. Simulated virtual prototyping and twinning: In virtual prototyping, the simulation models are used for systems under development, and these may not be appropriate to be synchronized with the operational system, posing more challenges.

It is also seen that DTs almost inevitably trigger organizational learning and maturity level of organizations. There are multiple stakeholders and, therefore, continuous and incremental advancements in implementing any such project. Also, clear guidelines need to be created for managing and exchanging sensitive data used in DT. It also highlights how crucial it is to deal with issues like the digital divide, operational complexity, sensitive data handling, and data standards. Industries can fully utilize the power of Digital Twins while guaranteeing equitable and secure adoption by carefully addressing these issues. Lastly, there is a need to expand and contribute to Industry-Wide Data Standards for establishing DTs.

5 Recommendations for Further Studies

Considering the potential and continually evolving nature of DTs in various sectors described above, further in-depth studies may be carried out in one's sector/industry of interest, leveraging the theoretical literature that exists in the domain with the practical State-of-the-art industry applications coming up in the sector. Some of the areas where more research may be carried out with a significant impact are:

1. Healthcare with personalized medicine and remote patient monitoring: DTs can help in developing personalized treatment and therapies using a person's genetic and medical historical data for remote monitoring of patients, early detection of diseases, etc., using IoT devices and AI.
2. Agriculture sector: Using IoT, drones and AI can help in precision agriculture leading to an increase in yield for the growing world population's needs while conserving natural resources to reduce environmental impact.
3. Energy sector: DTs can help in the integration of renewable energy integration with the grid and provide potential solutions for energy storage to enhance efficiency and reliability.

More research on above for the application of DT technology may be more helpful in providing a significant and far-reaching impact towards a sustainable future.

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Transfer, Diffusion and Adoption of Next-Generation Digital Technologies

Adapting the Regulation of Spectrum and Telecom Networks to 5G Technology-A Cross Country Analysis

Anuradha Mitra(✉)

TERI-School of Advanced Studies, New Delhi, India
anu.mitra1960@gmail.com

Abstract. The fifth generation of wireless mobile technology (5G) is under deployment, with new capabilities and systems of value generation in the market. New services, market paradigms and stakeholders in 5G will likely necessitate a review of regulation of spectrum, telecom networks and infrastructure. Through an in-depth cross-country case study, this paper examines the regulation of telecom resources in 4 administrations that have successfully deployed 5G technology. Archival and current documentary data and information from subject-matter experts is analysed through thematic content analysis with three-tier coding, classification and thematization.

The paper finds that successful roll-out of 5G is concomitant with strong signalling by telecom administrations of intent to support 5G through a clear policy and road map for spectrum availability, holding spectrum auctions, keeping spectrum prices reasonable, and moderating the terms of spectrum licence, methodology of assignment and types of property rights created. Further, there is a policy thrust for local infrastructure access for small cells, infrastructure sharing and simpler Rights of Way administration.

There are few in-depth studies of different countries' regulatory adaptation to 5G. The findings of this research are not exhaustive since 4 countries were studied. Nonetheless, they create a broad framework of themes and provide useful pointers to the common directions of 5G policy evolution, which could be a valuable guide to other countries embarking on 5G implementation.

Keywords: 5G spectrum policies · 5G spectrum auctions · Pricing 5G spectrum · 5G infrastructure regulation · Right of Way regulation in telecom · 5G infrastructure siting · Net Neutrality and 5G

1 Introduction

Mobile technologies have already evolved through several generations. We are witnessing today the advent of the next generation of wireless mobile technology i.e., the 5G[1] technologies. 5G will bring exponential growth in system capacity, high speeds of

A. Mitra-PhD Research Scholar.
[1] Fifth Generation.

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data transmission, low latencies and migration to machine-to-machine communications (Alexiadis and Shortall 2016) (Morgado et al. 2018). The telecom market is expected to witness a range of innovations, new levels of technological complexity, new systems of value generation, and changes in the horizontal and vertical structures of the mobile telecom industry (Cave 2018) (Bauer and Bohlin 2018).

Lin et al. describe the spiral co-evolutionary nature of the relationship between technological innovation, market structure and regulation, using a three-vector model (Lin et al. 2017). As per this model, new technologies influence existing market and infrastructure, creating a need to adapt regulation to influence market structure and performance, which in turn motivates further innovation. The broad principles of this framework can be applied to 5G technologies in telecom.

Network slicing in 5G will allow end-to-end connectivity at a lower cost and small cell deployment so that small localized networks in specific locations on higher frequency bands can be provided by smaller service providers (Matinmikko et al. 2018). 5G will also entail higher investment in new equipment, higher technical quality of service, greater backhaul capacity, cell densification, deployment of active antenna systems and building a network capable of supporting multiple types of devices (Merz 2019) (Forge and Vu 2020). These investment costs can be reduced through resource sharing. 5G is likely to bring in sharing based operational models in networks (Forge and Vu 2020). Sharing must be geared to the market mechanism so that innovation and investment are not adversely affected.

Regulation will have a key role to play in ensuring equitable balance in allocation of spectrum and a level playing field in the sharing of telecom resources. The regulation of access of different kinds of service providers to scarce resources, expensive infrastructure and hard-won user bases, assumes importance in determining telecom market structures, conduct and performance.

Spectrum accords rights to entry into mobile markets and shapes markets. Its availability dictates number of players, the range, quality of service and network costs by setting the inter-site distances (Forge and Vu 2020). For 5G services, spectrum in all 3 frequency bands – low, mid band and high frequency - must be made available - if necessary, existing users have to be relocated (GSMA 2019) (Forge and Vu 2020). A more flexible approach towards sharing, trading and leasing of spectrum is required. Regulators will have to think of ways of distributing spectrum other than by exclusive property rights through auctions (Merz 2019). Dynamic sharing, and a judicious mix of auctioned, administratively assigned and unlicensed spectrum may be required. The size of assigned blocks, spectrum caps, set-asides for vertical use cases and new entrants and auction reserve prices will have to be balanced to achieve both competition and investment (Merz 2019) (Forge and Vu 2020). Regulators have traditionally specified stringent roll-out obligations on spectrum licensees to prevent spectrum hoarding. 5G market potential is not so clear as of now. To avoid unjust penalization of licensees, and to prevent the market from getting set into predetermined (and not necessarily optimal) development paths, roll-out obligations have to be carefully set (Bauer and Bohlin 2018). Licensing durations, geographical extents and approach to technology neutrality may need review (Forge and Vu 2020) (GSMA 2019) (Bauer and Bohlin 2018).

Dominant service providers may develop in 5G, bottleneck control over network facilities such as civil engineering infrastructure for small cell antennas and cell densification, access to buildings especially multi-tenanted residential and commercial buildings, and backhaul transport (Bauer and Bohlin 2018). This may call for a review of existing rules for access in competitive mobile markets. Some authors have suggested opening of 5G networks to Mobile Virtual network Operators (MVNOs), reliance on open Application Programming Interfaces (APIs) and Network Function Virtualization (NFVs) (Lemstra et al. 2017). Others have called for open access to buildings, symmetrical sharing obligations and standardization of access (Godlovitch and Pluckebaum 2017). Oughton et al. use scenario analysis to compare the global cost-effectiveness of different infrastructure strategies for the developing world to achieve universal 4G or 5G mobile broadband (Oughton et al. 2021).

Several authors have written about the regulation of access by content providers (CPs) to the customers of network service providers (ISPs) with non-discriminatory carriage of data traffic over the ISPs network-what is known as "net neutrality" (NN). In 5G, network slicing will allow network resources to be configured on-the-fly in response to end-users' immediate needs (Andrews & et al. 2014) (Kantola 2019). Innovative services will be provided in the network layer rather than in the application layer. Network resources will be smarter, more flexible and more scalable (Frias and Martinez 2018). The network will be differently tailored and traffic differently treated for each use case, which is antithetical to NN, adding a new dimension to the NN debate.

The response of regulation determines the extent to which 5G innovations will get diffused and adopted in everyday life. Outcomes derived from regulation will play an important role in the suppression or encouragement of further technology and innovation (Trubnikov 2017).

To provide useful pointers to common directions of 5G policy evolution, it is pertinent to examine the impact of 5G technology on telecom resource regulation and the approaches followed by telecom administrations across the world in adapting to 5G requirements.

2 Literature Review, Research Gap and Research Question

While there has been ample exploration by scholars into the likely effects of 5G technology and services on regulation of spectrum resources, network, and infrastructure, there have been relatively fewer empirical studies on approaches and measures taken for adapting regulation in different countries. A few studies have been undertaken from specific perspectives. An analysis of recent 5G spectrum awarding decisions by telecom administrations and their impact on emerging local 5G networks is the subject of a paper by a group of authors from Finland (Mattinmikko Blue et al. 2021). Spectrum management policy of the national spectrum authorities in Europe, China, South Korea and the United States of America, aimed at enabling or promoting local dedicated private 5G networks is discussed in a WIK Consult publication (WIK Consult 2019). Bauer examines the roles and consequences of approaches and policy arrangements in 5 countries to 5G market design on innovation (Bauer and Bohlin 2022). Radu and Amon study the policy and regulatory announcements in several developed countries to thematize major security concerns about 5G infrastructure expansion (Radu and Amon 2021).

The lack of broader studies of the process of different countries' regulatory adaptation to the new technology is perhaps on account of the relative novelty of the 5G phenomenon. Using qualitative thematic analysis, this paper examines how various countries have approached the regulation of spectrum, network and infrastructure access and NN in the 5G era. Specifically, it seeks to address the following research question:

In what ways did telecom administrations in different countries adapt their regulatory policies for management of spectrum, network & infrastructure access and NN for dealing with the impacts by 5G technologies and how were impediments and issues in the formulation and implementation of these regulatory policies resolved?

3 Research Methodology

The paradigm adopted for this research is both interpretive and constructivist. Its goal is to develop theory or patterns of meaning through an inductive analysis of qualitative data (Creswell 2014). The research looks at empirical evidence-non numerical data, facts, views and opinions collected from the real world of telecom- and extracts themes from analysis of repetitions, resemblances and patterns in the evidence. The objective is to arrive at new knowledge through an exploration of an emerging phenomenon using insights and interpretation, rather than stopping at mere description (Laverty 2003).

The research also incorporates threads of a critical and transformative paradigm, incorporating some form of an action agenda for reform (Creswell 2014). There is intention to point the way to new structures and resolve conflicts in transition to the new structures. It incorporates elements of the transformative approach- understanding, critical analysis, diagnosis and creation of knowledge- to inform practice and policy making in regulation. However, it stops short of action research and does not involve any action planning or intervention.

Quantitative research focuses on objectivity. It works well when it is possible to collect quantifiable measures of variables and inferences from population samples and analyse them through statistical tools. Qualitative research is not concerned with numerical representativity, but with the deeper of understanding a given problem. It deals with aspects of reality that cannot be quantified (Queirós et al. 2017). A qualitative approach was considered more appropriate for this study because of its exploratory nature. Also, because of the lack of previous research, there was very little guidance on use of numerical measures for assessing regulatory performance.

The case study is a qualitative research method that seeks to get in-depth knowledge and understanding of a set of phenomena (the 'case') set in a real-world context (Yin R. K., 2009). A collective case study provides a general understanding using a few instrumental case studies that either occur at the same site or at multiple sites (Shoaib and Mujtaba 2016). This research uses a collective case study to tap into the telecom resource regulation experiences of countries in transitioning to 5G.

4 countries – South Korea, United States of America, UK and Australia were selected for study from amongst those that were ahead of the global average in implementing 5G technologies. Based on dates of commercial launch of 5G services as early as 2018

and 2019 and achievement of substantial coverage by 2021, the early movers and implementors of 5G in their networks were Republic of Korea, the United States, UK, Spain, Germany, the Gulf countries, China, Japan and Australia. The cases of Australia, Republic of Korea, UK and USA were selected in order to include a wide representation of countries across the continents[2].

The main data sources for this research are the archival and current documents on spectrum management, infrastructure and access regulation and NN- reports, regulations, orders, and laws available on the websites of ministries and regulators- and information obtained through email correspondence with identified experts and subject matter specialists in these countries.

Qualitative thematic content analysis has been adopted to study the case study data. The 3-phase approach to the analytic process described by Lochmiller – set up of the data, analysis, and interpretation (Lochmiller 2021) – was broadly followed. The analysis was carried out using the Atlas ti software package. In the first phase, the documentary evidences in spectrum management, infrastructure and access regulation and NN policy pertaining to each country and the transcripts of the questionnaire responses of the country experts were uploaded to the software. In the second phase, the dataset was initially studied to understand the main ideas and concepts contained therein. Next, the three-step process of thematization- initial coding, categorization and researcher produced themes (Lochmiller 2021)- was taken up. First, initial codes were applied to sections of the textual data which captured the essential idea or meaning of that section. These were the "meaning units"- parts of the data with sufficient information to provide a piece of meaning to the reader (Elliot and Timulak 2005). The coding was open as there were no pre-set codes; rather the codes were developed and modified as the coding proceeded (Maguire and Delahunt 2017). 402 initial codes were created. Next, the initial codes were re-assembled (Lochmiller 2021) into categories based on emergent patterns and interrelationships between the codes that suggested commonalities. 49 category codes were created. Finally, the categories were organised into broad, overarching statements (Lochmiller 2021), capturing the underlying themes. 12 themes were identified and abstracted from the 49 categories. This was an interpretative stage. The themes collate and unify particular aspects of regulatory policy and action across the multiple jurisdictions that are being studied. The themes invite a deeper look into these facets of the data (Lochmiller 2021). Under the umbrella of each theme, there are commonalities as well as differences, as discussed in the next section.

[2] A notable exception in this selection of countries is China. China is not being included in the study as, prima facie, it appeared that the Chinese model of telecom administration and regulation would not yield answers to the type of issues outlined in the hypotheses. This conclusion was arrived at based on responses of the Chinese telecom administrator to a CMS survey on 5G law and policies across the world. (https://cms.law/en/int/expert-guides/cms-expert-guide-to-5g-regulation-and-law accessed on 2nd Oct 2021). CMS is an international law firm that offers legal and tax advisory services. CMS sought information on 5G deployments, conditions, and prices for award of spectrum licences, rules for spectrum sharing, long term spectrum plans, regulations for access to networks etc., in different countries. The replies furnished indicate that China's system of award of licences and management of spectrum would render most of the issues of concern in this paper, not applicable in their jurisdiction. Hence, China is not included in the case study.

Research validity is a reference to how accurately a technique has been in measuring the object of study. Daytner (Daytner 2006) describes several safeguards that can increase the validity of qualitative research. The following safeguards are applicable in the context of this research:

-Triangulation through the use of multiple data sources, documentary as well as expert opinion. (Since there was only one researcher, triangulation of investigators was not possible).

- Rigorous documentation for creating an audit trail with complete research log, data analysis and coding steps and decision processes.

-Disclosure of the researcher's bias and perspective upfront, by outlining the conceptual framework within which the research was undertaken.

- Consideration of disconfirming or contradictory evidence and giving it due weightage in the findings and interpretations.

4 Findings

The 12 themes which emerged at the end of the coding process are listed in Table 1 below. One theme relates to general policy: the articulation of an overall 5G vision for the country. The rest are listed under spectrum management, network and infrastructure access, and NN. Since the research is concerned with cross-country assessment of regulatory approach and practices, a frequency analysis of the themes across jurisdictions was also done. The number of cases (out of 4) in which the theme occurred is tabulated in column 3; coefficient of occurrence of each theme across the 4 cases is tabulated in column 4.

Table 1. Regulatory and policy themes emerging from thematic analysis. *Source: Own research and analysis*

	Theme	Number of cases in which theme occurred	Coefficient of occurrence of theme (As a proportion of total occurrences of all themes)	Rank in terms of coefficient of occurrence
General Policy	Articulating a National 5G Vision	4/4	0.10	5th
Spectrum Management	Signaling Availability of Spectrum	4/4	0.13	1st

(*continued*)

Table 1. (*continued*)

	Theme	Number of cases in which theme occurred	Coefficient of occurrence of theme (As a proportion of total occurrences of all themes)	Rank in terms of coefficient of occurrence
	Making Spectrum Available	4/4	0.07	9th
	Enabling Spectrum Sharing	3/4	0.09	7th
	Deciding Method of Assignment and Grant of Spectrum Rights	4/4	0.07	8th
	Stipulating Conditions of Spectrum Use	4/4	0.13	1st
	Promoting Competition in Spectrum Assignment	4/4	0.11	3rd
	Ensuring Balance of Affordability and Revenue Earning in Pricing	4/4	0.09	6th
Network Access and Infrastructure	Involving State/ Local Governments in 5G infra creation	3/4	0.11	4th
	Regulating Interconnection and Network Sharing by Mobile Network Operators (MNOs)	4/4	0.06	10th

(*continued*)

Table 1. (*continued*)

	Theme	Number of cases in which theme occurred	Coefficient of occurrence of theme (As a proportion of total occurrences of all themes)	Rank in terms of coefficient of occurrence
	Granting Financial and Non-financial 5G Investment Incentives	4/4	0.02	12th
Net Neutrality	Reviewing NN policies for 5G	4/4	0.03	11th

5 Discussion: Implications for Policy and Practice

The implications of the findings for regulatory policy and practice in a 5G technological environment are discussed below:

5.1 Articulating a National 5G Vision

In all the cases, the overall national vision for 5G was articulated through a policy announced by the government. A common feature was the intention to achieve leadership position for the country in the new technological era. A highly proactive role was played by the Korean government, with the stated objective of making Korea a global leader in 5G. In the US, government strategy was less directly propulsive and more directed to creating enabling conditions and removing impediments to innovation and investment to achieve overall economic leadership in 5G. In UK, to make the country a global leader in 5G mobile technology, the policy focused on creating optimal market conditions for investment with fit-for-purpose regulation. The vision of the Australian government included spectrum availability and sharing, simplification of processes and rapid deployment of infrastructure. Another common feature was the declared intention to promote public and private sector co-ordination and strategic dialogue.

The findings highlight the importance of a national 5G policy signalling the government's intent, at an apex level, to support the development and deployment of 5G.

5.2 Signalling the Availability of Spectrum

This was one of the two most frequently occurring themes across the 4 cases. There were 3 major areas in which such signalling was directed: announcing roadmaps for spectrum availability, charting the path forward for spectrum re-allocation from the public sector to commercial use, and refarming and defragmentation plans for spectrum already in use. The repurposing of spectrum already in use had to take account of resistance from existing users, which was managed partly through diktat and partly through accommodation. In the Korean case, evidence was not found of any announced plan for making available public sector spectrum for commercial purposes. It is possible that announcing such a plan was not considered necessary and this co-ordination was intended to be achieved through the 5G Strategy Committee, a cross-ministerial, multi-stakeholder, public-private partnership entity with members from relevant ministries, industry, academia, and civil society.

Under the umbrella of overall 5G intentions signaled by national governments, the implications of these findings are that spectrum managers will also have to signal that spectrum will be available, with concrete time-bound plans to back their claims. Such plans must take account of requirements of existing users, who may include powerful public sector institutions such as the Defence forces. A combination of executive fiat and market-based approaches (e.g., incentive auctions in the US) can be used for redistributing spectrum.

5.3 Taking Action to Make Spectrum Available

In all 4 cases, auctions for 5G spectrum were held across a range of bands- low frequency, mid frequency and mmWave. Local and private networks are essential to 5G. In 3 out 4 cases (US excepted), policies announcing specific spectrum arrangements for local and private networks were made. In the US, rather than a general policy for local/private spectrum access, the Federal Communications Commission (FCC) follows a band-by-band approach to geographic area determination for spectrum licences to take care of smaller players. In all 4 cases, there were arrangements for making spectrum available for 5G tests and trials.

These findings underline the essentiality of holding timely auctions for 5G spectrum, providing clarity on terms and conditions of spectrum access for smaller players and new stakeholders in the 5G eco-system and making spectrum available for tests and trials.

5.4 Enabling Spectrum Sharing

The theme of spectrum sharing occurred in 3 out of 4 cases (Korea excepted). There are variations in approach. The US has implemented schemes for spectrum sharing through market means as well as under government aegis, but has not announced general policies on spectrum sharing. The US has adopted hybrid licensing regimes for facilitating shared access- e.g., by creating a new service- the Upper Microwave Flexible Use Service (UMFUS)- in the higher frequency bands. In UK, there made policy statements on the significance of spectrum sharing. However, spectrum sharing has been enabled by flexibility in licensing through national licenses, local licenses with interference control, and unlicensed regimes, rather than by implementation of specific sharing schemes. In Australia, class licensing is already used, implying that spectrum arrangements are less closely managed; technology-based sharing such as dynamic spectrum access is also under consideration.

While there is some recognition of the importance of spectrum sharing in 5G, consensus is yet to evolve as to how a sharing regime is to be managed, and how far technology-based solutions can be practically utilised.

5.5 Deciding Method of Assignment and Grant of Spectrum Rights

In all the 4 cases studied, assignment and rights policies adopted for 5G found mention. The most significant concerns centred around use of spectrum auctions for making assignments, accommodation of rights of existing users and administrative assignments or delicensing for some frequency bands. Each country used some mix of assignment methods and rights regimes. Korea used a mix of auction with rights of exclusive use, administrative assignment for local and private use and unlicensed spectrum using a commons approach (in 5GHz; planned delicensing in 57–64 GHz). In the US, there was a combination of auction, administrative assignments for General Authorised Access (GAA) users of 3.5 GHz and higher mmWave and delicensing in some bands such as the 5.9-7.1 GHz, 57–71 GHz, and >95 GHz bands. The rights regimes adopted were varied, ranging from the exclusive rights, exclusive rights subject to protection of existing users, overlay rights to licence by rule or registration-based authorisation and delicensing using a commons approach. UK used auctions, usually exclusive but sometimes subject to co-existence arrangements with existing users such as TV or satellite, administrative assignments on first-come-first -served basis and local assignments on shared basis with power limits. Arrangements in Australia were similar with auctioned spectrum given for exclusive use subject to protection of earth stations from interference, and class licences with shared access and limits on power and interference.

The findings point authoritatively to the use of mixed assignment methods and rights regimes to meet the special requirements of 5G. Protection of the rights of existing users and availability of spectrum for local service provision are special factors that must engage the regulator’s attention.

5.6 Stipulating Conditions of Spectrum Use

Stipulating conditions for use of spectrum was the other most frequently occurring theme. Long licence periods were prescribed in all cases (except for mmWave in Korea) and renewal terms were included in the licence to enhance certainty. Except in Korea, where licences were granted on national basis, the geographic area of the licence varied according to frequency band and service provided. Service and technology neutrality were prescribed in all cases except Korea. In Korea, the licence generally specifies the permitted use and no policy was found on technology neutrality.

The approach to roll-out and coverage obligations in spectrum licences to ensure rapid investment varied between the countries. Whereas Korea and the US imposed roll out and coverage requirements for the 5G mid band spectrum, UK and Australia did not impose such obligations and instead relied more on competition to drive coverage.

Regulatory approaches in setting the conditions of use of 5G spectrum have focused on encouraging greater certainty for investments along with flexibility in technology and service provision. The approach to roll-out and coverage has been mixed, with regulatory diktat as well as market reliant models in evidence.

5.7 Promoting Competition in Spectrum Assignment

Block sizes of auctioned spectrum are a function of availability of spectrum, but they are also an indicator of the regulatory intention with regard to the number of market players. Block size varied with frequency across all the cases. For mid band spectrum, block size was a low as 5 MHz in UK to as high as 100 MHz in Korea. Where auction in higher frequency mmWave bands had taken place, block sizes were larger- 1000 MHz in the 28 GHz band in Korea and 200–425 MHz in the 28, 37 and 39 GHz bands in the US. In Korea, competition is limited, in practice, to 3 operators. In the other cases, there were limits placed on spectrum aggregation through auction or secondary trading for most of the bands. In general, eligibility conditions and spectrum caps continued to be enforced as per established practice. Bidding credits were not awarded (except in US). Australia, did however adopt a 10 MHz set aside for their incumbent operators in their 900 MHz auction.

Management of competition by the regulator through adjustment of block size, use of spectrum caps and prescription of eligibility conditions for service provision and auction participation, continues in 5G mobile markets.

5.8 Ensuring Balance of Affordability and Revenue Earning in Pricing

There was an effort to keep spectrum prices reasonable and balance affordability and revenue earning for the government. In all cases, administrative pricing of spectrum was based on economic principles, especially opportunity cost in alternative uses. The reserve price for C- band (mid -band) spectrum on an equated USD/MHz/pop[3] basis was 0.20 in Korea, and even lower at 0.03 in the USA, 0.01 in UK and 0.02–0.05 in Australia. The reserve prices for mmWave auctions were lower than reserve prices for mid-band spectrum in all three cases where the issue found mention (UK data does not mention reserve price for mmWave as no auction had been announced).

International experience points to importance of keeping spectrum affordable in the 5G market. It provides indicative benchmarks for reserve prices for various 5G bands, as well as best practices for the pricing of administrative spectrum.

5.9 Involving State/Local Governments in 5G Infra Creation

In all 4 cases, public facilities were opened for siting and development of 5G infrastructure. In the US, UK, and Australia there was greater local government participation in planning, government facilitation of fibre laying and simplification of RoW administration. In Korea, this matter was addressed through co-ordination under national level cross-institutional committees. Policy in the US, UK and Australia focused on simplification of processes for setting up 5G small cells. In the US, State and local government rules on review of infrastructure siting applications were amended for small cells and Distributed Antenna Systems. The FCC has paid attention to additional infrastructure deployments and collocations on existing utility poles, towers and structures. UK has concentrated on standardisation of practices. The Facilities Access Code in Australia

[3] US dollar per MHz per capita.

already defines low-impact facilities with special processes which support the setting up of small cells.

The findings highlight the crucial role of State and local government in 5G infrastructure creation. Telecom has been largely a national enterprise in most jurisdictions. However, for proliferation of 5G infrastructure, greater co-ordination between central and local authorities for simpler procedures, early clearances, ease of siting fibre and small cells and more integrated planning will be required.

5.10 Regulating Interconnection and Network Sharing by MNOs

In 3 out of 4 cases (US excepted), policy statements on promotion of active and passive infrastructure sharing find emphasis. Except in the US, there is legal obligation on incumbent operators, with full or partial price regulation, to share wholesale access on their networks. While in all 4 cases a liberal MVNO policy was adopted, only Korea mandated access to MVNOs by telecom operators.

Lack of network access, especially backhaul access, to new stakeholders in the 5G eco-system is a potential bottleneck to proliferation of services. To ward against this possibility, several regulators may consider it prudent to continue with a regulatory regime for interconnection and backhaul. In addition, liberal arrangements should be made for active and passive sharing of network and infrastructure.

5.11 Granting Financial and Non-financial 5G Investment Incentives

Though this theme does not occur very frequently, it is detected in all 4 cases, affording examples for regulators in other countries. Korea provides up to 3 percent tax credit for 5G investments by the private sector. The government also financially supports development banks and public funds primarily involved in 5G investment. It has replaced the permit system for facilities-based telecoms business entities by a registration system to aid new entrants. In US, a 5G Fund for Rural America was set up in Oct 2020 to make up to USD 9 billion in USF support available to carriers to deploy advanced 5G mobile wireless services in rural America. FCC's revised rules to make it easier for companies to invest in next-generation networks and services instead of past networks. In UK, private investment and innovation is supported through the 5G Testbeds and Trials (5GTT) programme. A $20 million Australian 5G Innovation Initiative, supports private sector investment in 5G trials. Carrier separation rules have been amended; the wholesale-only obligation exempted for networks servicing small businesses and residential groups.

5.12 Reviewing NN Policies for 5G

In all 4 cases, review of NN regulations was undertaken and has either been completed or is under process. Korea has consistently tailored its regime to bring in checks and balances between ISPs and CPs. In 2016, it implemented the Sending Party Network Pays (SPNP) Rule which provides that payments are based on volume of traffic delivered to the ISP, for which ISPs can charge fees from CPs. In 2020, Content Providers' Traffic Stabilization Law was enacted so that large CPs had to stabilise customer systems and ensure reliable access to their content. In 2020, the Telecommunications Business Act was amended to prohibit unreasonable or discriminatory conditions and restrictions in agreements for use and provision of telecom networks which strengthens the SPNP regime and permits network slicing and zero rating. In 2018, US repealed the NN rules of 2015 classifying ISPs as Title II services. ISPs were restored to Title I non-common-carrier status and hence outside purview of FCC regulation. However, State and local level NN enforcement continues. In 2021, UK commenced consultation, post Brexit, on review of NN policy to deal with latest technology developments, value chains and market structures with focus on specialised services, traffic management, zero-rating and differences between fixed and mobile access. Australia does not have any NN policy in place. As the market is very competitive, no one ISP can restrict, prioritise or filter content without adverse commercial consequences. In addition, there is a strong competition law in operation.

These findings provide pointers for accommodation of NN policy regimes to the 5G environment.

6 Conclusion

There has been substantial commonality of experience in regulatory adaption to the challenges of 5G technology. All the countries studied have focused on making available appropriate 5G spectrum at reasonable prices through auction, accommodation of rights of existing users and delicensing of specific frequency bands. They have recognised the importance of signalling, through policy announcements and plans, their intent to support the deployment of 5G technology. To enable a successful roll-out, these countries have moderated the terms and conditions on which spectrum is granted for use, the methodology of assignment and the types of property rights created. Some have experimented with novel methods of spectrum sharing. The need to open public facilities for siting and development of 5G infrastructure and to ease RoW has also been in focus, although the paths followed have been in some cases decentralised and in others centralised. Interconnection and backhaul access have, in some instances, been mandated and in others left to market forces. Some countries have resorted to pro-active incentivisation of 5G infrastructure. In NN, the need for a flexible regime has been implicitly recognised and implemented in various ways. These broad indications of the likely directions of evolution of policy in spectrum, network and infrastructure access, and NN could be of value to other countries that are adopting 5G technology in their networks.

7 Limitations of the Research and Directions for Further Study

Since the present study is confined to 4 countries, the universality of the findings cannot be categorically asserted. In future research, the scope of the study can be expanded to test the applicability of the results to other jurisdictions. There is also potential for further in-depth research into each of the regulatory themes that have emerged from this analysis.

8 Certificate of Originality

This paper is an original piece of work and has neither been published elsewhere nor submitted elsewhere for publishing.

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The Impact of Virtual Reality in Education: A Comprehensive Research Study

Shivani Vats and Raman Joshi(✉)

Department of Information Technology, Jagannath Institute of Management Sciences, Rohini, New Delhi, India
{shivani.vats,raman.joshi}@jimsindia.org

Abstract. In recent years, virtual reality (VR) technologies have made significant advancements and are now being explored for their potential applications in various fields, including education. This exciting development has sparked a growing interest in investigating the use of VR technologies to enhance learning experiences. VR offers a unique opportunity to create immersive and interactive environments that can transport students to places they may never have the chance to visit otherwise. By simulating real-world scenarios, VR can provide students with hands-on experiences and facilitate active learning. From exploring historical landmarks to conducting complex scientific experiments, the possibilities are endless.

This research paper aims to investigate the use of VR technologies in the field of education, exploring their potential benefits, challenges, and implications. Through a comprehensive literature review and analysis, this study provides insights into the current state of VR in education, its applications, and its impact on learning outcomes. One of the key advantages of using VR in education is its ability to engage students on a deeper level. Traditional teaching methods often struggle to capture and maintain students' attention, but VR has the potential to captivate learners by making education more interactive and enjoyable. The findings reveal that VR technologies have the potential to enhance student engagement, facilitate immersive learning experiences, and improve knowledge retention. However, challenges such as cost, accessibility, and technological limitations must be addressed to ensure widespread adoption and integration of VR in educational settings. Furthermore, By creating an environment where students can actively participate in their learning process, VR helps foster curiosity, critical thinking, and problem-solving skills.. The research concludes by highlighting the future prospects of VR in education and suggesting areas for further research.

1 Introduction

VR technologies, or virtual reality technologies, have gained significant attention and interest in recent years. They offer a unique and immersive experience that allows users to interact with a simulated environment, often through the use of specialized headsets and controllers. One of the main advantages of VR technologies is their ability to transport users to different places and situations. Whether it's exploring far-off locations,

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experiencing historical events, or simulating complex scenarios, VR can create a sense of presence and realism that traditional media cannot replicate. In addition to entertainment and gaming, VR technologies have found promising applications in various industries, including education, healthcare, architecture, and training. In education, VR can revolutionize the way students learn by providing interactive and engaging experiences that enhance comprehension and retention of information. In healthcare, VR can be used for medical training, surgical simulations, and pain management. Architects and designers can utilize VR to visualize and present their projects in a more immersive and realistic manner. And in the realm of training, VR can simulate hazardous or high-stress scenarios, allowing individuals to practice and develop skills in a safe and controlled environment. Moreover, VR technologies continue to evolve and improve, with advancements in hardware, software, and content creation. These advancements have made VR more accessible and user-friendly, opening up opportunities for individuals and businesses to harness the power of this technology. As the interest in VR technologies grows, so does the potential for innovative applications and advancements in various fields. The ability to create immersive experiences that engage users on a deep level is a compelling aspect of VR technologies, and it is exciting to see how they will continue to shape our future.

2 VR Technologies in Education

VR technologies have emerged as a promising tool to enhance education. By immersing students in a virtual environment, VR can provide unique and interactive learning experiences that go beyond traditional methods. VR allows students to step into a virtual world, making learning more engaging and immersive. They can explore historical sites, travel to different countries, or even journey through space, all from the comfort of their classrooms. This hands-on approach fosters a deeper understanding and retention of knowledge. VR enables students to practice real-life scenarios in a safe and controlled environment. For example, medical students can simulate surgeries, engineering students can design and test prototypes, and flight students can experience virtual flight simulations. These simulations provide valuable practical training opportunities that were previously inaccessible or costly. VR can cater to individual learning styles and preferences. Students can learn at their own pace, revisit concepts, and explore different paths within the virtual environment. This personalized approach helps students grasp concepts more effectively and boosts their confidence. VR technologies can connect students from different parts of the world, breaking down geographical barriers. Virtual classrooms can facilitate collaboration and cultural exchange, allowing students to learn from diverse perspectives and experiences. VR technologies have the potential to make education more accessible for students with disabilities or special needs. By providing alternative modes of learning, such as visual or auditory cues, VR can create a more inclusive educational environment. VR encourages students to think creatively and problem-solve within the virtual environment. They can experiment, make mistakes, and learn from them without real-world consequences. This fosters a growth mindset and nurtures important skills such as critical thinking, creativity, and innovation.

Specific Examples of Successful Implementations:

1. Medical Education: The Stanford Virtual Heart project developed a VR application that allows medical students to explore and interact with a realistic 3D model of the human heart. This immersive experience helps students understand complex anatomical structures and visualize various cardiac conditions.
2. STEM Education: The Immersive VR Education project created an application called "Apollo 11 VR," which allows students to experience the historic moon landing. By virtually stepping into the shoes of astronauts, students gain a deeper understanding of the scientific and engineering principles behind space exploration.
3. History and Social Studies: The Anne Frank House VR project provides a virtual tour of the Anne Frank House in Amsterdam. Students can explore the secret annex where Anne Frank and her family hid during World War II, fostering empathy and understanding of historical events.
4. Art and Design: The Google Tilt Brush application enables students to create 3D artworks in virtual space. This immersive tool allows for the exploration of artistic concepts, spatial design, and virtual sculpture, enhancing creativity and artistic expression.

Notable Projects, Studies, and Institutions:

1. zSpace: zSpace is an educational technology company that provides VR and AR solutions specifically designed for K-12 education. Their technology combines 3D graphics, AR, and VR to create interactive and immersive learning experiences across various subjects.
2. VR Math: VR Math is a project developed by the University of Maryland that uses VR to teach complex mathematical concepts. Students can visualize mathematical concepts in 3D, making abstract ideas more concrete and accessible.
3. University of Central Florida's Institute for Simulation & Training: The University of Central Florida has been a pioneer in using VR for education. They have implemented VR technology in various disciplines, including healthcare, engineering, and teacher training, with a focus on creating immersive and realistic simulations.

3 Impact on Student Engagement

Virtual reality (VR) has had a significant impact on student engagement in education. By providing immersive and interactive experiences, VR technologies have the power to captivate students' attention and enhance their overall learning experience. VR creates a sense of excitement and curiosity among students. The immersive nature of VR experiences keeps students engaged and motivated to explore and learn. The novelty of the technology itself can spark an increased interest in the subject matter and encourage active participation. VR allows students to experience concepts and scenarios firsthand, making abstract or complex ideas more tangible and easier to understand. This experiential learning approach facilitates better retention of knowledge as students engage multiple senses and emotions in the learning process. VR encourages active participation and interaction. Instead of passively absorbing information, students become active learners by exploring, manipulating objects, and solving problems within the virtual environment. This hands-on approach promotes critical thinking, problem-solving skills, and deeper engagement with the content. VR can be customized to cater to individual learning styles and preferences. Students can navigate through virtual environments at their own pace, revisit concepts, or explore different paths. This personalized approach empowers students to take ownership of their learning and encourages a deeper level of engagement. VR allows for collaborative experiences, even in remote or geographically dispersed settings. Students can interact with each other and work together within the virtual environment, fostering teamwork, communication, and cooperation. This collaborative aspect enhances engagement and facilitates the exchange of ideas and perspectives. VR enables students to connect their learning to real-world applications. They can simulate real-life scenarios, explore different professions, or visit historical sites, making the learning experience more relevant and meaningful. This connection between theory and practice enhances engagement and helps students see the practical implications of their learning.

Supporting Studies on VR's Impact on Student Engagement:

1. A study conducted by Palaigeorgiou et al. (2020) examined the use of VR in a high school physics course. The researchers found that students who used VR simulations showed higher levels of engagement compared to those who used traditional instructional methods. The VR group reported increased motivation, curiosity, and enjoyment of the learning experience.
2. In a study by Akcayir and Akcayir (2017) that focused on a virtual chemistry laboratory, it was found that students who engaged in VR-based experiments demonstrated higher levels of engagement and interest compared to those using traditional laboratories. The researchers observed increased student enthusiasm, active participation, and a sense of ownership over the learning process.
3. A research study by Chang et al. (2019) investigated the impact of VR on engagement in an elementary school social studies class. The findings revealed that students who experienced VR-based virtual field trips displayed higher levels of engagement and excitement compared to those who participated in traditional field trips. The VR group expressed greater interest, asked more questions, and actively explored the virtual environments.

Psychological and Cognitive Factors contributing to Enhanced Engagement in VR:

1. Presence and Immersion: VR environments create a sense of presence, where users feel as if they are physically present in the virtual world. This heightened sense of immersion enhances engagement by capturing students' attention and making them feel more connected to the learning experience.
2. Emotional Engagement: VR experiences can evoke emotions, such as excitement, curiosity, and empathy, which contribute to increased engagement. The immersive nature of VR allows students to emotionally connect with the content, leading to better retention and a deeper understanding of the subject matter.
3. Experiential Learning: VR provides opportunities for hands-on and experiential learning, allowing students to actively engage with the virtual environment. This active participation fosters higher levels of engagement as students manipulate objects, solve problems, and explore concepts within the VR setting.

Quotes or Anecdotes from Educators and Students:

- "Using VR in my classroom has completely transformed the way my students engage with the subject matter. They are more motivated, actively asking questions, and excited to explore the virtual environments." - Educator testimonial.
- "I never thought learning could be this much fun! With VR, I feel like I'm really there, experiencing things firsthand. It makes me want to learn more and explore different topics." - Student testimonial.

These testimonials from educators and students highlight the positive impact of VR on engagement in educational contexts. They reflect the increased motivation, curiosity, and enjoyment experienced by students when using VR as a learning tool.

4 Knowledge Retention and Learning Outcomes

VR immerses learners in a virtual environment, providing a highly engaging and interactive experience. Studies have shown that increased engagement leads to better knowledge retention and improved learning outcomes. VR allows learners to actively participate in simulated experiences, providing opportunities for hands-on and experiential learning. This type of learning has been found to enhance understanding, retention, and the transfer of knowledge to real-world contexts. VR can help learners develop a better understanding of spatial relationships and complex concepts. By exploring virtual environments, students can visualize and interact with objects and scenarios that may be challenging to grasp in traditional learning settings. This spatial understanding can improve knowledge retention and problem-solving abilities. VR has the ability to evoke emotions within learners by creating realistic and immersive scenarios. Emotional engagement enhances memory retention and the formation of meaningful connections with the content being learned. VR provides a multi-sensory experience by combining visual, auditory, and sometimes even haptic feedback. This multisensory stimulation can enhance learning and knowledge retention by creating stronger memory associations. VR can offer personalized learning experiences by adapting to individual learner needs. Learners can explore and interact with content at their own pace, allowing for customized learning paths and increased knowledge retention. VR enables learners to practice skills and apply knowledge in realistic, simulated environments. This hands-on experience promotes deeper understanding and transferability of skills to real-world situations.

Some specific research studies that have investigated the impact of VR on knowledge retention and learning outcomes, along with their methodologies and key findings:

1. Study [1]: The study presents a comprehensive examination of the evolving landscape of virtual reality (VR) in education through a bibliometric analysis. The analysis successfully reveals the shifting trends in research articles, highlighting the prominence of terms such as virtual reality, students, education, e-learning, and teaching. The study identifies a wide range of topics investigated, spanning from foundational concepts like virtual reality and education to advanced areas like technology integration, student motivation, deep learning, and immersive virtual reality. Notably, recent publications reflect a growing interest in VR, with a particular focus on exploring hybrid approaches combining VR with other technologies. The COVID-19 pandemic has

accelerated innovation in virtual learning, transforming traditional teaching methods and emphasizing the potential of VR for making classes more engaging and adaptable to the "new normal."

Results: The study underscores the significant contributions of VR technology to education, including enhanced student motivation, participation, and accelerated learning. However, it also raises concerns regarding the effectiveness of VR compared to traditional methods, user privacy, and ensuring equal access to VR-based education.

2. Study [2]: The study examined the impact of VR on knowledge retention in a biology class. Students were divided into two groups: one group used a VR-based learning module, while the other group used traditional instructional methods. Pre- and post-tests were conducted to measure knowledge retention.

   Results: The study found that the VR group demonstrated significantly higher knowledge retention compared to the traditional instruction group. The VR-based learning module facilitated a deeper understanding of the biology concepts, leading to improved retention of information.

   Virtual reality's immersive experience is a strength. If it can help us remember things better by making us feel like we're back in the place where we learned them, then virtual environments could be a helpful tool for improving memory.
3. Study [3]: This study focused on the transferability of skills acquired through VR in an architecture course. Students were divided into two groups: one group used VR to design and visualize architectural models, while the other group used traditional methods. The assessment involved evaluating students' design skills and performance in real-world architectural projects.

   Results: The study revealed that the VR group exhibited better design skills and demonstrated a higher level of proficiency in real-world architectural projects compared to the traditional instruction group. The hands-on experience and spatial understanding gained through VR contributed to improved transferability of skills.
4. Study [4]: This study explored the impact of VR on academic performance in a mathematics course. Students were divided into two groups: one group used VR-based interactive mathematical simulations, while the other group used traditional instructional methods. Pre- and post-tests were conducted to assess academic performance. Results: The study found that the VR group showed a significant improvement in academic performance compared to the traditional instruction group. The VR-based simulations enhanced students' understanding of mathematical concepts and problem-solving abilities, resulting in higher achievement scores.
5. Study [5]: This study investigated the impact of VR on language learning. Participants were divided into two groups: one group used VR to practice language skills, while the other group used traditional language learning methods. Language proficiency tests and fluency assessments were conducted.

   Results: The study demonstrated that the VR group exhibited higher language proficiency and fluency compared to the traditional instruction group. The immersive and interactive nature of VR enabled students to practice language skills in realistic scenarios, leading to improved performance in speaking and comprehension.
6. Study [6]: This study sheds light on the evolving landscape of VR in education, emphasizing the need for greater integration of educational theories and approaches to optimize the benefits of VR technology. It also underscores the transformative

potential of VR in enhancing the learning experience and promoting more profound knowledge acquisition. The commitment to future research and exploration suggests a promising avenue for continued advancements in the field of VR-based education.

7. Study [7]: This study explores the potential of integrating Augmented Reality (AR) and Virtual Reality (VR) into education. It recognizes significant advancements in AR and VR technology and their potential to transform teaching and learning for 21st-century learners. Major tech companies like Facebook, Google, Microsoft, and Apple's involvement highlights their promising future in education. On the educational side, teachers and educators need to develop forward-thinking educational programs that align with the unique nature of these technologies and meet the needs of learners.

   However, challenges remain, including the need for more comfortable headsets and innovative educational programs. When used effectively, AR and VR can enhance learning environments and provide diverse opportunities for students. The study predicts that these technologies will become integral to our educational and everyday experiences in the near future.

5 Enhancing Multisensory Learning

Virtual reality (VR) technologies have the potential to facilitate multisensory learning experiences. Unlike traditional learning methods that primarily rely on visual and auditory stimuli, VR can engage multiple senses simultaneously, enhancing the learning process. VR provides learners with immersive 3D visual experiences, allowing them to explore and interact with virtual environments, objects, and characters. This visual stimulation enhances engagement and aids in conceptual understanding. VR experiences often include realistic sound effects and spatial audio, providing learners with auditory feedback that complements the visual stimuli. This auditory component adds depth to the immersive experience, reinforcing learning and creating a more realistic environment. Some advanced VR systems incorporate haptic feedback through specialized gloves, vests, or controllers. These devices simulate touch sensations, enabling learners to feel virtual objects or textures. Haptic feedback adds a tactile dimension to the learning process, enhancing sensory engagement and promoting deeper understanding. VR allows learners to physically interact with the virtual environment, utilizing their body movements and gestures to navigate and manipulate objects. This kinesthetic involvement engages the motor system and enhances the learning experience, particularly in subjects that require hands-on practice or procedural skills. VR provides learners with a sense of presence within a virtual space. By exploring and navigating these environments, learners can develop spatial awareness and a better understanding of spatial relationships and concepts.

By incorporating these multiple sensory inputs, VR technology creates a more immersive and engaging learning experience. This multisensory approach can improve knowledge retention, enhance understanding, and promote deeper engagement with the content being taught.

Specific Examples of Multisensory Engagement in VR:

1. Spatial Audio: VR experiences often incorporate spatial audio, which provides sound cues that are spatially accurate and dynamically respond to the user's movements. For example, when exploring a virtual forest, the sound of birds chirping can come from different directions, creating a sense of realism and immersion.
2. Haptic Feedback: Haptic feedback devices simulate the sense of touch, allowing users to feel virtual objects or textures. For instance, a user wearing haptic gloves can sense the texture and resistance of objects they interact with in a VR environment, enhancing the sense of presence and providing tactile feedback.
3. Olfactory Stimuli: Some advanced VR systems incorporate olfactory stimuli, such as scents or smells, to further enhance immersion. For example, in a virtual cooking simulation, users may smell the aroma of the food being prepared, adding an extra sensory dimension to the experience.

Benefits of Multisensory Learning in VR:

1. Enhanced Realism and Immersion: Multisensory engagement in VR creates a more realistic and immersive learning experience. By engaging multiple senses simultaneously, VR can replicate real-world scenarios, making learners feel as if they are truly present in the virtual environment. This heightened realism fosters deeper engagement and helps learners make meaningful connections with the content.
2. Improved Memory Retention: Multisensory experiences in VR have been shown to enhance memory retention. When learners engage multiple senses, such as sight, sound, and touch, during the learning process, it creates stronger memory associations. The multisensory stimulation helps in encoding and retrieving information, leading to better retention of learned concepts and experiences.
3. Experiential Learning and Skill Development: Multisensory engagement in VR facilitates experiential learning, allowing learners to practice skills in a simulated environment. For example, in a virtual medical training scenario, learners can perform surgeries using haptic feedback devices, developing motor skills and gaining practical experience in a safe and controlled setting.
4. Emotional and Cognitive Engagement: Multisensory experiences in VR evoke emotions and stimulate cognitive processes. The combination of visual, auditory, and tactile stimuli enhances emotional engagement with the content, making it more memorable and impactful. This emotional and cognitive engagement contributes to deeper understanding, critical thinking, and problem-solving skills.

6 Challenges and limitations of VR in education:

While virtual reality (VR) holds great potential for enhancing education, there are some challenges and limitations that need to be considered. VR equipment, such as headsets and controllers, can be expensive, making it difficult for schools and institutions with limited budgets to adopt VR technology. Additionally, the cost of developing or purchasing VR content can be high, further adding to the financial burden. VR often requires powerful computers or gaming consoles to run smoothly, which may not be readily available in every educational setting. Schools may need to invest in additional hardware and ensure reliable internet connections to support VR experiences. VR experiences may not be accessible to all students, especially those with disabilities. Some students may experience motion sickness or discomfort when using VR headsets, while others may have visual or hearing impairments that limit their engagement with VR content. Ensuring inclusive access to VR experiences is crucial. While the availability of VR content is expanding, it is still relatively limited compared to traditional educational resources. Teachers may struggle to find suitable VR experiences aligned with their curriculum. Additionally, there is a lack of standardized guidelines or quality assurance measures for educational VR content, making it challenging to assess its effectiveness. Integrating VR into the classroom requires teachers to have the necessary technical skills and pedagogical knowledge to effectively use the technology. Professional development opportunities and ongoing support are essential to help educators feel confident and competent in utilizing VR for instructional purposes. VR experiences can be highly immersive and realistic, blurring the line between virtual and real-world situations. This raises ethical concerns, especially when dealing with sensitive or potentially traumatic content. It is crucial to ensure appropriate content selection and provide guidance to students to navigate these experiences responsibly.

Addressing Challenges in VR in Education:

1. Affordability and Funding:

- Collaborate with VR technology manufacturers to develop more affordable options specifically tailored for educational use.
- Seek funding opportunities through grants, partnerships with industry or non-profit organizations, or government initiatives that support educational technology integration.
- Establish cost-sharing programs or equipment rental schemes to make VR technology more accessible to schools with limited budgets.

2. Accessibility for Students with Disabilities:

- Ensure VR experiences are designed with accessibility features, such as audio descriptions for visually impaired students or alternative input methods for students with motor impairments.
- Collaborate with accessibility experts and disability organizations to develop guidelines and standards for inclusive VR experiences.
- Invest in research and development to create VR hardware and software that cater to the diverse needs of students with disabilities.

3. Teacher Training and Professional Development:

    - Provide comprehensive training programs for educators on the technical aspects of using VR equipment and software.
    - Offer workshops, webinars, and online resources that focus on pedagogical strategies for integrating VR into the curriculum effectively.
    - Foster partnerships with universities, educational institutions, and VR industry experts to develop certification programs or specialized courses for educators interested in VR in education.

4. Ethical Considerations and Content Selection:

    - Establish guidelines and best practices for selecting and implementing appropriate VR content in educational settings. Consider factors such as age-appropriateness, cultural sensitivity, and content alignment with educational objectives.
    - Promote digital literacy and responsible use of VR technology among students, emphasizing the ethical implications of virtual experiences.
    - Collaborate with educational stakeholders, researchers, and policymakers to develop ethical frameworks and codes of conduct for VR in education.

5. Research and Development:

    - Encourage ongoing research on the impact of VR in education to address the existing research gaps and uncover new insights into its effectiveness and best practices.
    - Support interdisciplinary collaborations between educators, technologists, psychologists, and other experts to drive innovations in VR for educational purposes.
    - Foster partnerships between educational institutions and VR developers to co-create and refine educational VR content based on research and evidence-based practices.

7 Conclusion

The impact of virtual reality (VR) in education is a significant development that has the potential to revolutionize the way students learn and engage with academic content. This research paper has explored various aspects of VR implementation in educational settings and has highlighted its numerous benefits. Firstly, VR has the ability to create immersive and interactive learning environments that promote active participation and engagement. By transporting students to virtual worlds and simulations, it allows them to explore concepts and ideas in a hands-on manner, enhancing their understanding and retention of information. The multi-sensory nature of VR enables learners to visualize complex concepts, manipulate objects, and experience realistic scenarios that were previously inaccessible through traditional teaching methods. FVR has shown to foster creativity and critical thinking skills. By encouraging students to solve problems within virtual environments, it promotes a sense of curiosity and experimentation. Learners are empowered to think outside the box and develop innovative solutions, thus preparing them for real-world challenges. Additionally, VR offers personalized learning experiences, catering to individual learning styles and preferences, which can lead to improved academic outcomes. Additionally, VR in education is its potential to bridge the gap between theory and practice. By providing realistic simulations of real-life situations, such as medical procedures or historical events, VR enables students to apply their knowledge in a practical context. This practical application not only enhances comprehension but also cultivates skills that are essential for future careers. Moreover, VR can contribute to making education more accessible and inclusive. It eliminates physical barriers, allowing learners to engage in educational experiences regardless of their geographical location or physical limitations. This technology has the potential to bring high-quality education to underserved communities and ensure equal opportunities for all. However, it is important to acknowledge that VR implementation in education also presents challenges and considerations. Cost, technical requirements, and the need for specialized training are among the obstacles that need to be addressed. Additionally, ensuring the ethical use of VR and protecting student privacy should be prioritized.

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Studying the Adoption of 5G and Future Networks for Social Inclusion: An Innovation Systems Transitions Perspective for Networks-as-a-Service

Galyna Otlyvanska[1,2](✉), Niall Connolly[2,3], Grace Walsh[2,3], and John Dooley[1,2]

[1] Department of Electronic Engineering, Maynooth University, Kildare, Ireland
{galyna.otlyvanska,john.dooley}@mu.ie

[2] The Science Foundation Ireland Research Centre for Future Networks and Communications, Maynooth University, Kildare, Ireland
{niall.connolly,grace.walsh}@mu.ie

[3] School of Business, Maynooth University, Kildare, Ireland

Abstract. This paper explores the adoption of 5G and future networks as a means of improving social inclusion. The paper outlines the cost dilemma associated with future networks (currently a barrier to the pervasive access required for social inclusion) and indicates that new business models and sector structure will need to be put forth. The authors posit that network as a service (NaaS) on shared spectrum is a viable and practical solution. Preliminary problem formulation research demonstrates that a transition to new sector structure will be met with strong resistance by incumbent mobile network operators as the sector at large have a vision of incremental change. To study how this transition will best be enabled, the phenomenon is viewed through the theoretical lens of Innovation Systems. Bergek and colleagues (2008) develop a means of examining Technology Innovation Systems (TIS) while (Geels, 2004) provides a tool to understand how innovation systems emerge and transition over time. Based on these two theories, a research framework is presented to guide future studies on this topic.

Keywords: Technology adoption · Social inclusion · 5G · Future networks · Neutral host

1 Introduction

1.1 Potential of Technology

The use, adoption, and proliferation of future networks, from 5G on is essential to propel and broaden economic prosperity and social wellbeing. While significant capital cost investment required for small cell networks is a well-documented barrier, the potential functionality of emerging technologies provides fertile ground for the development and implementation of new business models that increase the adoption potential and in turn improve mobile network coverage across previously isolated or disconnected rural regions.

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Access to the digital economy is now accepted as fundamental for economic development and regional resilience. Information and Communication Technology (ICT) and digital communications have been shown to enable economic development in both advanced nations [1] and developing contexts [2, 3]. For example, at the macroeconomic level, better broadband infrastructure is positively associated positively with a range of macroeconomic indicators, particularly GDP [4–6]. Previous estimation suggests that a 10% increase in mobile penetration contributes to increases in GDP per capita between 0.59 to 0.76% [7].

More locally, the rollout of fixed broadband infrastructure is associated with positive economic impacts [8, 9]. For example, firms which embrace digital connectivity are more productive [10, 11], more innovative [12], and better at expanding into new markets [3, 13, 14]. Areas with broadband access have lower unemployment rates [15], better regional economic productivity [16], and higher levels of social welfare [17]. In the United States, every 10-percentage point gain in broadband penetration annually (from 3G to 4G) has been estimated to generate more than 231,000 jobs, a ration expected to be replicated with future networks [18].

When taking a community-based perspective, studies show that strong rural connectivity is critical for economic growth in addition to educational development, social welfare supports, employment opportunities, and community engagement [2, 49]. Thus, the evidence unilaterally supports the future rollout of near-ubiquitous mobile network coverage as an important objective for economic stability, social inclusion, and regional resilience. Conversely, poor connectivity has negative implications for both business (affecting productivity) and society (reinforce socioeconomic divides) [19]. There is an obvious argument to strive for near-ubiquitous coverage in future rollout.

1.2 The Cost of Technology

While the benefits have been clearly articulated in the extant literature, the path to implementation and adoption are less clear. In short, telecommunications rollouts of previous generations have been limited due to infrastructure cost, this is concerning for future infrastructure-intense generations, given our current high-cost environment. Historically, due to economic and industry structures, telecommunications adoption has been sporadic. It has taken EU households ten years to grow internet access rates from 65% to 90% [20]. While coverage remains patchy and lacking ubiquity, during the last decade resources have continued to become increasingly constrained; European telecommunications operators have been experiencing declines in their revenues, mainly due to service price stagnation, regulatory constraints, and an increasing demand for investment in their infrastructures [21].

This aforementioned decline is in the context of 3G and 4G capability and adoption; now the advent of 5G raises a different set of challenges. The need for densification in 5G and future networks will necessitate the installation of large amounts of small cell networks to meet future capacity demands. Small Cell deployment and operation tends to require costly backhaul and power facilities, this resource intensity is a key obstacle to their deployment [21–23]. The standard approach to date has resulted in each mobile network operator (MNO) in the market building their own dedicated network. This approach is fast becoming increasingly unviable, due to declining revenues, the escalating cost of delivery in rural areas [21], and resistance from local authorities to excessive street-based infrastructure [50]. It is estimated 5G will cost almost US $1 trillion to deploy over the next half decade. That enormous expense will be borne mostly by network operators, companies like AT&T, China Mobile, Deutsche Telekom, Vodafone, and dozens more around the world that provide cellular service to their customers [24].

1.3 The Solution

While these obstacles are real and immediate, there are characteristics of 5G, and other maturing technologies such as cloud, which lend themselves to new, more efficient, telecommunications business models. Primarily, these new business models are based on infrastructure (and possibly spectrum) sharing, titled neutral host. Secondly, virtualization of networks involves abstraction and sharing of resources among different parties. With virtualization, the overall cost of equipment and management can be significantly reduced due to the increased hardware utilization, decoupled functionalities from infrastructure, easier migration to newer services and products, and flexible management [25].

One obvious way to reduce costs, and thus potentially increase the pace of rollout, would be to build a single shared layer of small cells routing traffic of any provider – a neutral host [14]. This goes against business trends to date where a static approach has been dominant, i.e., squeezing out market efficiencies. The challenges and obstacles discussed above, in addition to the identification of a potential solution foreshadow a need for a more dynamic efficiency approach gaining long-term benefits from infrastructure-based market competition [26]. Yet MNOs are naturally taking a conservative approach to disrupting the dominant logic of their businesses and caution reigns supreme even if the proposed neutral host solution would open new growth opportunities [27], they are now becoming more open to the idea of market co-operation with competitors [28–30], including consolidating infrastructure duplication, in turn producing savings on capital and operational costs [31]. Apart from basic efficiencies, another advantage to having ‘open’ deployments of neutral small cells serving subscribers of any service provider is that this shared infrastructure approach would encourage market entry and improve the industry’s competitive dynamics by making it easier for networks to get closer to a critical mass.

Beyond network cost efficiencies, a critical aspect of the 5G and future network is the ability to create customized network slices, i.e., logical network that provides specific network capabilities and features with logical isolation. Instances of virtual network resources and applications can be delivered to a new breed of cross-sector services tailored to specific customer needs with service level agreed (SLA) performance on demand. The flexibility offered by these technologies, mainly Software Defined Networking (SDN) and Network Function Virtualization (NFV) can be employed to develop virtual frameworks or network slices, including sets of logically segmented virtualized resources (such as compute, storage, and networks), shared within the same physical infrastructure [32]. Such flexibility in the infrastructure enables customization of the network slices in terms of resource placement, alignment to specific verticals, and more [48].

With virtualization, MNOs can attract greater numbers of customers from MNOs and SPs. For MNOs, since the network can be isolated into several slices, any upgrading and maintenance in one slice will not affect other running services. For SPs, leasing virtual networks enables them to "get rid of" the control of MNOs, so that customized and more flexible services can be provided more easily and the quality of service (QoS) can be enhanced as well. This also brings impressive revenues to MNOs, because SPs will need to pay more to the MNOs for use of their infrastructure and the clarity around roles and service provision in a neutral host network environment will reduce existing underlying arguments between MNOs and SPs around such issues [25].

Given these characteristics of neutral host and network-as-a-service, that strive to optimize the design and use of future networks we can posit that medium term network environments will be characterized by network-as-a-service on shared infrastructure. Our goal is to develop knowledge such that we can provide guidance on optimum network deployment and adoption paths with a view to maximizing the public good. Therefore, we define our research question as:

> *How can we create an enabling environment to support the rollout of 5G (and future) network-as-a-service shared infrastructure, in rural areas?*

2 Problem Formulation

In a classic engaged scholarship, problem formulation approach [33], when considering the problem of transitioning to a neutral host structure, the authors set out to engage industry and academic experts to "situate, ground, diagnose and infer the problem up close". 24 problem formulation interviews were held with: Irish based industry representatives (MNOs, telecoms hardware and systems, and infrastructure providers); academics; and the Irish regulator. These interviews were designed to extract opinions on the possibility of, and an adoption path to, a network-as-a-service on shared infrastructure solution for the Irish market.

2.1 Problem Formulation Findings

Currently two versions of neutral hosts were being piloted in UK and Irish cities. The most prominent model, offered by both infrastructure service providers and telecoms hardware systems providers, is a set of, up to four, small scale antennas enclosed within one package. This offers up to four MNOs the option of passive sharing base stations and backhaul connections. In essence, this model is the efficient bundling and use of infrastructure and cabling. There is no active sharing, with infrastructure management similar to current models. Therefore, incumbent business (or only incrementally different) models are envisaged when mainstream.

The less dominant neutral host model being offered is that of spectrum with small-cell infrastructure within confined geographical areas (e.g., campuses, commercial area). The dominant attitude of the MNOs operating in Ireland is to focus on a return of current assets. The backdrop to this attitude is the continuing decrease in return on invested capital (ROIC) which, in 2021, was 6.3% for Europe – barely higher than the cost of capital. This is before new investment in 5G. The dominant attitude of the three MNOs operating in Ireland is to focus on a return on current assets. The backdrop to this attitude is the continuing decrease in return on invested capital (ROIC) which, in 2021, was 6.3% for Europe – barely higher than the cost of capital. This is before new investment in 5G (McKinsey, 2023). Therefore, MNOs are working with a short-term focus the is rapidly becoming financially unviable, and this approach is becoming particularly less attractive in a high interest rate environment coupled with concerns of a recession or even stagflation. However as competitive strategic organization they are continuously scanning for opportunities, yet through a conservative aperture whereby any future investment will only be made with a high degree of certainty that a return can be extracted. This hesitancy and conservatism are particularly true in the case of potential small cell applications, where the marketplace is unknown. The reasoning is that MNOs will follow the market, i.e., they will invest when they are confident that a market does/will exist. At this point, collaboration is not a priority, yet consolidation is occurring as evidenced by the recent merger of Three and Vodafone in the UK. Reasons quoted for this are unknown in relation to guaranteeing customer service. With respect to the future, the attitude is that the market will evolve incrementally, and any vision of a future market structure looks broadly similar to the current market structure.

There has long been a move towards passive shared infrastructure. For cost efficiency reasons, MNOs have moved away from owning mast sites, and specialty site ownership/operations business have emerged. Their customers are the MNOs and, in the main, their view of the future is a strengthening of these relationships. Technology providers, in support of these trends, have begun to offer passive products. For example, Ericsson offer four miniature transceivers packaged in one box – a form of passive sharing.

Cities are actively reviewing the possibility of monetizing their city assets (lampposts, public buildings, etc.) as these become more important in higher frequency, small cell, urban applications (e.g., mobility and health). This aspiration is negated by the EU Commission's article 57 which defines the physical and technical characteristics of small cells and exempts them from any current or prior individual local authority planning permits. It also stipulates that, without impacting existing commercial agreements, deployments of small cells should not be subject to any fees or charges beyond the administrative charges.

3 Theoretical Perspectives

What is obvious from the interview content is that change is happening slowly and reactively. That is, advances are made when opportunities offer themselves in a reactive rather than a proactive manner. The status quo, in terms of power and power relationship is being maintained, evidenced by each stakeholders' behaviors which appear to be designed to strengthen their own position.

What is obvious from the interview content is that change is happening slowly and reactively. That is, advances are made when opportunities offer themselves in a reactive rather than a proactive manner. The status quo, in terms of power dynamics and power relationships is being maintained, evidenced by each stakeholders' behaviors which appear to be designed to strengthen their own position in isolation without exploring the combination power to be gleaned from collaboration.

The slow rate of change may suggest that a difficulty in overcoming inertia is changing business models; there is a reticence to learn new knowledge; or possible strategic, cognitive, or resource lock-ins due to historical events or performance. From a theoretical perspective, all of these suggestions point to the notion of ‘history matters’, wherein these organizations have charted and set course on along a particular trajectory from which they are reluctant to change.

There are two possible broad perspectives based on level of analysis. That is, can we treat this as a system of independent organizations, or as a set interdependent actor. As independent organizations there are a myriad of theories that fit with ‘history maters.’ Vergne and Durand [34] identified many theoretical arguments that are based on the “notion” of history maters. The arguments that may apply to future network adoption include path dependency, absorptive capacity, institutional persistence, resource accumulation, structural inertia and imprinting.

Path dependency suggests that firms, based on a contingent event, develop self-enforcing behaviors, leading to lock-ins (e.g., [35–38]). Absorptive capacity is the ability of groups or organizations to take in knowledge [39]. Knowledge absorption is more likely, the similar the knowledge is to the organization’s current knowledge. Conversely, knowledge absorption is less when new knowledge is very different from the organization’s current knowledge. Institutional persistence asserts that socio-cognitive institutional patterns become sticky in an attempt to retain or gain resources, or to gain or retain control [40]. Resource accumulation, is derived from the resource-based view of the organization where unique capability, developed over time, is difficult to discard. Structural inertia suggests that organizations respond relatively slowly to the occurrence of threats and opportunities in their environments [41]. Finally, imprinting asserts that founding organizational characteristics, such as structure and social relations continue to influence the organization indefinitely [41].

From past literature, Vergne and Durand [34] identify the barriers to change, which lock-in or cause inertia, in three categories: cognition (metal maps and decisions making process); resource (sunk costs in operations and infrastructure); capability (knowledge and capability boundaries); and social relationships.

As a set of interdependent actors, a suitable perspective is the transitions of technology innovation systems. A technological system is defined as a network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilization of technology. Technological innovation systems are defined in terms of knowledge/competence flows rather than flows of ordinary goods and services. They consist of dynamic knowledge and competence networks. In the presence of an entrepreneur and sufficient critical mass, such networks can be transformed into development blocks, i.e., synergistic clusters of firms and technologies within an industry or a group of industries [42]. Innovation Systems transition, that it, the change and evolution of innovations systems (such as the industry structure change in the adoption of a new technologically disruptive mobile network), is viewed in terms of overcoming history [45].

To critique innovation systems, we first need to be able to describe the system and its functions; followed by providing an understanding of how they emerge and evolve. From a systems level, different innovation systems can be assessed and compared with regard to the functions they fulfil [43, 44]. Functions are emergent properties of the interplay between actors and institutions. They can be assessed in order to derive policy recommendations, e.g., for supporting the development of a specific technology, such as a future network.

Bergek's et al. [43], focus was on technology innovations systems (TIS) and whose schema for analysis is depicted in Fig. 1. This is a seven-step process, starting with defining the TIS. The critical questions are: 1) the choice between knowledge field or product as a focusing device; (2) the choice between breadth and depth; and (3) the choice of spatial domain. The second step is to identify the structural components of the innovation systems. In the case of mobile telecoms, this can be ascertained through interviews.

Step 3 is the mapping of the functional pattern of the innovation system. This analysis aims at ascertaining to what extent the functions are currently filled in that TIS, i.e. to analyse how the TIS is behaving in terms of a set of key processes. Step 4 assesses the functionality and sets process goals. Initially the maturity of the innovation systems must be ascertained. This can be followed by comparing against other innovation systems to improve our understudying of how decisions are made. Step 5 ascertains the inducements and blocking mechanisms. In this, the cause and effect between inducements, such a policy, through functions and blocking mechanisms are articulated so that behaviour is better understood. Step 6 aims to develop modified policy that best enables a desired functional patter.

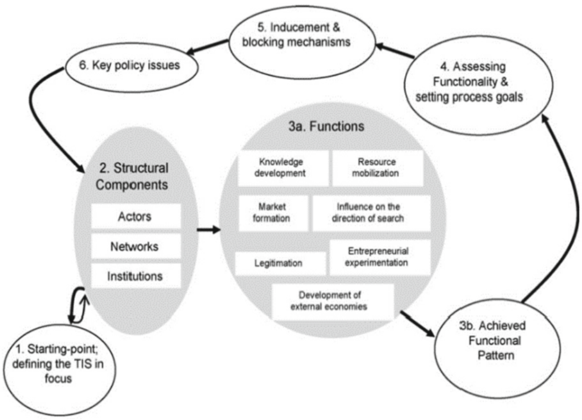

Fig. 1. The Scheme of Analysis *(Bergek et al., 2008, adapted from Oltander and Perez Vico, 2005)*

Authors, such as Geels [45] have identified large technology systems (LTS) as a separate unit of analysis. LTS refer to a particular kind of technology involving infrastructures, e.g., electricity networks and telephone systems, internet. The assertion it that among the components of a LTS are physical artifacts (such as network infrastructure), but also organizations (e.g., manufacturing firms, investment banks, research and development laboratories), natural resources, scientific elements, legislative artifacts (e.g., laws) and university teaching programs [47]. Geels [45] asserts that literature on technological transitions (TT) has elaborated the concepts of socio-technical regimes, niches and landscapes, which form the basis of a so-called multi-level framework to study the transformation of regimes. The multi-level framework conceives technological transitions as interactive processes of change at the micro-level of niches and the meso-level of socio-technical regimes both embedded in a broader landscape of factors at the macro-level (e.g., [46]) as depicted in Fig. 2.

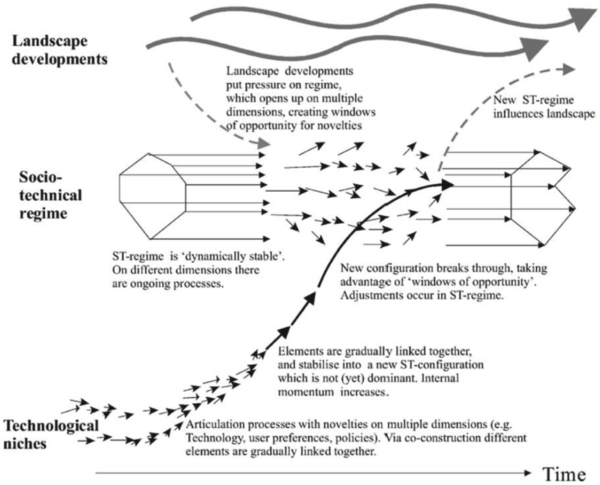

Fig. 2. The Scheme of Analysis *(Bergek et al., 2008)*

Radical innovation niches, such as 5G, provide space for learning processes, e.g. about technical specifications, user preferences, and public policies. Niches allow a deviation from the rules in the existing regime. Rules in technological niches are less articulated and clear-cut. There may be uncertainty about technical design rules and search heuristics, and niches provide space to learn about them. The work in niches is often geared to the problems of existing regimes (hence the arrows in Fig. 1). Niche-actors hope that the promising novelties are eventually used in the regime or even replace it. Technology niches interact with the sociotechnical regime and can be viewed from seven perspectives: technology, user practices and application domains (markets), symbolic meaning of technology, infrastructure, industry structure, policy and techno-scientific knowledge. The last layer, landscape, refers to aspects of the wider exogenous environment. Landscapes are beyond the direct influence of actors, and cannot be changed at will.

The major point is that a TT occurs as the outcome of linkages between developments at multiple levels. Radical innovations break out of the niche-level when ongoing processes at the levels of regime and landscape create a 'window of opportunity.' These windows may be created by tensions in the socio-tech regime or by shifts in the landscape which put pressure on the regime. TTs are about the linking of multiple technologies. TTs do not only involve technology and market shares but also changes on wider dimensions such as regulation, infrastructure, symbolic meaning, industrial networks (represented by the increased density of arrows). Once established, a new sociotechnical regime may contribute to changes on the landscape level. With respect to change, socio-technical systems, rules and social groups provide stability through different mechanisms. For a transition to happen, it is these concepts that must be considered:

Socio-technical systems, in particular the artefacts and material networks, have a certain 'hardness', which makes them difficult to change. Once certain material structures or technical systems, such as market structure, they are not easily abandoned.

Rules include: 1) Cognitive rules that direct us to look in particular directions and not in others. This can make us 'blind'. Competencies, skills, knowledge also represent a kind of 'cognitive capital' with sunk investments; 2) Normative rules: built on social and organizational networks that have been stabilized by mutual role perceptions and expectations of proper behavior. For example, in some relationships, it is not seen as 'proper' to raise certain issues; and 3) Regulative and formal rules, which are established systems stabilized by legally binding contracts. Contracts, technical standards, or rules for government subsidies are examples.

Social groups are actors and organizations embedded in interdependent networks and mutual dependencies which contribute to stability. Once networks have formed, they represent a kind of 'organizational capital', i.e., knowing who to call upon (trust). In organization studies it has been found that organizations are resistant to major changes, because they develop "webs of interdependent relationships with buyers, suppliers, and financial backers and patterns of culture, norms and ideology".

4 Building a Research Framework

The development of a research framework is the operationalization of the described theories (Fig. 3). We use the Bergek's et al. [43] scheme of analysis to describe the innovation systems, i.e., the current structure, policy and motivations of mobile telecoms operations.

Along with the different elements, as per Bergek et al. [43], this will describe both the Socio-Tech systems (the artefacts and material networks, that have a certain 'hardness', that are difficult to change) and the Social Groups (actors and organizations embedded in interdependent networks and mutual dependencies which contribute to stability).

With this done, the focus can then be on understanding the coordination of the innovation system. That is understanding the cognitive, normative, and regulative rules that MNOs, infrastructure providers, and technology providers adhere to.

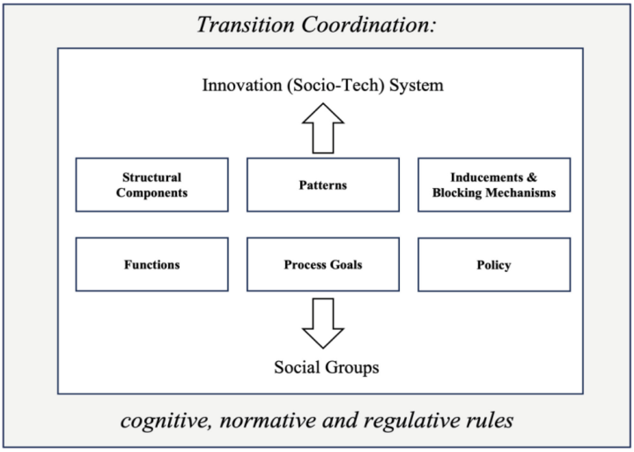

Fig. 3. Research Framework

4.1 A Path to a Methodology

This paper is intended to: a) describe the significant issues associated with the adoption of 5g and future networks for social inclusion; and b) present a theoretical foundation from which to investigate. These are the first two phases of the classic engaged scholarship process [33]. The next phases are Research Design and Problem Solving. In this case the Research Design should be examined through the use of a process model – an event-driven explanation of the temporal order and sequence in which a discrete set of events occur based on a story or historical narrative. The intent is to understand history, so that recommendations (to enable the management of mobile networks through network-as-a-service on shared infrastructure,), can be developed with a high degree of confidence of their efficacy.

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Examining the Factors Influencing Diffusion and Adoption of AI Chatbots in Tourism and Travel Industry

Sanjay V. Hanji[1](✉), Sumukh Hungund[2], Evgeny Blagov[3], Sumanth Desai[4], and Savita S. Hanji[1]

[1] KLE Technological University, Dr. MSSCET, Belagavi, Karnataka, India
{sanjayhanji,savitahanji}@klescet.ac.in

[2] Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal, Karnataka, India
sumukh.hungund@manipal.edu

[3] Graduate School of Management, St. Petersburg State University, St. Petersburg, Russian Federation
blagove@gsom.spbu.ru

[4] KLS Institute of Management Education and Research, Belagavi, Karnataka, India
sumanth@klsimer.edu

Abstract. AI chatbots have become increasingly important in various industries, especially with the rise of artificial intelligence and other emerging technologies. Chatbots engage with customers, address common inquiries, and perform specific tasks. The tourism and travel industry uses AI chatbots to enhance customer service for travellers. However, there is a lack of comprehensive research on the adoption of AI chatbots by the customers in tourism sector. To bridge this research gap, the present study utilizes the theoretical lens of Roger's diffusion model to investigate the factors that impact the adoption of AI chatbots in the tourism and travel industry. The study employs a quantitative research approach with a cross-sectional design and collects data from 495 frequent travellers through random sampling technique using Google forms. The analysis of the data is conducted using the Partial Least Squares (PLS) approach. The study findings show that relative advantage and trialability have a positive impact on adoption of AI chatbots. Compatibility, complexity and observability remain to be hindering factors for its adoption. Trust significantly moderated the relationship between adoption intention and their actual usage. This paper provides valuable and distinctive perspectives for executives, practitioners, and managerial-level employees within the tourism sector, as well as for system designers and creators of AI chatbot technologies.

Keywords: Artificial intelligence · Chatbots · Diffusion of Innovation · Adoption

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1 Introduction

The emergence of Industry 4.0 has significantly contributed to the development and adoption of advanced technologies, revolutionizing various aspects of businesses [1, 2]. This transformative wave has introduced innovations such as automation, artificial intelligence, Internet of Things (IoT), and data analytics, enabling improved efficiency, productivity, and competitiveness in diverse industries. The tourism and travel industry has witnessed a significant transformation with the emergence of Artificial Intelligence (AI) technologies [3]. These chatbots, powered by sophisticated algorithms and Natural Language Processing capabilities, offer the potential to revolutionize customer service interactions and improve overall guest experiences [4, 5]. Many leading companies who are in tourism business have adopted chatbots for various operational purposes [6]. Here the chatbots are employed in various aspects such as trip planning, ticket booking, online customer support, and providing recommendations and suggestions to customers, offering 24/7 support that improves customer service, boosts revenues, engagement, and lead generation, reduces costs, saves time, and provides a competitive advantage to businesses [7]. Understanding the factors that influence the adoption of AI chatbots in this industry is crucial for businesses seeking to enhance their service offerings and stay competitive in the digital era. The adoption of innovative technologies in the tourism and travel industry is a complex process that requires a comprehensive theoretical framework to capture the underlying dynamics [8]. While previous research has explored the adoption of chatbots in various domains banking, online learning, the insurance, and the telecom sector [9, 10], there is a dearth of literature specifically focused on AI chatbot adoption within the tourism and hospitality sector [11]. However, despite the growing interest in chatbot adoption, the theoretical lens of the Diffusion of Innovation (DOI) theory, which provides a comprehensive framework to understand the adoption and diffusion of innovations, has been largely overlooked in the context of AI chatbots in the tourism and hospitality industry. The DOI theory, developed by Rogers [12], offers a systematic approach to studying the process of innovation adoption, emphasizing the roles of various factors such as relative advantage, compatibility, complexity, trialability, and observability. These factors have been extensively studied in the adoption of various innovations, yet their application in the context of AI chatbot adoption within the tourism and travel industry remains limited [8]. Additionally, trust and social influence have been identified as significant predictors of chatbot usage intention; however, their exploration within the tourism sector remains relatively limited [13, 14]. The research on tourism sector is important due to its customer focus and the potential for AI chatbots to enhance guest experiences. This is especially relevant in the post-pandemic digital transformation of the industry, offering a unique context for studying AI chatbot adoption and innovation diffusion. Further, DOI theory is appropriate for this study because it offers a robust theoretical framework that aligns with the technological innovation of AI chatbots and can provide valuable insights into their adoption within the tourism and travel industry. Hence, this research aims to bridge this gap by investigating the adoption of AI chatbots in the context of the tourism and travel industry, using the DOI theory as a guiding framework. Hence, this research tries to address two research questions:

- RQ1: What are the key factors that influence the adoption of AI chatbots in the tourism industry?
- RQ2: How does trust and social influence moderate the relationship between customers' behavioral intention and actual usage of AI chatbots in the tourism and travel industry?

By investigating these aspects, this study aims to enhance both theoretical and practical knowledge of AI chatbot adoption in this industry. The findings will offer valuable insights for businesses to promote adoption, enhance customer experiences, and foster innovation.

2 Literature Review

2.1 Theoretical Background

The Diffusion of Innovation theory, as outlined by Rogers et al. [15], examines how innovations spread within a social system and the factors affecting their adoption. Given the recent integration of AI technologies in the hospitality industry, it provides a suitable foundation [8]. In this context, AI chatbots are considered innovations, and this theory helps understand their adoption drivers, considering factors such as perceived relative advantage, compatibility, complexity, trialability, and observability. Relative advantage signifies superior benefits, compatibility aligns with user values, complexity gauges perceived difficulty, trialability assesses testing ease, and observability involves visible outcomes. The study acknowledges that adoption intention precedes actual usage [3] and explores trust and social influence as potential moderators in this relationship. See Fig. 1 for the conceptual framework.

2.2 Hypotheses Development

Relative Advantage

According to the Rogers model [12], the higher are perceived relative advantages, the higher is (or, more correctly, the faster goes) the adoption. Although AI chatbots are a relatively new technology in tourism and travel sector, evidence of such dependency in literature already does exist, generally confirming the evidence from Rogers' work [3, 10, 16, 17]. Hence the hypothesis: *H1: Relative Advantage (RA) has a significant and positive influence on Behavioral Intention (BI) to Adopt AI chatbots.*

Compatibility

Continuing the logic behind explanation of the previous hypothesis, it can be stated that the Rogers' suggestion and evidence of positive relationship between compatibility and adoption has confirmations in the literature related to AI chatbots [10, 17, 18].

Hence the hypothesis: *H2: Compatibility (CP) has a significant and positive influence on Behavioral Intention (BI) to Adopt AI chatbots.*

Complexity

Artificial intelligence and chatbots by themselves and AI based chatbots all the more so have been initially developed for decreasing users' perceived complexity of performing various activities [16]; however, as these technologies are nowadays on comparatively early stages of their development, they sometimes haven't yet developed to a level of simplicity of usage that would satisfy most of the user categories in tourism [10]. Hence it is important to know to what extent complexity affects AI chatbot adoption. Hence the hypothesis: *H3: Complexity (CM) has a significant and negative influence on Behavioral Intention (BI) to Adopt AI chatbots.*

Trialability

According to the model of [12], trialability counteracts the perceived complexity of usage and thus increases the intention to adopt a technology. A considerably strong side of AI chatbots is that they are by definition triable, as chatbots are specifically designed for communicating with people. Evidence exists in literature that this trait does increase the adoption level [17]. However, different specific realizations of AI chatbot technology in different products and services may differ in the level of trialability in different sector such as tourism thus, a hypothesis related to it must be checked. *H4: Trailability (TA) has a significant and positive influence on Behavioral Intention (BI) to Adopt AI chatbots.*

Observability

This hypothesis considers relationship between observability and AI chatbots Adoption. Reasoning under it has logic close to that behind the logic of the previous hypothesis H4. In Roger's model [12] positive influence of results of observability on technology adoption is stated, and the recent literature demonstrates confirmation of this result for the AI in general and AI chatbots in particular [17]. The users who are aware of the service benefits and can observe its positive impact are more likely to adopt and embrace the technology [18]. This has to be confirmed in tourism sector, hence, the hypothesis: *H5: Observability (OB) has a significant and positive influence on Behavioral Intention (BI) to Adopt AI chatbots.*

Adoption and Usage

An obvious suggestion about this relationship developed in such renowned frameworks as TAM or UTAUT can be that, adoption is a direct prerequisite of usage [19]. Specificity of such a novel instrument as AI chatbots, including specificity of AI and of chatbots as such, surely can potentially exert influence of less direct inclination to usage after adoption. However, most evidence demonstrates that this specificity does not create any specific distortion of the typical positive relationship [3]. *H6: Behavioural Intention* *to Adopt AI Chatbots has a significant and positive influence on their Actual Usage Behaviours.*

Trust

The service sector is experiencing rapid growth, creating ample opportunities for AI chatbots to thrive [20]. Usage of novel technologies, especially having such controversial reputation as AI, highly depends on subjective perceptions of the user [13]. One of the perspectives from which these subjective perceptions can be analyzed is the trustability of the technology, in this research formulated in a shorter form as "Trust". Notable examples of articles present in current literature that analyze influence of trust on AI chatbots and related technologies usage are, e.g., [17]. In all these articles evidence of positive influence of trust on the described technology usage is demonstrated. *H7: Trust moderates the relationship between Behavioral Intention to Adopt and Actual Usage of AI chatbots.*

Social Influence

Humans are inherently social beings, and our behaviours and attitudes are often shaped by the influence of others. If individuals observe their peers or influential figures using and endorsing AI chatbots, they may be more likely to adopt them themselves, leading to increased usage [21]. Conversely, negative social influences or stigmas attached to AI chatbots could hinder their adoption. Social influence can provide valuable information about the efficacy and utility of AI chatbots. Recommendations and testimonials from trusted sources can serve as social proof, influencing individuals' intentions to use and ultimately their actual usage [14, 22]. *H8: Social Influence moderates the relationship between Behavioral Intention to Adopt and Actual Usage of AI chatbots.*

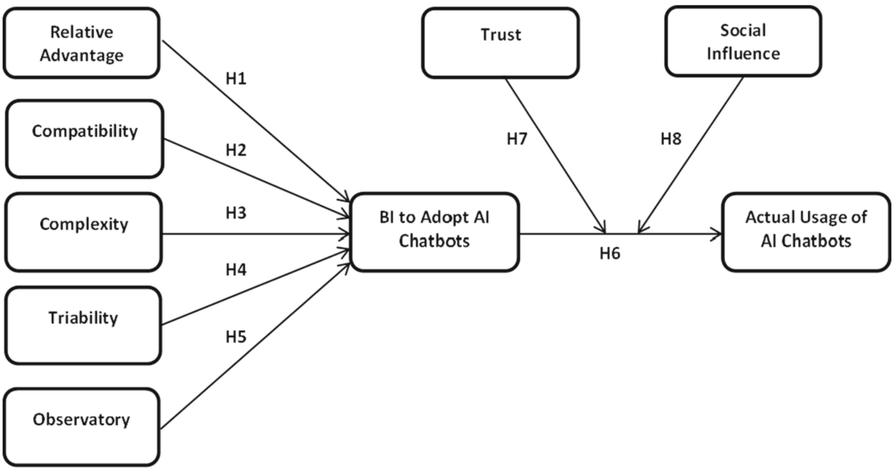

Fig. 1. Conceptual Framework

3 Methodology

The study adopts a deductive reasoning with a quantitative approach. A cross-sectional design is used to collect the data from Indian subcontinent who independently organizes their travel plan. The participants were recruited from social networking sites such as Facebook and WhatsApp, based on their expressed interest in tours and travels. To ensure representation from a diverse population, a random sampling method was utilized to reach out to a larger pool of potential respondents across the Indian subcontinent. A total of 495 participants were included in the study, and data collection took place over a period of three months. To ensure the validity and reliability of the study instrument, a systematic survey was developed and thoroughly assessed. Prior to the main data collection phase, a pilot study was conducted to evaluate the instrument's reliability and validity. Google Forms were chosen as the platform for administering the survey to the target population. The questionnaire consisted of multiple-choice questions that were linked to a Likert scale. Participants were asked to indicate their level of agreement or disagreement, ranging from "strongly agree" (denoted as 1) to "strongly disagree" (denoted as 5), regarding their general behavior towards the usage of chatbots when booking online tours. The SEM is performed on the data collected using smartpls 4.

3.1 Measures

As shown in the Fig. 1, all DOI theory scales were sourced from [9], actual usage scale was sourced from [23], behavioural intention (BI), trust (TT), social influence (SI) scales were sourced from [21, 24].

4 Results

A descriptive analysis of the respondent's profile revealed that out of the 495 survey responses, 42% were male and 58% were female. The majority of respondents, comprising 60%, fell within the age group of 18–25, followed by 29% in the age group of 26–35. Approximately 9% of the respondents belonged to the age group of 36–45, while only about 2% were aged 45 and above. Regarding occupation, students accounted for the largest proportion of respondents at 45%, indicating their frequent usage of chatbots for online tour bookings. Job holders represented 31% of the respondents, followed by self-employed individuals at 16%, and retired or homemakers at 8%.

For data analysis, we employed the partial least squares (PLS) approach. The data was analyzed using Smart-PLS Version 4. To assess the statistical significance, a two-tailed technique with 5000 bootstrap samples was utilized. The bootstrap samples were bias-corrected and expedited, and no significant modifications were made.

4.1 Reliability and Validity

To ensure the reliability of the measuring model, composite reliability and Cronbach's alpha were used [25]. The values for both exceeded the threshold of 0.7 [26], indicating internal consistency. Convergent validity was assessed using the AVE value, which should exceed 0.50 for adequate convergent validity [27]. The AVE values ranged from 0.628 to 0.797, indicating satisfactory convergent validity. For discriminant validity, Fornell and Larcker's two criteria prescribed by were met: (i) each item primarily loaded on its related construct, and (ii) the square root of each construct's AVE was higher than its correlation with another construct [27] (Tables 1 and 2).

Table 1. Reliability and Convergent Validity

Construct	Item	Factor Loading	AVE	Composite Reliability	Cronbach's Alpha
Relative Advantage (RA)	RA1	0.775	0.628	0.871	0.803
	RA2	0.845			
	RA3	0.771			
	RA4	0.777			
Compatibility (CP)	CP1	0.858	0.694	0.871	0.781
	CP2	0.886			
	CP3	0.749			
Complexity (CM)	CM1	0.845	0.755	0.902	0.838
	CM2	0.895			
	CM3	0.867			
Triability (TA)	TA1	0.792	0.672	0.860	0.757
	TA2	0.869			
	TA3	0.797			
Observability OB)	OB1	0.810	0.679	0.862	0.790
	OB2	0.938			
	OB3	0.707			
Trust (TT)	TT1	0.903	0.672	0.860	0.757
	TT2	0.911			
	TT3	0.927			
Social Influence (SI)	SI1	0.890	0.797	0.922	0.873
	SI2	0.911			
	SI3	0.878			
Behavioral Intention (BI)	BI1	0.876	0.683	0.865	0.769
	BI2	0.881			
	BI3	0.710			
Actual Usage (AC)	AC1	0.826	0.683	0.855	0.746
	AC2	0.809			
	AC3	0.806			

Table 2. Discriminant Validity

	ACU	BIA	COM	COP	OBS	REA	SOI	TRI	TST
ACU	0.814								
BIA	0.377	0.826							
COM	−0.273	−0.517	0.869						
COP	−0.159	−0.3	0.205	0.833					
OBS	−0.062	−0.112	0.063	0.066	0.824				
REA	0.215	0.61	−0.296	−0.186	−0.031	0.793			
SOI	−0.668	0.08	0.03	−0.053	−0.043	0.067	0.893		
TRI	0.207	0.371	−0.168	−0.2	−0.04	0.431	0.051	0.82	
TST	−0.394	0.296	0.012	−0.083	0.046	0.133	0.515	0.072	0.914

Table 3. Structural Paths

Hypothesis Number	Hypothesis Relationship	Original Sample	T Statistics	P Values	Hypothesis Results
H1	RA -> BI	0.444***	11.625	0.000	Supported
H2	CP -> BI	−0.125***	4.01	0.000	Supported
H3	CM -> BI	−0.340***	9.622	0.000	Supported
H4	TA -> BI	0.095*	2.45	0.015	Supported
H5	OB -> BI	−0.065*	2.102	0.036	Supported
H6	BI -> AU	0.46***	11.356	0.000	Supported
H7	TT x BI -> AU	0.096***	3.7	0.000	Supported
H8	SI x BI -> AU	0.062	1.958	0.051	Not supported

***** Significant at $p \leq 0.001$ ** Significant at $p \leq 0.01$ * Significant at $p \leq 0.05$ ns Not Significant**

4.2 Data Analysis

The results of PLS are summarized in Table 3. According to the immediate effects between all independent and dependent variables, Hypotheses H1 and H4 are supported as RA ($\beta = .444$, $t = 11.625$, $p < .001$) and TA ($\beta = .095$, $t = 2.45$, $p < .05$) have positive and significant influence on BI. Similarly, Hypothesis H2, H3 and H5 are supported as CP ($\beta = -.125$, $t = 4.01$, $p < .001$), CM ($\beta = -.340$, $t = 9.622$, $p < .001$) and OB ($\beta = -.065$, $t = 2.102$, $p <= 0.05$) have significant but negative influence on BI. Hypothesis H6 is supported as TT ($\beta = 0.021$, $t = .390$, $p < .000$) positively moderates the relationship between BI and AU whereas, hypothesis H7 is not supported as SI ($\beta = 0.062$, $t = 1.958$, $p = .051$) has no significant influence on BI.

5 Discussion

The first hypothesis (H1) suggests that RA significantly impacts customers' behavioral intention (BI) to adopt AI chatbots in the tourism industry. Factors such as convenience, accessibility, personalized assistance, time-saving efficiency, and 24/7 availability drive customers' intention. Additionally, self-service options, novelty, technological advancements, trust in AI technology, and positive word-of-mouth further motivate adoption, enhancing the service experience. These findings align with previous research by [3, 16]. Hypothesis H2 indicates that CP has a significant but negative impact on BI as customers may perceive AI chatbots as incompatible with their lifestyles due to differences in interaction preferences. Overcoming compatibility issues and addressing customer concerns is crucial for fostering acceptance and adoption in the tourism industry. This result is consistent with [10] but contradicts [18]. Hypothesis H3 suggests that CM negatively affects BI, as customers may find AI chatbots complex to use. Simplifying the user interface, providing clear instructions, and ensuring helpful responses can address these concerns. This aligns with previous research by [10, 16]. Hypothesis H4 is supported, showing that TA positively impacts BI, as customers' ability to track and evaluate AI chatbot performance enhances trust and encourages adoption. This finding is similar to [17]. Hypothesis H5 suggests that OB negatively affects BI, as customers lack visibility of AI chatbots in daily life. Increasing visibility through marketing and case studies can familiarize customers with AI chatbots. This differs from [17]. Hypothesis H6 shows that BI positively impacts actual usage (AU), indicating customers' willingness to engage with AI chatbots translates into active usage. This aligns with [3]. Hypothesis H7 is supported, with TR positively moderating the relationship between BI and AU. Trust in AI chatbot technology strengthens confidence and mitigates uncertainties, facilitating the transition from intention to usage. Hypothesis H8 is not supported, as SI does not significantly moderate the BI-AU relationship. Individual motivations and perceptions play a more prominent role in determining usage, rather than social influence. Thus, trust-building efforts are more effective than relying on social influence mechanisms [13].

6 Conclusion

This research advances chatbot and consumer behavior studies by applying DOI theory to AI chatbot adoption in tourism and travel, enhancing our understanding of key DOI concepts. It extends the model by incorporating trust and social influence from UTAUT-2 theory, improving our framework for comprehending AI chatbot adoption. Integrating chatbots into tourism and travel offers convenience and positive feedback, benefiting businesses through efficiency, cost reduction, enhanced service, and competitive advantage. However, it's essential to acknowledge study limitations like cross-sectional data and potential biases in self-reported data. Future research should explore long-term chatbot adoption effects, their impact on customer satisfaction and loyalty, and their role in different tourism segments. Examining ethical implications and user perceptions would also enrich our understanding of chatbots' role in enhancing customer experiences.

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Bridging Realities: Understanding the Factors Influencing Visitor Satisfaction and Authentic Experiences in Virtual Tourism

Kousik Mandal(✉) and Sudin Bag

Department of Business Administration, Vidyasagar University, Midnapore, West Bengal, India
kousikmandal1997@outlook.com

Abstract. The viability of virtual tourism (VT) as a feasible alternative or interim solution has been heavily debated considering the growing interest in virtual reality (VR) tourism and its relevance. There is, however, no information on how to keep visitors satisfied with VT, enhance their contentment, and turn good experiences into genuine travel ambitions. This paper presents a conceptual model that blends the uses and gratifications theory with the innovation diffusion theory to understand the drivers of VR tourism. The main objective is to explore the factors related to innovation diffusion and gratification that contribute to tourist satisfaction and authentic experience in VT. The study also attempts to find out how satisfaction and authentic experience affect the desire to go to suggested places. Furthermore, the study looks at the function of connection to nature as a moderator in the link between satisfaction and on-site destination intention. The PLS-SEM analysis was used to evaluate the model on a sample of 285 respondents. The findings show that variables related to innovation diffusion, uses, and gratifications have a considerable impact on visitor satisfaction and authentic experience. Furthermore, as compared to authentic experience, visitor satisfaction has a larger effect on the intention to visit the place. However, as the amount of connection to nature grows, the favourable effect of VT satisfaction on on-site tourist intention increases. This study adds to the uses and gratifications theory and the innovation diffusion theory, giving significant insights for tourism practitioners and management looking to improve visitor satisfaction and authentic experience with VT and other attractions.

Keywords: Virtual reality · innovation diffusion theory · uses and gratifications theory · authentic experience · connection to nature · virtual tourism · satisfaction

1 Introduction

Virtual reality (VR) is a remarkable innovation in the domain of information and communication technology (ICT) that is prophesied to have a big influence on today's tourism sector. Many newsworthy advances, like VR platforms, devices, and content creation tools, allow VR to evolve. As a result, VR technologies now have limitless potential

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for mass virtual visits to genuine tourism places. Furthermore, the importance of these technologies in the tourist and hospitality sectors, management, and marketing has been thoroughly documented in the literature. They have been recognised for their extraordinary ability to imitate real-life settings and surroundings, and have been lauded as a feasible substitute to actual travel on occasion. As a result, they have evolved as enormously powerful instruments for meeting the different demands of travellers.

Vicissitudes that are expected to happen in future are continually underestimated and arrive much sooner. Thus, tourism and hospitality organisations ought to be encouraged for more forward-thinking and well-equipped technological adaption planning. The purpose of this paper is to develop links between the ideas of VR and tourism and the hospitality industry, as well as to provide prospects for the tourism sector that consider the values articulated in the concept of VR marketing in attempts to satisfy the demands of visitors in the future. The study investigates the potential of VR as a helpful tool for tourist planning and management, technology-based marketing of tourism destinations, and the influence of VR on consumer requirements.

Rogers (1983) defined diffusion of innovation (DOI) as a method through which an innovation is spreading among individuals within a social system. According to Agag and El-Masry (2016), this approach adequately explains visitors' adoption of several technology. Furthermore, the DOI model has been shown to be beneficial in analysing VR consumers' attitudes towards information technology (Pan and Lin, 2011).

The uses and gratifications theory (UGT) are used to describe how people use communication and other environmental resources to mitigate their needs and accomplish their goals. The UGT, for example, has recognised the reasons behind the use of mobile information technologies such as social network services (Han et al., 2015), and the forecast of VR technology usage for gaming (Gallego et al., 2016).

Given the promising findings of both the theories in amplification VR tourism behaviour, we propose to combine and expand upon these research streams to determine the reasons why people utilize VR technology in tourism. This research aims to construct a conceptual framework that integrates both the theories i.e., DOI and UGT, to predict the behaviour of VR tourists.

Although satisfaction and authentic experience have significant implications on technological acceptability in the tourist business, these ideas have received little attention among VR travel users. To address the void, we construct and test a theoretical framework that integrates innovation diffusion, uses and gratifications theories, and takes pleasure and experience into account as significant aspects of tourist activity. As a result, this study analyses consumer behaviour while using virtual reality and offers academics and practitioners with a novel framework that incorporates the two important theories as well as the construct like satisfaction and authentic experience.

The heterogeneity of tourists' preferences regarding nature-related destinations is likely to influence their travel decisions and behaviours (Jiang et al., 2018). The connection to nature, a subjective sense of relationship with the natural world, emerges from the value of experiencing nature and the emotional bond between the individual and nature (Beery & Wolf-Watz, 2014). Some studies have noted that, for the natural landscape, it will be much better to go for an onsite visit, because they could appreciate the scenery in various times or seasons and 'inhale fresh air' (Lu et al., 2022). Hence, the moderating effects of connection to nature in VT satisfaction evaluation and intention of on-site tourism are examined in this study.

2 Literature Study

2.1 Theoretical Underpinning

2.1.1 Diffusion of Innovation Theory

The diffusion of innovation theory (DOI) is explained how and when a new idea or technological development spread through a social system (Robertson, 1967). In the current study, DOI is utilised as an analytical framework to examine the topics connected to the diffusion of innovation from the standpoint of virtual reality in tourism. Everett Rogers introduced the DOI theory in 1962, which gave a framework for researching how innovations are communicated inside businesses and understanding the process and variables that influence new idea adoption. Diffusion implies transfer an innovation over the time frame within a social system through specialised channels, whereas communication comprises the development and sharing of information among participants in order to achieve mutual understanding (Rogers, 2003). According to Rogers (2003), DOI is having four dimensions such as innovation, channels of communication, time, and social systems. In addition, it is an idea, product, or technique that the adopter sees as unique may be considered as an innovation. Relative advantage, complexity, compatibility, trialability, and observability are the spatial characteristics of this theory (Rogers, 2003). Channels of Communication refer to how information about the invention is communicated across individuals or organisations, including those who are and are not familiar with the innovation. The inventive decision-making process, adopter categories, and adoption rate are all affected by time. Individuals or organisations are categorised as innovators, early adopters, early majority, late majority, or laggards based on their inclination for innovation. The term 'adoption' pertains to the act of individuals accepting a change in their behaviour, which can encompass various actions such as purchasing or utilizing a novel product, acquiring skills in a new endeavour, and more. While DOI is not commonly employed in tourism-related consumer behaviour research, it has been utilised in other sectors to cope up with the breakthroughs in information systems, strategic management, healthcare, education, and business research. DOI is used as a theoretical lens to examine emergent innovations in tourist firms in the context of this article.

2.1.2 Uses and Gratifications Theory

The Uses and Gratifications Theory (UGT) is extensively used to describe why people use certain technologies or media, as well as how these novel models may meet their motivations and demands (Katz et al., 1973). In contrast to prior theories, UGT emphasises that users are active participants who select certain communication channels or technological equipment based on their wants and motives, rather than being passive recipients (Ball et al., 2021). UGT has been critical in understanding customer behaviour, intents, and happiness when utilising social platforms, media technologies, web-based, or mobile services (Ho & See-To, 2018). This methodology has recently been used by scholars to investigate virtual augmentation (Ibáñez Sánchez et al., 2022) and virtual reality (Cheng et al., 2022). Since UGT becomes more pertinent when introducing new communication technologies, it is well suited for researching the effects of VR (Ruggiero, 2000). This makes it the perfect theory to study novel scenarios and developing technology (Taherdoost, 2018). In the end, UGT is ideally suited for study from the perspectives of both passive and active visitors, as well as the virtual tourism setting. There are three main types of gratifications, according to the UGT (Uses and Gratifications Theory): content satisfaction, process pleasure, and social gratification. According to Katz et al. (1973) and Palos-Sanchez et al. (2021), these categories can also be referred to as hedonic, utilitarian, and social pleasure, respectively. This study explores the aspects that lead to satisfaction based on these original dimensions, building on earlier studies that used UGT to Virtual Tourism (VT) and identified links between uses and gratifications and satisfaction (Ibáñez Sánchez et al., 2022). Additionally, Wu et al. (2020) found that experience happiness in VT is significantly influenced by users' emotional connection to virtual reality (VR) activities. Accordingly, authentic experience may be thought of as a possible derived variable of UGT.

2.2 Hypotheses Development

2.2.1 Innovation of Diffusion and Satisfaction

The VR technology is spreading in the tourism sector because of high degree of pleasure. The simplicity of innovation dissemination quality that influences potential visitors' perceptions and trust (Agag and El-Masry, 2016). Another feature of innovation diffusion that impacts travel customer happiness is benefit (Kim et al., 2017). According to Chiang (2013), certain users, specifically those in the laggard, late majority, and early majority categories of technology adopters, have a more positive attitude towards continuing to use a particular technology when it is compatible with their previous experiences. This suggests that congruence with past experience is important in influencing travel customer happiness. Based on these findings, we propose that investigating the characteristics of innovations might offer insight into the happiness of VR customers in the tourist environment. The statements that follow establish our suggested framework for understanding this relationship.

H1: Innovation diffusion's attributes positively influence satisfaction of VR tourists.

2.2.2 Innovation Diffusion and Authentic Experience

Because visitors believe they are experiencing authentic experiences, VR technology is becoming more and more popular in the tourism industry (Yung and Khoo-Lattimore, 2017). The ease of use of the technology, which is one of the characteristics of innovation diffusion, affects potential tourists' perceptions of and confidence in online travel communities (Agag and El-Masry, 2016). Additionally, a further characteristic of innovation diffusion is the advantage from VR technology, which affects how authentic travel experiences are for customers (Kim et al., 2017). Additionally, for some users—especially those who fall into the categories of laggards, late majority, and early majority in terms of technology adoption—the compatibility of the technology with their prior experiences has a positive impact on their attitudes towards continued use of the technology (Chiang, 2013). This implies that travellers' impressions of the authenticity of VR encounters are influenced by how well they mesh with their past experiences. Based on this research, we suggest that the characteristics of innovations play a vital role in explaining customers' views of authenticity in the context of VR technology within the tourist business.

H2: The attributes of innovation diffusion have an impact on authentic experience of VR tourists.

2.2.3 Uses and Gratification and Satisfaction

In the UGT, the idea of informativeness denotes the extent to which media or technology material helps consumers to find, develop, and share important information (Palos-Sanchez et al., 2021). Tourism satisfaction is defined as comparing the amount of satisfaction received from the actual experience to personal expectations (Goo et al., 2022). Smart tourism technology can help travellers make educated decisions by delivering relevant information, resulting in increased travel satisfaction (Goo et al., 2022). Furthermore, the exchange of knowledge and experiences while travelling via mobile tourism apps or digital platforms improves travellers' happiness with their visits (Ha et al., 2015). The capacity to connect with others is referred to as social interaction. According to earlier studies (Kim et al., 2020b), there may be a connection between social contact, genuineness, subjective well-being, and satisfaction. Social interactions are crucial in determining satisfaction levels, as evidenced by the fact that using social media or other smart technologies to communicate with people might satisfy some user demands (Goo et al., 2022). Based on the above discussion, the following research hypotheses are proposed:

H3: VR tourists' satisfaction positively influences by meeting their needs of gratification.

2.2.4 Relationship Between Uses and Gratifications and Authentic Experience

When people view VR experiences as satisfying their want to learn, the ease and enjoyment features of VR impact their willingness to utilise it for learning (Gallego et al., 2016). The pleasure that comes from information seeking and the desire for social status that comes from sharing VR experiences are both viewed as gratifying (Gallego et al., 2016), demonstrating that VR features like innovation contribute to the feeling of authenticity. Furthermore, the social connection and distraction provided by VR games, as well as their pleasing aesthetics, have a considerable favourable influence on users' psychological reliance on online games (Chen et al., 2010). Building upon these literatures, this research suggests that meeting the gratification needs of VR users enhances the authenticity of the tourism activities they engage in. Thus, we propose the following hypothesis:

H4: Meeting the needs of gratification of VR travellers remarkably influences their authentic experience.

2.2.5 Satisfaction and Intention to On-Site Tourism

Intention to travel to the actual locations is influenced by tourists' readiness to engage in on-site tourism activities in order to experience suggested attractions or projects via virtual tourism (VT). Tourists get a sense of pleasure when their expectations or requirements are met (Wu et al., 2020), which in turn motivates their behavioural intention to travel to the actual tourism location. Additionally, users' willingness and capacity to visit the real area may increase as a result of their pleasure with the usage of tourist applications or virtual reality (VR) devices (Morrison et al., 2023). According to Ho & See-To (2018), consumers' happiness with the digital tourism platform favourably affects their propensity to travel to the actual locations.

H5: Tourist satisfaction and behavioural intention.

2.2.6 Authentic Experience and Intention to On-Site Tourism

Based on the studies by Kim et al. (2017) and Yung and Khoo-Lattimore (2017), the authentic experience gained from utilising different technologies favourably influences users' behavioural intention. The desire of travel customers to reuse mobile information technology is specifically increased when an authentic experience is provided (Kim et al., 2017). Similarly, if virtual reality (VR) can provide experiences that are close enough to the real thing, customers may view VR excursions as an alternative to actual travel (Guttentag, 2010). Since it increases the feeling of authenticity and motivates visitors to these locations, heritage sites are becoming more appealing as travel destinations using VR technology (Dueholm and Smed, 2014). Additionally, if VR technologies can deliver a high degree of realism, virtual vacations might act as stand-ins for actual travel encounters and affect the behavioural intentions of VR tourists (Mura et al., 2017). In their assessment of the literature, Yung and Khoo-Lattimore (2017) looked at earlier research on travellers' views of the authenticity of VR travel by Dueholm and Smed (2014) and Mura et al. (2017). They discovered that a higher feeling of authenticity increases the desire to engage in virtual reality tourism. Based on the literature review mentioned above, we propose that the authentic experience plays a crucial role in shaping users' behavioural intention towards VR tourism.

H6: Subjective well-being of VR tourists significantly impact on their intention to visit.

2.2.7 Connection to Nature

According to Strzelecka et al. (2021), the specific goal of travel brought about by virtual tourism (VT) might change based on elements including visitor traits and preferences, how they view the place, and how much VR equipment is being used. According to several studies (Tussyadiah et al., 2018; Nam et al., 2022) the sensation of presence is what distinguishes virtual tourism from actual tourism. The impact of visitors' assessments of their contentment with or attachment to virtual reality on their desire to engage in on-site tourism can be influenced by several factors, including their connection to nature. An individual's emotional, cognitive, and experiential connections with the natural world are referred to as their connection to nature. It covers the extent to which people identify with and feel a connection to nature. The significance of connection to nature as a psychological concept that affects people's attitudes, behaviours, and preferences about the natural environment is emphasised by Baxter and Pelletier (2019). Lower demand for nature connection people may be more likely to shun actual situations and restrict their contact with it. To encourage and strengthen their intention to engage in on-site tourism in such circumstances, extra external information and emotional triggers are needed. Based on these considerations, the following research hypotheses are proposed (Fig. 1):

H7: Connection to nature positively moderates the effect of VT experiential satisfaction on the intention of on-site tourism.

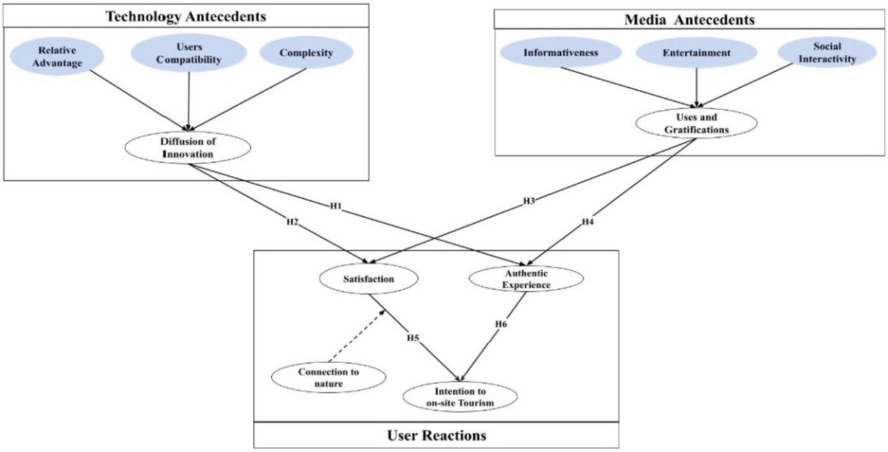

Fig. 1. Conceptual Framework

3 Methods

3.1 Measurement Design

By using a set of previously validated multi-measurement items, this study attempted to address the shortcomings of single-item measurements (Churchill's, 1979). The 44 items on the questionnaire were intended to evaluate 10 different themes. Relative advantage, user compatibility, and complexity were the main constructs connected to DOI. Social interaction, informativeness, and entertainment were among the characteristics connected to UGT. Authentic experience, satisfaction, intention to engage in on-site tourism, and connection to nature made up the remaining components under research. To enhance construct validity, the study primarily selected construct items from previous research.

To enhance construct validity, the study primarily selected construct items from previous research. These items were then slightly modified to align with the virtual reality (VR) context. Specifically, the attributes related to the theory of innovation diffusion, namely relative advantage, users' compatibility, and complexity, were adapted from studies conducted by Fang et al. (2017), Kim and Ammeter (2014), and Lin and Lu (2015). Similarly, the attributes associated with the uses and gratifications theory (UGT), including informativeness, entertainment, and social interactivity, were measured using 11 items from Kim et al. (2020b). The measurement items for authentic experience in virtual tourism were sourced from Gilmore and Pine (2007) and Meng and Choi (2016a, 2016b). Satisfaction and intention to engage in on-site tourism were assessed using three items each, which were derived from the research of Atzeni et al. (2022) and Kim et al. (2020a).

3.2 Participants and Procedure

The survey initially recruited 393 respondents. To ensure data validity, two additional procedures were used to screen out invalid responses. First, we removed respondents who had spent less than five minutes completing the survey according to the online system, following common data cleaning practice. Second, the survey contained several attention questions to check for careful reading. Respondents were removed if these questions were answered incorrectly. Finally, 285 valid responses remained. Overall, the sample of respondents was deemed adequate for attaining our study goals. To evaluate the hypotheses SmartPLS4 software was utilised in this work to perform PLS-SEM.

4 Results

4.1 Validation of Outer Model

We conducted a comprehensive assessment of reliability and validity, following established research guidelines. The results indicate strong reliability and validity for our measurement model, with all factor loadings greater than 0.5 and Cronbach's alpha and composite reliability values more than 0.7, and an Average Variance Extracted (AVE) surpassing 0.5, (Hair et al., 2017). Additionally, all Variance Inflation Factor (VIF) values are below 3.3, and the Heterotrait-Monotrait (HTMT) values, a measure of discriminant validity, are below 0.9, further confirming the robustness of our measurement model. In conclusion, our findings support the validity and reliability of our measurement model. Table 1 and 2 shows the reported measurement model values for each latent variable in the separate models.

4.2 Testing of Hypotheses

The hypotheses were examined using the structural model once the measurement model had been validated. Rasoolimanesh and Ali (2018) proposed using the Stone-Geisser index (Q2) and the coefficient of determination (R2) to evaluate the structural model. The R2 score has a range of zero to one, with values of 0.682, 0.654, and 0.509 considered strong for on-site tourism, satisfaction, and authentic experience (Hair et al., 2017). According to Ali et al. (2018), the Q2 value reflects the predictive capability of the structural model and should be greater than zero. Table 3 shows the acceptable R2 and Q2 values for each endogenous component. The bootstrap function was used in the structural

Table1. Reliability and Validity of measurement items

Construct	CA	CR	AVE
AE	0.942	0.948	0.775
CP	0.930	0.932	0.783
CN	0.880	0.894	0.739
DOI	0.950	0.953	0.570
ET	0.889	0.890	0.819
INF	0.912	0.912	0.791
IOT	0.924	0.928	0.728
RA	0.951	0.952	0.805
SA	0.939	0.941	0.805
SI	0.891	0.894	0.699
UC	0.896	0.898	0.707
UGT	0.943	0.947	0.619

AE = Authentic Experience; CP = Complexity; CN = Connection to nature; ET = Entertainment; INF = Informativeness; IOT = Intention to on-site Tourism; RA = Relative Advantage; SA = Satisfaction; SI = Social Interactivity; UC = Users Compatibility

Table 2. Discriminant Validity (HTMT ratio)

Construct	AE	CP	CN	ET	INF	IOT	RA	SA	SI	UC
AE										
CP	0.530									
CN	0.131	0.101								
ET	0.673	0.552	0.123							
INF	0.687	0.571	0.101	0.806						
IOPT	0.646	0.459	0.101	0.600	0.650					
RA	0.651	0.534	0.429	0.646	0.702	0.836				
SA	0.695	0.521	0.102	0.681	0.732	0.878	0.752			
SI	0.620	0.547	0.157	0.710	0.728	0.649	0.657	0.656		
UC	0.521	0.897	0.493	0.531	0.570	.0.452	0.533	0.529	0.542	

model, with a statistical sample size of 271 and 5000 bootstrapping test samples. The links between the latent variables, which correspond to the study hypotheses, are depicted in Fig. 2, and the values presented in Table 3 along these associations indicate the path coefficients and t-statistics.

PLS-SEM hypothesis testing reveals that all t-statistics values are greater than 2.57, indicating that all hypotheses are verified at a 99% level. In other words, the characteristics of innovation dissemination (H1; H2) of virtual reality have direct and substantial influence on visitor satisfaction and genuine experience. However, the direct consequences of the dimensions of uses and gratifications (H3; H4) on visitors' authentic experience and pleasure are substantial. The product of the coefficients approach (indirect effect) was used to examine the mediating effects in this study, where mediation is deemed present if the indirect impact is statistically significant, as described by Rasoolimanesh et al. (2021). Rasoolimanesh et al. (2021) also used bias-corrected bootstrap confidence intervals (CIs) to assess the significance of the indirect effects. Through the mediating factors of satisfaction and genuine experience, the data demonstrated that the dimensions of innovation diffusion and uses gratification had a strong indirect influence on tourist intention to visit on-site tourism. Furthermore, tourist desire to attend on-site tourism was significantly influenced by satisfaction (H5) and authentic experience (H6). Consequently, it can be concluded that authentic experience and satisfaction play the role of mediators within the research framework. Table 4 shows the medicating impact of SA and AE in the relationship between DOI, UGT, and IOT.

Table 3. Hypothesis Testing Results

Path	Direct Effect	Mediating Effect	Total Effect	Supported
AE → IOT	0.243***	–	0.243***	Yes
DOI → AE	0.324***	–	0.324***	Yes
DOI → SA	0.569***	–	0.569***	Yes
DOI → IOT	–	0.401***	0.401***	Yes
SA → IOT	0.566***	–	0.566***	Yes
UGT → AE	0.445***	–	0.445***	Yes
UGT → SA	0.297***	–	0.297***	Yes
UGT → IOT	–	0.276***	0.276***	Yes

4.3 Moderating Effect

The interaction effect technique was used in this research to investigate the moderating impact (Rasoolimanesh et al., 2021). The t-statistic value surpasses the minimal criterion of 1.64 with a confidence level of 0.01 in relation to the moderating influence of connection to nature in H7 (Table 4). This demonstrates that proximity to nature moderates the association between happiness and inclination to engage in on-site tourism. A further calculation yields a value of 0.099 for the f square (f2) for hypothesis 7. Kenny (2018) claims that interaction effect sizes of 0.005, 0.01, and 0.025 correspond to modest, medium, and high impact sizes, respectively (Rasoolimanesh et al., 2021). The interaction effect's f2 value is statistically significant in this investigation. Additionally,

Fig. 3 graphically illustrates that a higher level of connection to nature (represented by the green line) compared to a lower level (shown by the red line) results in a larger association between satisfaction and desire to engage in on-site tourism.

Table 4. Moderating Effect

Path	Original Sample	T statistics	P values	f^2
Connection to nature x Satisfaction → Intention to on-site Tourism	0.217	10.597	0.000	0.252

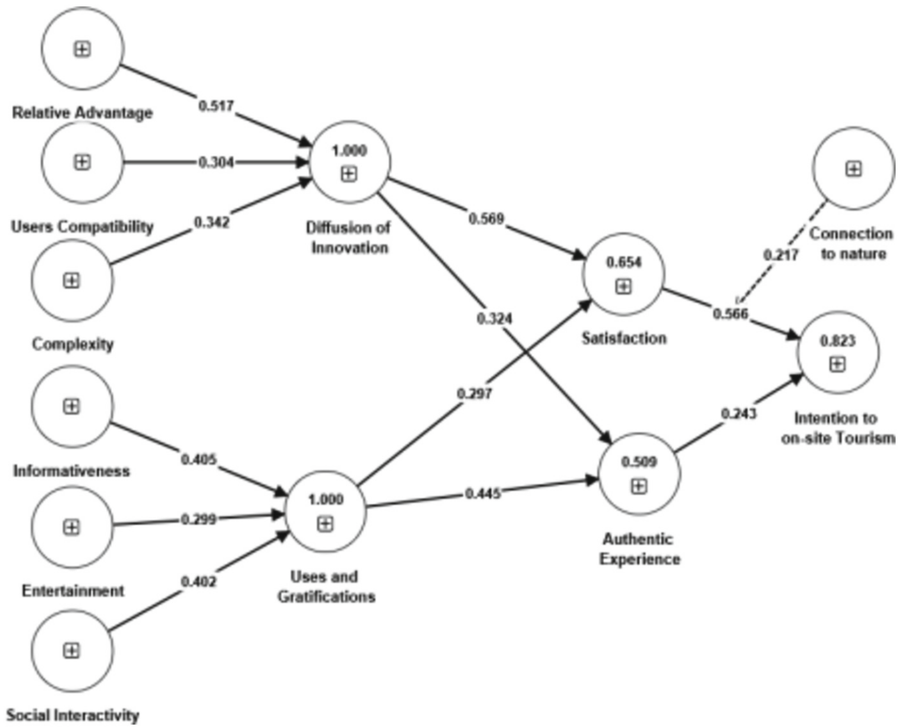

Fig. 2. Result of Structural Model

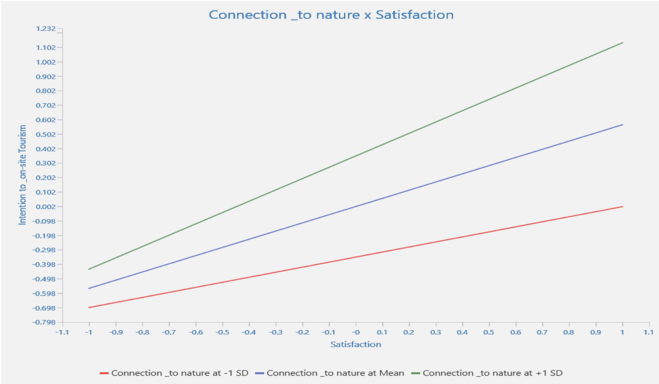

Fig. 3. Moderating Effect of Connection to Nature

5 Discussion

VR technology, devices, and content development tools have a significant influence on VR tourism, significantly improving tourist experiences (Kim et al., 2020a, 2020b). In spite of the rising concentration in and relevance of virtual reality tourism, no such integrated theoretical framework has been established and confined in this area (Yung and Khoo-Lattimore, 2017). To remedy this hole, we develop and test a conceptually integrated model that incorporates theories of innovation diffusion as well as uses and gratifications to explain why individuals engage in VR tourist activities. Moreover, it investigated the moderating effect of connection to nature on the relationship between VT satisfaction evaluation variables and intention to visit the actual tourism destinations.

This study demonstrates that relative advantages, user compatibility and complexity (components of diffusion innovation) are interrelated to satisfaction and authentic experience. The connotation between innovation diffusion and satisfaction is stronger than the connotation between innovation diffusion and authentic experience. Furthermore, informativeness, entertainment and social interactivity (components of uses and gratifications) are found to positively influence satisfaction and well-being. The effects of uses and gratifications on authentic experience are larger than the effects of uses and gratifications on satisfaction. Additionally, in line with other studies (Atzeni et al., 2022) VT experience happiness has a beneficial contribution to predicting the intention of on-site tourism. Virtual tourism has unique and cutting-edge qualities that have the ability to pique tourists' interests and satisfy a range of travel motives and objectives. Visitors' intents to travel on-site are influenced by virtual tourism through immersive, real-world, and interactive travel experiences. It is important to note that the impact of satisfaction is greater than the effect of genuine experience on behavioural intention towards tourism-related activities. Additionally, when visitors feel strongly connected to nature, their VT pleasure has a substantial impact on their inclination to engage in on-site tourism.

6 Implications

6.1 Theoretical Implications

This theoretical research provides some significant contributions in the disciplines of VR tourism. To begin, the study creates a complete model based on the DOI and UG theories to describe travel customers' intentions to use or enjoy VR programmes. This is the first attempt in the VR domain to identify an integrated model of travel customer behaviour. This study shows experimentally that both the theories make substantial and different aspect to understand VR travel consumer behaviour. Second, by including the impacts of satisfaction and well-being on behavioural intention, the integrated model created in this study adds to well understanding of VR travel customers. Third, empirical data supports the theoretical model's identification of the theoretical model's influence on genuine experience and subjective well-being.

The study model describes how satisfaction and authentic experience affect behaviour intention. The findings also add to previous research on the relationship between satisfaction and intent to participate in VR travel programmes (Yung and Khoo-Lattimore, 2017). Finally, by merging DOI and UG theories, this study gives acumens into behavioural intention to embrace new technologies in the field of VR tourism.

Moreover, this study discovered a significant moderating impact of connection to nature on the relationship between satisfaction and intention towards on-site tourism. This study is the first to investigate the moderating role in the area of virtual tourism (VT), therefore broadening the scope of connection to nature research. By studying the moderating function of connection to nature, the theoretical implications of this study provide to a better understanding of the interaction between visitors' evaluations of pleasure in VT and their behavioural intentions towards on-site tourism.

6.2 Practical Implications

This study provides significant practical insights to the relationship between innovation dissemination and pleasure that VR travel industry practitioners may employ. Given the importance of relative advantage, user compatibility, and complexity in driving the diffusion of innovations, it is critical for VR technicians to carefully consider these attributes when designing their products and services, particularly in the context of VR technology in the tourism sector. VR specialists may increase the uptake and acceptability of VR technology among visitors by including these features into their products. However, VR engineers should not go ahead of where consumers are in terms of adopting VR technology into their experiences (i.e., VR tourism should be well-suited with users' degrees of comfort with the technology). VR developers should also consider the benefits that customers expect from VR technology and strive to match those expectations in terms of both technology and content (compatibility). Similarly, VR practitioners should simplify how the programmes are used so that first-time users do not quit up in frustration due to challenges in getting the technology to work.

The same elements that impact the dissemination of innovation listed above are equally significant to fostering subjective well-being. In other words, simple, useful, and beneficial VR tourism material that promotes enjoyment will most likely be psychologically pleasant to potential VR tourists. The findings of the study on the influence of uses and gratifications on satisfaction and subject well-being may be of interest to tourism marketers. For example, if marketers create virtual reality goods that are instructive, interesting, and socially linked (factors that promote subjective well-being), they may improve consumers' affection for the VR programmes. Furthermore, practitioners may find it useful to include the discovery of the impacts of uses and gratifications on the emotional and well-being of VR users. Therefore, VR tourism practitioners should incorporate components of information, social relationships, and entertainment into their VR products and services to provide customers with a greater sense of emotional well-being.

The outcomes of this study will help field professionals who want to adopt good practises about the relationship between satisfaction and behavioural intention. VR tourism practitioners should make their VR programmes authentic; one method to do so may be to include unique parts of material. This might be accomplished by developing VR tourism activities with realistic sound, video, and haptics. Marketers must consider the impact of subjective well-being on behavioural intention when using technology and creating content that fosters a sense of subjective well-being. VR developers, for example, could generate psychologically exciting VR tourist material by utilising sophisticated techniques such as three dimension (3D) and 360-degree technology. Importantly, by adding the concept of authentic experience, this study gives fresh insights on VR tourist products. According to the findings, commercial operators whose VR tourism programmes generate high levels of pleasure, enjoyment, and contentment will contribute to the sustained usage of VR tourism and may lead to visits to the places shown in VR content. By using any or all these strategies, the industry should become more user-friendly and profitable for practitioners. In conclusion, this study has practical implications for VR tourist marketers.

The findings addressing the moderating influence show that the multisensory and near-nature experience part of virtual tourism (VT) need refinement. This data can help marketers design customised marketing strategies based on various customer categories. Furthermore, tourism managers must prioritise the delivery of high-quality services in Vermont in order to improve the satisfaction and expectations of client groups with a strong natural affinity. This, in turn, may stimulate their desire to visit genuine locations. Destination managers should prioritize nature-oriented experiences in tourist attractions to strengthen visitors' connection with nature. By integrating nature-based activities like hiking trails, wildlife encounters, and scenic viewpoints, destinations can increase satisfaction levels and increase on-site tourism intention. Tailoring marketing efforts to highlight the connection to nature as a unique selling point can attract visitors who value immersive nature experiences. Targeted campaigns can convey the message that visiting a physical destination provides an unparalleled opportunity to connect with nature.

7 Limitations and Direction for Future Studies

When implementing the findings, keep the study's limitations in mind. Because the sample was taken from Indian tourists, the study's conclusions should be used with caution outside of India. We concentrated on the usage of VR material rather than the devices; more research should be undertaken to evaluate if the findings apply to all types of VR devices. The technological acceptance model, in particular, is beneficial in understanding the adoption of VR devices. To further understand VR technology adoption by tourists, future studies may investigate adding other theories of human behaviour into an expanded VR technology acceptance model.

Furthermore, further study on the reasons individuals do not use VR for tourism can help practitioners recruit non-VR tourism consumers, ultimately expanding the VR travel industry. Furthermore, customers who have no experience with using technology for tourism and/or visitors who intentionally seek to avoid technological encounters are part of the market to target. As a result, future research should employ a variety of samples to capture non-users' perceptions about digital encounters. Furthermore, because there are several methods to enjoy VR tourism, ranging from smartphone applications to large-scale VR attractions at amusement parks, future study should concentrate on various sorts of VR experiences. Because this study does not take into account the impact of various tourism experiences (e.g., visiting museums, nature excursions, dark tourism, shopping, and so on) and the various motivations that may be associated with each of them, qualitative research on various types of VR tourism would deepen our understanding of tourist/visitor behaviour.

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Purchasing e-Bikes: Prioritization of Decision Factors Using AHP

Himasmita Das(✉), Arshdeep Kaur, and P. Vigneswara Ilavarasan

Indian Institute of Technology Delhi, New Delhi, India
himasmita.das@gmail.com, arshdeep.kaur23@dmsiitd.org, vignes@iitd.ac.in

Abstract. Electric vehicles (EVs) play a critical role in mitigating emission of greenhouse gas and focusing on issue of global warming. Transitioning conventional transportation to EVs has been driven by recent developments in digital technology. Several nations are actively advocating adoption of EVs as part of their sustainable development goal efforts. Nevertheless, EVs are essential, its adoption rate is quite minimal. This research paper seeks to identify factors affecting users' decisions to purchase electric bikes (e-bikes) in India. The study used analytic hierarchy process (AHP) to identify factors and its priorities. Using a survey-based methodology, data was gathered from a sample of 31 users who had recently purchased an e-bike. The analysis discovered that technological factors and financial factors are identified as most significant factors while planning to purchase e-bike, along with psychological and enthusiasm factors. Study offers insights for e-bike manufacturers and marketers on successfully targeting and appealing to customers based on their priorities and preferences in India.

Keywords: Electric Vehicle · Electric Bike · Analytic Hierarchy Process

1 Introduction

Electric vehicles (EVs) offer carbon free transportation and help as an operative solution to address air pollution [1]. The adoption of electric transit plays a crucial role in controlling global warming by 1.5 °C [2]. In recent years, EVs' popularity has been notable, although their sales still make up a relatively small fraction of the global new vehicle market [2]. The global community is facing significant challenges such as energy scarcity, air pollution and many more [2]. These emissions from the transportation sector have been increasing with its growing contribution to overall energy consumption [3, 4]. The use of EV can help reduce or alleviate global warming while contributing to sustainable development goals SDG 7 (clean energy), SDG 12 (sustainable production and consumption) and SDG 13 (climate action). EVs possess the capability to revolutionize the realm of road transportation, although their acceptance and utilization are still in their initial phases [5]. In spite of numerous benefits offered by EVs, their market presence and acceptance level have not experienced substantial expansion [6].

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Furthermore, situation in developing countries remains challenging. It is anticipated that by 2030, the transportation sector in Asia will be responsible for approximately 31% of carbon emissions [7]. China holds the largest share of the global EV market, accounting for half of it, followed by Europe and the United States. In the Asia Pacific region's market share in 2022, China sales 5.9 million electric cars. In contrast, India's sales of electric cars were significantly lower, reaching only 48000 units [8].

India has committed to decreasing its carbon footprint by 33–55% below the 2005 levels by 2030. Utilizing alternate fuels such as hydrogen, ethanol, natural gas, electricity, methanol, biodiesel, and propane is a viable solution to decrease dependence on fossil fuels and gasoline [9]. India has established a national objective of achieving a 30% penetration rate for EV sales by 2030. To support this goal, the country has initiated "National Mission on Transformative Mobility and Battery Storage," seek to promote local manufacturing components of EVs. Despite these measures, India's EV market has not experienced the anticipated growth. This situation calls for a comprehensive assessment to detect barriers and challenges within the EV market that hinder the expansion of electric transport and various other lower carbon public transportation systems in India. Even psychological and emotional factors on Indian user intention to purchase EVs has not been explored, despite their growing interest in EVs [10].

The Indian e-bike market has several significant players contributing to its growth and development. Many companies including Ola Electric, Hero Electric, Ampere, Ather, and TVS, Okinawa, are known as prominent players in this business [11]. Ola Electric has introduced electric scooters that cater to the Indian market needs, focusing on affordability, performance, and sustainability. Hero Electric, a well-established brand in India's two-wheeler market. It is leveraging its expertise in manufacturing conventional motorcycles. Ampere, a subsidiary of Greaves Cotton Limited, specializes in electric mobility solutions, including e-bikes. With a strong focus on technology and innovation, Ampere provides reliable and efficient e-bike options to Indian users. TVS, a renowned Indian two-wheeler manufacturer, has also entered the e-bike market with its range of electric scooters. Combining their expertise in traditional motorcycle manufacturing with electric mobility, TVS offers e-bikes that balance performance, style, and affordability.

To promote the wider acceptance of e-bikes, it is vital to identify and prioritize factors of e-bikes that attract users and encourage their adoption. This prioritization will enable policy-level interventions aimed at presenting e-bikes as an appealing choice for commuters in India. The importance of prioritizing these factors arises from the basic understanding that each factor affects users differently and notably impacts commuters [12]. Experts and users are beneficial as it offers a more comprehensive and insightful perspective on the factors. Experts can contribute their valuable experience to assess the level of importance of these factors. On the other hand, users can evaluate the factors based on their own commuting experiences and the perceived benefits they have experienced.

Addressing climate change and working towards its mitigation requires us to tackle the significant challenge of decarbonizing transport sector [13]. Adoption of e-bike can influence decarbonization of transport segment by effectively reducing CO_2 emissions [14]. Hence, the rate at which e-bikes are adopted becomes critical in determining whether world can achieve its CO_2 mitigation goals.

Despite EVs importance, there is a scarcity of research focused on e-bikes, and a thorough examination has failed to uncover any dedicated studies specifically addressing e-bike-related topics [15]. The primary focus of the present study is to examine user intentions and attitudes toward adopting e-bike. Based on the above discussion the following research questions have been formulated.

- RQ1: What are the factors that influence user decision to purchase e-bikes?
- RQ2: What is the priority of the factors while making purchase decisions?

2 Literature Review

This section offers a summary of current body of research. The objective is to establish a comprehensive framework for understanding the research problem by presenting relevant literature on factors influencing use of e-bikes. Additionally, it identifies gaps in the existing literature that highlight areas where further research is needed.

2.1 Factors Influencing e-Bike Adoption

A substantial body of literature covers numerous studies exploring various aspects of e-bikes such as financial, technological, psychological, and enthusiasm. Previous study found that economic advantages associated with transportation policies significantly influence users' choices when purchasing EVs [16].

Financial factors pertain to the monetary aspects and consequences related to the ownership and utilization of an EVs [13]. Potential buyers assess the affordability [1] initial expenses, ongoing costs, maintenance outlays [11], cost-efficiency, and possible long-term savings provided by e-bikes in comparison to alternative means of transportation. There are sub-criteria: Value for money, Low Maintenance Cost, and Purchase price. The purchase choice for e-bikes is significantly influenced by the concept of getting value for money. Users analyze the overall worth they obtain with the price they pay for an electric bicycle. This evaluation involves determining whether the benefits, features, and quality of the e-bike adequately justify its price. The perceived value for money is not solely based on the initial purchase cost but also considers long-term factors such as maintenance, operating costs, and potential resale value. The comparative cost savings of owning an e-bike instead of conventional vehicles are considered. The reduced expenses on fuel and lower maintenance requirements of e-bikes add to their perceived value for money, making them a more economically viable option in the long term.

The maintenance cost plays a vital role in shaping user choices when it comes to purchasing e-bikes. The overall cost of having EV is lower compared to conventional vehicles due to savings in fuel expenses and thus reduced maintenance costs [17]. People often consider the long-term costs and upkeep involved in owning an e-bike, weighing the financial values.

The initial cost of buying an e-bike is a crucial consideration that requires careful assessment. In many countries, purchase price of electric transportation is notably elevated due to substantial charges associated with their batteries [18]. Users evaluate the price of e-bike based on their financial situation and affordability. Therefore, they compare the cost of e-bikes with regular bicycles or conventional vehicles to determine their cost-effectiveness and potential long-term savings. When individuals evaluate e-bikes compared to regular bicycles or traditional gasoline-powered vehicles, they consider the cost-effectiveness parameter.

Technological factors encompass a range of technical aspects and advancements that improve the performance, functionality, and user experience of e-bikes. The adoption is significantly influenced by technological factors such as speed, power production and safety [13]. Users are drawn to the technological features and innovations that enhance the overall appeal and value of e-bikes. Sub-criteria include battery life, charging time, distance range, easy to use and safety. The propulsion of EVs heavily depends on lithium-ion batteries, which are essential for storing the necessary energy [2]. The battery's longevity plays a crucial role in shaping the purchasing choices of e-bike users. Potential buyers take into account battery life [19] and its dependability since these aspects directly impact the e-bike's range and convenience.

The charging time of an e-bike's battery is a crucial factor that affects users' purchasing decisions [19]. When assessing the charging time, users prioritize e-bikes equipped with batteries that can be recharged swiftly and effectively. They favor shorter charging durations, as it reduces the waiting time for the battery to regain power, allowing them to enjoy their rides more [11]. Rapid charging also offers flexibility and convenience, particularly for individuals with busy schedules or limited access to charging infrastructure [5]. Apart from speed, efficiency is also an essential aspect of charging time. Users seek e-bikes that optimize the charging process, ensuring the battery is effectively charged while minimizing energy consumption. Efficient charging helps prevent energy wastage, lowers electricity costs, and contributes to a more sustainable and environmentally friendly charging experience.

The distance range of an e-bike refers to the utmost distance it can travel on single charge of its battery. Users consider the distance range as it directly impacts the practicality and usability of the e-bike for their specific needs. Users assess their daily commuting or recreational requirements when considering the distance range [19]. They prefer e-bikes that can cover the necessary distance without requiring frequent recharging [3]. A longer distance range enables riders to travel more extensively and confidently without worrying about running out of battery power.

The user-friendliness and convenience of operating an e-bike are essential factors that directly impact users' overall riding experience and satisfaction with the vehicle. Users evaluate various aspects of the e-bike's design and functionality when assessing ease of use. They seek intuitive controls and a user-friendly interface that enable effortless operation. Features such as clear and easily accessible displays, ergonomic handlebar controls, and comprehensible settings contribute to a positive user experience. Previous research indicates that individuals generally exhibit aversion towards uncertainty [20]. Users also consider the ease of starting and stopping the e-bike and its maneuverability and stability while riding. They value responsive acceleration, smooth braking systems, and stable handling, which enhance overall ease of use and make the e-bike comfortable and enjoyable.

Users prioritize their safety while riding e-bikes [13]. They consider various safety features and design elements contributing to their confidence while using the vehicle [2]. Features such as a low center of gravity, robust frame, and dependable suspension systems enhance stability and handling, particularly when navigating various road conditions or challenging terrains. Braking performance is another critical aspect of safety. E-bikes equipped with reliable braking components, such as hydraulic or disc brakes, instill confidence in riders, enabling them to have better control and reducing the risk of accidents or collisions.

Psychological factors encompass an individual's mindset, attitudes, perceptions, and emotions, all of which significantly impact their motivation and inclination to choose e-bikes as their preferred mode of transportation. Environmental consciousness and social influence are intertwined and play a crucial role in influencing the decision to purchase e-bikes. In terms of environmental belief, users who prioritize environmental values are strongly inclined to choose sustainable transportation options to decrease their carbon footprint and diminish their environmental impact. The previous study's findings indicate that environmentally responsible behavior in Malaysia is significantly influenced by environmental beliefs [21]. E-bikes run on electricity and produce zero tailpipe emissions, making them a cleaner mode of transportation. Users who prioritize environmental sustainability appreciate the energy efficiency of e-bikes. Unlike internal combustion engine vehicles, e-bikes are known for their higher energy efficiency. They can travel longer distances using less energy, reducing reliance on fossil fuels and lowering overall energy consumption. Users who hold environmental beliefs often consider their choice of transportation as an expression of their values [22]. By choosing an e-bike, they can demonstrate their commitment to sustainability and inspire others to adopt eco-friendly modes of transportation.

Social influence refers to the impact of social networks, interactions on an individual's choices and behavioral intention [23]. Users can be influenced by the perceptions and experiences of others, as well as societal trends and attitudes towards e-bikes. Personal recommendations and testimonials from individuals within one's social circle can significantly sway purchasing an e-bike. Positive experiences shared by friends or colleagues who already own e-bikes can establish trust and credibility, making potential buyers more inclined to follow suit. Social influence can also arise from the desire to conform to social norms or peer pressure. If owning an e-bike is seen as a status symbol, individuals may be more inclined to purchase one to fit in or to be perceived in a specific way by their peers.

Enthusiasm to use the latest technology is a significant factor that strongly impacts purchasing e-bikes. Many users are enthusiastic about the advanced features and innovations e-bikes offer [24]. E-bikes frequently incorporate cutting-edge technologies such as smart displays, electric motors, lithium-ion batteries, connectivity options, and regenerative braking systems. The attraction to using the latest technology goes beyond the functional aspects of e-bikes; it encompasses the satisfaction and pride of owning a cutting-edge vehicle. Being an early adopter of new technologies can be seen as a symbol of progressiveness and staying ahead of the curve. The enthusiasm for embracing the latest technology drives individuals to explore and invest in e-bikes, personally allowing them to experience the benefits and advancements firsthand. The prospect of staying at the forefront of technological advances and enjoying the benefits of future upgrades motivates individuals to choose e-bikes over conventional alternatives.

3 Research Methodology

The study utilizes AHP methodology to determine factors that lead to e-bike adoption in India. It is a hierarchical multi-criteria decision-making approach, enabling calculation of weights for key criteria and evaluating alternatives by comparing their relative importance. As a result, AHP has been widely applied in various fields. To acquire more accurate and organized information about the elements that impact the decision to purchase e-bikes, a questionnaire was created. The questionnaire was designed by considering the factors identified in earlier studies and the knowledge shared by industry experts and e-bike owners. Considering the insights from prior works, AHP is deemed suitable for determining the priority of e-bike purchases in the present study.

3.1 Analytic Hierarchy Process

AHP is a decision-support method that facilitates the systematic assessment of mutually exclusive alternatives in complex situations that involve multiple decision goals or evaluation criteria [25]. At the core of the AHP lies its primary feature, which is the utilization of pairwise comparisons to establish a hierarchical structure for complex problems [26]. AHP breaks down a problem into higher-level and lower-level factors and determines the weights that represent their relative significance among all the factors involved. To determine the weights, user responses are translated into a pairwise comparison matrix. AHP can compute the consistency index (CI) and consistency ratio (CR) to assess the level of consistency in the decision-making process.

A questionnaire was design to gather user opinions on the comparative importance of every sub-criterion within a specific category. The AHP technique utilizes the principles of priority theory to address complex problems that require selecting the most optimal option from a set of multiple alternatives [12]. Calculating the comparative importance of criteria was implemented using a systematic process. AHP encompasses several stages, which are outlined as follows.

- The initial step in this process involves recognizing the decision problem. Define research objectives.
- Next step is to identify sub-criteria associated with each primary criterion.
- The following step entails establishing the relative weights of the criteria by comparing them pairwise on a scale ranging from 1 to 9.
- The comparative weights of sub-criteria are determined based on importance of each sub-criterion to its respective main criterion.
- Consistency checks are performed to ensure accuracy and reliability.
- AHP method establishes priorities of its criteria and sub-criteria. Weights for each criterion level and sub-criteria are multiplied to determine their preferences.

3.2 Data Collection

Data collection for the study involved obtaining individual responses from a specific group of respondents who had purchased e-bikes. Respondents were responsible for sharing their judgments and opinions concerning the factors influencing their decision-making process. The study aimed to collect data from a particular age group, specifically respondents aged 25 to 40. This age range was chosen under the assumption that individuals within this demographic are more likely to be actively employed and may be thinking of using e-bikes for their traveling needs. The study included a sample size of 31 respondents, deliberately chosen to represent the desired target population. Each participant in the study was either employed professionals or businesspeople who commuted to their workplaces regularly. By concentrating on this specific group, the study aimed to acquire valuable insights into the factors influencing the decision-making process of purchasing e-bikes among individuals who frequently commute for work.

4 Results

The weights of financial, technological, psychological and enthusiasm to use latest technology along with the consistency ratio (CR) were computed. The pairwise comparison matrices and priorities obtained from the AHP analysis are presented in the tables below, providing a quantitative representation of the relative importance assigned to each factor influencing the purchase decision of e-bikes. Based on the responses provided by the respondents and the pairwise comparison matrices, the priorities of each of the factors were calculated. The priorities indicate the comparative importance of every factor in the overall decision making process. Higher the priority value, greater is influence of factor on purchase of e-bikes.

The results demonstrate that technological factors are identified as the most significant criterion, indicating that users place a high value on the technological aspects of e-bikes as shown in Table 1. This criterion encompasses safety, ease to use, distance range, charging time, and battery life. Similarly, financial factors are ranked as the second most crucial criterion, indicating that users also consider financial aspects when making purchasing decisions. Moreover, psychological factors, including social influence, environmental beliefs, and enthusiasm to use the latest technology, are important but to a lesser degree compared to the top two criteria.

The pairwise comparison matrix for sub-criteria within the financial category reveals their relative importance shown in Table 2. The analysis highlights that purchase price is the most crucial sub-criterion, suggesting that users attach significant importance to the initial cost of e-bikes. Subsequently, value for money is ranked second, indicating users consider the overall cost-effectiveness and long-term savings associated with owning an e-bike. Low maintenance costs are also considered a factor in the purchase decision, although to a slightly lesser extent.

Table 1. Pairwise comparison matrix of the main criteria

	Financial Factors	Technological Factors	Psychological Factors	Enthusiasm to use latest technology	Priorities
Financial Factors	1	0.74460	3.52911	3.5583	0.36298
Technological Factors	1.34298	1	3.67801	3.24279	0.41498
Psychological Factors	0.28335	0.27188	1	0.97584	0.10847
Enthusiasm to use latest technology	0.28103	0.30837	1.02475	1	0.11356

* Consistency Ratio calculated as 0.0052

Table 2. Pairwise comparison matrix for sub-criteria concerning financial factors

Financial Factors 0.36298	Value for money	Low Maintenance Costs	Purchase Price	Priorities
Value for money	1	1.75521	0.74451	0.34339
Low Maintenance Costs	0.56973	1	0.42550	0.19584
Purchase Price	1.34316	2.35013	1	0.46075

* Consistency Ratio calculated as 0.00000095

The pairwise comparison matrix for sub-criteria within the technological category illustrates their relative importance shown in Table 3. The analysis reveals that safety is the most significant sub-criterion, suggesting users prioritize the safety features and considerations associated with e-bikes. Ease of Use is ranked second, indicating the importance of user-friendly features and intuitive operation. Distance range, charging time, and battery life influence the purchase decision, although their priorities are relatively lower than safety and ease of use.

Table 3. Pairwise comparison matrix for the sub-criteria concerning technological factors

Technological Factors 0.41498	Battery Life	Charging Time	Distance Range	Easy to use	Safety	Priorities
Battery Life	1	0.63563	0.33829	0.41187	0.18046	0.06952
Charging Time	1.57323	1	1.09471	0.31950	0.17987	0.09734
Distance Range	2.95604	0.91347	1	0.84289	0.18996	0.13848
Easy to use	2.42792	3.12988	1.18638	1	0.52385	0.21350
Safety	5.54111	5.55929	5.26426	1.90892	1	0.48113

* Consistency Ratio calculated as 0.04

The pairwise comparison matrix for sub-criteria within the psychological category presents their relative importance shown in Table 4. Social influence is recognized as the most significant sub-criterion in this category, indicating that users are influence by their social network opinions, recommendations, and norms when making purchasing decisions. Environmental beliefs are ranked second, suggesting that users who prioritize environmental sustainability take into account the eco-friendly e-bikes in their decision-making process.

Table 4. Pairwise Comparison Matrix for the sub-criteria concerning Psychological Factors

Psychological Factors 0.10847	Environmental Beliefs	Social Influence	Priorities
Environmental Beliefs	1	0.37310	0.27172
Social Influence	2.68023	1	0.72827

5 Discussion

From the sustainability and policy perspectives, it is evident that there is an enthusiasm for EV, once potential buyers become aware of specific details and expenses associated with EVs.

The study makes it evident that both financial and technological factors are considered the most influential factors in e-bike adoption. This finding aligns with previous research on [1, 2], which also emphasized the importance of technological factors in acceptance of e-bike. Therefore, it is utmost important for organizations to emphasize technological safety and user-friendly features in the operating e-bike. Distance range, charging time and battery life are also important aspects to consider while buying an e-bike. Consumers in India are sensitive about safety, vehicle features which also found in the previous study.

The study highlights the significance of financial factors as influencing factors in the adoption of EVs [2]. The result focus that purchase price is the most crucial sub-criterion, suggesting that user give more importance in initial cost of e-bikes which align with the previous research [3]. Subsequently, value for money is ranked second, indicating user consider long-term investment associated with purchasing and owning an e-bike followed by maintenance costs are also considered a factor in the purchase decision. Regarding the incentives provided through FAME (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles) in India, it is highlighted that FAME incentives is an important program to reduce purchase price of e-bikes. Authors argue that it will be necessary to sustain these incentives going forward to tackle initial price of purchase and make e-bike attractive to consumers.

The findings also indicate that individuals who exhibit enthusiasm about latest technology are more inclined to purchase e-bike as their prefer mode of transportation. The preference for purchasing the latest technology extends beyond the functional features of e-bikes; it incorporates happiness and pride of owning a cutting-edge vehicle.

Finally, the study identifies psychological factors as critical factors influencing purchase of e-bike in India. Study identified that social influence is the most impactful sub-criteria while making e-bike purchasing decision emphasized opinion of social network, their recommendations [4]. Similarly, users who prioritize environmental sustainability take into account the eco-friendly e-bikes in their decision-making process. These factors help mitigate global warming and contribute to sustainable climate action.

6 Practical Implications

The findings can serve as a beneficial resource for e-bike manufacturers when developing their marketing plans. Transferring conventional bike with e-bike, there will be a significant improvement in air quality. Consequently, carbon emission can be reduced. E-bike adoption are still in the premature stages of adoption, prospective user may wish to consider several factors before making a purchase. The study's conclusion highlights those technological and financial factors, significantly influence user's decision to purchase e-bike in India. In this alarming global warming situation, this is essentially important to promote benefits and implication of e-bike in order to create a habitable and sustainable environment. In line with this, marketers of e-bike manufacturers can focus on explaining technological and financial benefits associated with them. Additionally, psychological and enthusiasm have influence on user purchase intention of e-bike, therefore, it is essential that firm should communicate the advantages to the public.

The government needfully provides additional financial support to encourage widespread adoption of e-bike. Although government have taken various initiative, enhancing infrastructure facilities, and offering subsidies to people will further increase purchase of e-bike. To promote the purchase of e-bike in India, it is recommended that government should take measures to provide subsidies, tax exemption and providing other benefit to buyers. Furthermore, research indicates that working professional or businessman are more inclined to purchase e-bike as they travel shorter distances and avoid traffic problem. Therefore, companies can target working professional or businessman and develop campaigns that cater to their specific requirements to promote e-bike.

7 Conclusion and Limitation

The research investigates the crucial factors that influence intention to purchase environmentally friendly e-bike in India. This study aims to prioritize different performance measurements of e-bikes using AHP and rank criteria and sub-criteria for e-bikes in the market. Drawing upon existing literature and interviews with experts and users, four main criteria were identified, and ten sub-criteria have been examined and ranked according to their importance. The study offers valuable contributions to marketers, managers, and manufacturers in promoting environmentally friendly practices. For instance, marketers can improve users' perception of their intention to an e-bike, enhancing their appeal and desirability. This study can be a valuable guide for engineer who design e-bike in integrating customer likings into the design process. Furthermore, this can be foundation for policymakers to prioritize critical criteria in e-bike choice and user preferences. The government should consider enhancing infrastructure to promote e-bikes more effectively while implementing subsidies and incentive schemes at the national and local levels to encourage e-bike adoption within the country. There are a few drawbacks to this research. First, the ability to generalize the finding is limited. The study collected data from specific groups who had purchased e-bikes at the age of 25 to 40. Data was not gathered from random sample. Second, study examined four main key factors based on literature and expert opinion. There could be more factors which lead to purchase intention of Indian consumers.

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From Screens to Shopping Carts: Unravelling the Impact of Digital Influencers' Credibility on Hyper-Local Brand Perception and Purchase Intentions

Munsifa Hoor[1](✉), Prabhjot Singh[1], P. Vigneswara Ilavarasan[1], and Yash Chawla[2,3]

[1] Department of Management Studies, Indian Institute of Technology Delhi, New Delhi 110016, India
munsifaali5@gmail.com, vignes@iitd.ac.in
[2] Department of Operations Research and Business Intelligence, Wroclaw University of Science and Technology, Wroclaw, Poland
yash.chawla@pwr.edu.pl
[3] Department of Engineering, University of Messina, Messina, Italy

Abstract. The influence of digital influencers (DIs) on consumer purchase intention has been widely examined in the luxury brands context. However, there remain a noticeable gap in literature concerning the impact of DIs on consumer willingness to purchase hyper-local brands. The current study aims to address this gap. We develop a conceptual model using source credibility theory and examine the influence of DIs credibility components (i.e., expertise, trustworthiness, and similarity) on consumers perception towards brand (i.e., advertising trust) and purchase intention. To test the model, we employed structural equation modelling (SEM) using a sample of 110 social media users in India. We found out DIs expertise, trustworthiness and similarity significantly affect purchase intention. However, only similarity is positively affecting advertising trust, which subsequently influence purchase intention. Implications, limitations and future research directions are also discussed.

Keywords: Digital influencers · social media · hyper-local · source credibility · advertising trust · purchase intention

1 Introduction

Advancement of information and communication technologies such as social media, has given opportunity to ordinary individuals to become 'digital influencers' (DIs) simply by creating and sharing content on social media platforms [1]. DIs are those who have cultivated a committed and engaging audience on social media platforms (like YouTube, Instagram, and Twitter) and holds the power to impact and shape the opinions and behaviours of their audience leading to social commerce [2]. The growth of social commerce in India, as indicated by the Statista data [3], revealed that 52% of surveyed

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social media users have purchased a product or service based on DIs recommendation. Brands are increasingly approaching them compared to traditional celebrities (e.g., actors, athletes and models) as they are more affordable, have expertise in particular domain, and often interact and engage with their audience on social media platforms [4].

While the influence of DIs on consumers' purchase intention has been extensively studied, most of them have focused on luxury brands [5, 6]. There is a noticeable lack of research in existing literature concerning the impact of DIs on consumer purchase intent specifically related to hyper-local brand. Hyper-local brands are those which operates on a smaller scale and serve nearby communities. These brands are now receiving increased exposure and attention through the efforts of DIs who promote them on their social media accounts [7]. DIs are giving voice to these businesses by featuring and endorsing them, effectively raising awareness among their followers about the existence of such local establishments. Further, individuals can also place orders on social media platforms like Instagram for these businesses [8], such as profiles like Love Local India and Sarojini Market Online. Therefore, the growing popularity of hyper-local brands motivates us to explore the role of DIs in affecting the consumer willingness to purchase. Accordingly, the present study proposes the following research question. *Do DIs credibility components affect consumers hyper-local brand perceptions and purchase intentions?*

Using source credibility model [9], we investigated the mechanism by which DIs influence purchase intention of consumers. We have also examined the perception of consumers towards hyper-local brands i.e., the advertising trust in DIs generated branded content [1]. By taking the holistic perspective of influencer marketing, we demonstrated the influence of DIs credibility determinants (i.e., expertise, trustworthiness, and similarity) on consumers perception towards brand (i.e., advertising trust) and purchase intention of hyper-local brands. We also tested the mediating effect of advertising trust on credibility components and purchase intention. The study contributes in two ways. Firstly, it will help in understanding the consumer perception towards hyper-local brands through DIs generated content, which is not explored. Secondly, implications of DIs characteristics in enhancing consumer willingness to purchase hyper-local brands.

2 Theoretical Background and Hypothesis Development

2.1 Source Credibility

Source credibility model was proposed by Hovland, Janis, and Kelley [9]. According to this model, the characteristics of a communicator or information source can persuade the behaviour of receiver towards the message being conveyed. DIs are considered as 'micro-endorsers' [10] and generally play similar role like of information sources in persuasion process. A favourable perception of endorser credibility can influence consumers' evaluation of a product or service, thereby yielding a positive advertising outcome [1]. Thus, the DIs' perceived credibility holds an important role in shaping the effectiveness of any advertisement.

In the seminal work, Hovland, Janis, and Kelley [9] suggested two components of source credibility, that is expertise and trustworthiness. Over the years, researchers have conducted empirical studies and identified various dimensions of source credibility [11, 12]. However, source expertise and trustworthiness remain the two primary factors of source credibility, that are considered to have significant influence on how individuals evaluate the credibility of information [13].

Expertise means the receiver's perception of whether the communicator possesses the necessary knowledge and skills to make valid claims related to the shared message [9]. The perceived expertise of a communicator depends on various factors, including their knowledge in a particular area, having a reputable title, or having know-how of doing something [14]. On social media platforms, DIs create content related to their specific fields such as fashion, fitness, food, beauty, etc. Consequently, perceived as knowledgeable or expert in their respective area [4].

Source trustworthiness denotes the perceived truthfulness of the communicator and the receivers believe in the communicator's ability to convey honest and valid assertions [9]. Thus, it is essential for the DIs to go beyond mere knowledge and also be recognised by audience as reliable and trustworthy. Trust being an important determinant of source credibility significantly affect receiver's evaluation on credibility of message [15]. DIs often share their experience and product or service usage; hence perceived as authentic and trustworthy by their followers [4].

Another determinant of source credibility is similarity [16]. Source similarity means the extent to which the receiver perceives a communicator as similar or likable in terms of shared characteristics such as demographics, culture or beliefs [11]. DIs often interact with their followers on social media platforms and thereby, establish and nurture a social bond with them. They present themselves as accessible and authentic by capturing, documenting, and sharing their personal lives on social media platforms. Thus, DIs are likely to be perceived similar to their followers [1, 11].

The question of whether DIs credibility factors (expertise, trustworthiness and similarity) affect consumers response and if they do, then how they are doing it are discussed in the subsequent section.

2.2 Perceived Advertising Trust

Advertising trust pertains to consumer's cognitive beliefs and assessment of whether the content of an advertisement is primarily aligned with the self-interest or interest of message source [17]. It depends on the degree of confidence and reliance that target consumers place on the DIs advertising content. The existing literature on advertising trust suggest that trust in advertising, in general, enhances consumers' evaluation, processing and response to the message [17]. Advertisements perceived as trustworthy reduces uncertainty and are viewed as more appealing and similar to consumers [18]. Likewise, Racherla et al. [19] shows that perceived source similarity and argument quality increases trust of consumers in online reviews. Further, in the context of mobile banking, Lee & Chung [20] examined the role of quality factors on consumer's trust and satisfaction and found that information quality and system quality significantly affect consumer's trust as well as satisfaction.

Similarly, the concept of advertising trust is gaining popularity in research examining the credibility of DIs in affecting the purchase decision of consumers. Previous literature has shown the effect of source characteristics like expertise and trustworthiness on consumers perception related to brand and purchase intention [12].

Furthermore, source similarity can improve consumers perception about the brand and mitigate purchase risk, thereby fostering trust in advertisement. Prior studies have demonstrated the significant role of similarity in affecting the information consumers acquire, the interactions they encounter and the attitude they develop [21]. In the realm of social media, researchers have examined the influence of source perceived credibility on target consumers and have shown its persuasive power through various scenarios [1, 6]. Also, the research on celebrities and DIs has been a prominent domain in establishing the relationship between source credibility and trust on advertisement [1]. However, scare studies have investigated this relationship in hyper-local brand context. Thus, due to the increase role of DIs in influencing the purchase decision of their followers and shaping their attitude towards the advertisement it become important to examine whether the DIs credibility determinants are significant in affecting advertising trust in the context of hyper-local brand. Hence, we propose that

H1: *DIs credibility determinants, (a) expertise, (b) trustworthiness, and (c) similarity, will positively affect advertising trust of consumers in DIs brand related content.*

2.3 Purchase Intention

Purchase intention means the willingness of individuals to plan consciously and make an attempt to purchase a particular brand [22]. It can lead to actual purchase behaviour as it encompasses the intention or likelihood to purchase a product. Recently, social media platforms have gained considerable interest from marketers who aim to leverage the potential opportunities for influencing consumer's purchase intention. Previous literature has shown the impact of attitude related to advertisement and brand and/or source credibility on purchase intention [1, 11].

Regarding source credibility, studies have shown a significant relationship between source perceived credibility (expertise, trustworthiness and similarity) and intention to purchase. For example, most studies have found a significant positive relationship between perceived trustworthiness and purchase intention [13] as when consumers perceive DIs as trustworthy the willingness to purchase increases. Similarly, source expertise can influence purchase intention, because when DIs demonstrate their knowledge and expertise in a particular area through their social media account or about a product or service in their posts, it may enhance consumers purchase intention. Several studies have shown the significant influence of perceived expertise on intention to purchase [11–13]. Likewise, source similarity can also affect purchase intention [11], if consumers perceive DIs as similar and relatable through their social media posts. Therefore, we propose that,

H2: *DIs credibility determinants, (a) expertise, (b) trustworthiness, and (c) similarity, will positively affect purchase intention of consumers.*

Moreover, prior research has stated that advertising trust can enhance individual's inclination to take action based on the information conveyed in advertisement [17]. Trust in advertisement plays a crucial role in achieving the desired outcomes or expected results. Consumers perceived trust in advertising content of DIs, can reduces risk and enhances willingness to take action [18]. Literature have demonstrated a significant relationship between advertising trust and purchase intention [1]. Hence, we propose that,

H3: *The advertising trust of consumers in DIs generated content will positively affect purchase intention of consumers.*

Figure 1 presented the conceptual model based on the review of literature and hypothesized relationships which are to be examined in the study.

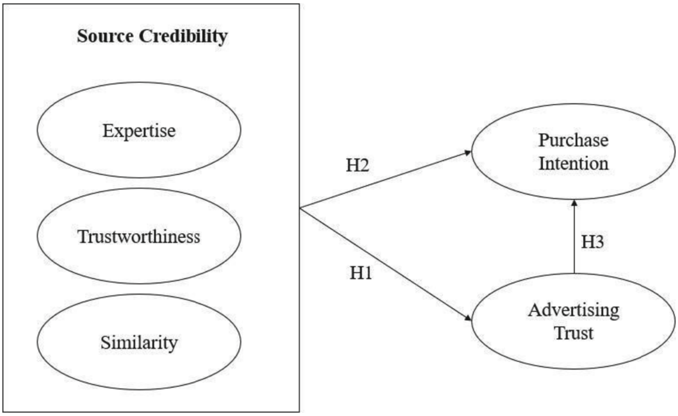

Fig. 1. Conceptual model

3 Method

We used survey method to test the conceptual model. We collected data through convenience sampling via a self-administered online questionnaire from 110 Indian social media users who were following at least one DI. All respondents provided their gender information and there were no instances of non-disclosure or selection of the "other" category. 41.8% and 58.2% of the respondents were male and female respectively. Regarding respondents age, it was noted that the age group between 18 to 24 and 25 to 31 accounted for largest portion of valid sample, comprising 71.8% or 79 responses. Relating to annual income level, the majority of participants reported an annual income of less than 5,00,000 i.e., 57.2%. All the items of the construct were measured on a five-point Likert scale where '5' being strongly agree and '1' being strongly disagree. Source expertise and trustworthiness were captured using scale established by Ohanian [12]. Similarity was measured using Bower & Landreth [16]. Advertising trust was measured via Chaudhuri & Holbrook [18] and purchase intention from Stubb & Colliander [23]. The SPSS 22.0 and AMOS 26.0 were used to conduct statistical analyses.

4 Results

The skewness and kurtosis approach were adopted to check the data normality for each item. The range of skewness values (−0.044 to −0.905) and kurtosis values (0.802 to −1.257) of the data were within the acceptable limits (±2 for both skewness and kurtosis) suggested by Garson [24], implying that the present study data is a normal distribution. Further, data was evaluated using structural equation modelling (SEM) through two-step procedure – measurement model followed by the structural model [25]. The purpose of two-step process was to check the reliability and validity of the constructs before testing the hypothesized relationships.

4.1 Measurement Model Assessment

The Cronbach alpha (α) values for all constructs in the study exceeded 0.7 (as shown in Table 1), indicating acceptable reliability [26]. Further, CFA (confirmatory factor analysis) was employed to measure the construct validity of constructs. The convergent validity was examined via three criteria given by Fornell & Larcker [27]: the loading of each item on their corresponding construct should be more than 0.7, CR (composite reliability) for each construct should exceed 0.7 and AVE (average variance extracted) should be more than 0.5. In this study, the results demonstrated that all factor loadings were more than 0.7 except for two items (S1 and AT1) where it was almost 0.7. Moreover, the constructs CR and AVE values range between 0.820 to 0.883 and 0.607 to 0.654 respectively, which exceeds their threshold values (Table 1). Thus, convergent validity was acceptable using all three criteria.

Thereafter, we determine the constructs' discriminant validity as given by Fornell & Larcker [27]. The AVE square root for each construct should be more than their inter-construct correlation coefficients. Table 2 indicates a good discriminant validity as the AVE square root for all constructs exceeded the correlation shared between the construct with other constructs.

To determine the fitness of the model, various indicators of model fit were assessed. These were the ratio of $\chi 2$ to Degrees of Freedom (d.f.), Incremental Fit Index (IFI), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA) and Standardized Root Mean Squared Residual (SRMR). The measurement model is considered acceptable when these indicators are <3, >0.90, >0.90, >0.90, ≤ 0.06 and ≤ 0.08 respectively [26, 28]. In this study, the indicators values: $\chi 2/\text{d.f.} = 1.723$ ($\chi 2 = 161.990$, d.f. $= 94$), IFI $= 0.935$, CFI $= 0.933$, TLI $= 0.915$, SRMR $= 0.059$, were greater than their minimum acceptable values. However, RMSEA of 0.08 obtained in the present study was greater than the required criteria (≤ 0.06). The possible explanation is that RMSEA is less preferred for use with small sample size ($N \leq 250$) because it has a tendency to reject true-population models more frequently in such cases [28]. The current model was deemed acceptable based on the above-mentioned criteria.

4.2 Structural Model Assessment

Once the measurement model was validated, the hypotheses were examined through structural model in AMOS software via Maximum Likelihood Estimation (MLE). Figure 2 represent the path significances and standardized path coefficients.

Hypotheses 1a, 1b and 1c posit that DIs credibility determinants (expertise, trustworthiness and similarity) positively influence advertising trust of consumers in DIs

Table 1. Construct's reliability and convergent validity

Constructs	Factor Loading
Expertise (α = 0.879, CR = 0.883, AVE = 0.654)	
E1: Expert in hyper-local brand recommendation E2: Experienced in hyper-local brand recommendation E3: Knowledgeable in hyper-local brand recommendation E4: Skilled in hyper-local brand recommendation	0.777 0.845 0.757 0.852
Trustworthiness (α = 0.820, CR = 0.822, AVE = 0.607)	
T1: Honest opinion regarding hyper-local brand T2: Reliable in recommending hyper-local brand T3: Trustworthy in recommending hyper-local brand	0.803 0.724 0.807
Similarity (α = 0.840, CR = 0.841, AVE = 0.641)	
S1: I and influencer are very much alike S2: I and influencer have lot of commonalities S3: I can easily relate to influencer	0.677 0.917 0.790
Advertising Trust (α = 0.822, CR = 0.820, AVE = 0.609)	
AT1: I trust influencer's advertisement content AT2: Advertising content provides lot of information about brand AT3: I rely on the information provided by advertising content	0.679 0.935 0.701
Purchase Intention (α = 0.841, CR = 0.841, AVE = 0.639)	
PI1: I am very much likely to buy hyper-local brands PI2: I will purchase hyper-local brands in future. PI3: I will definitely try hyper-local brands	0.845 0.818 0.731

Notes: α, CR and AVE represent Cronbach alpha, composite reliability and average variance extracted respectively

Table 2. Constructs correlations and discriminant validity

Constructs	Expertise	Trustworthiness	Similarity	Advertising Trust	Purchase Intention
Expertise	**0.809**				
Trustworthiness	0.672**	**0.779**			
Similarity	0.556**	0.467**	**0.801**		
Advertising Trust	0.457**	0.327**	0.606**	**0.780**	
Purchase Intention	0.539**	0.507**	0.206*	0.327**	**0.799**

Notes: Correlations significant at ** $p < 0.01$ level
Diagonal values (bold) are showing the AVE square root for each latent construct.

content. We found positive significant relationship between DIs' similarity and advertising trust of consumers ($\beta = 0.786$, $t = 5.277$, $p < 0.001$). However, Hypotheses 1a and 1b were not supported. Further, hypotheses 2a, 2b and 2c posit that DIs credibility determinants (expertise, trustworthiness, and similarity) positively influence purchase intention of consumers. The results showed that DIs' expertise ($\beta = 0.452$, $t = 2.301$, $p < 0.05$), DIs' trustworthiness ($\beta = 0.399$, $t = 2.163$, $p < 0.05$) and DIs' similarity ($\beta = -0.502$, $t = -2.479$, $p < 0.05$) significantly influence purchase intention. Moreover, Hypothesis 3 stated that advertising trust of consumers in DIs generated content positively affect purchase intention of consumers. The analysis shows the similar result that is we found a positive significant relationship between trust in advertising and purchase intention ($\beta = 0.359$, $t = 2.037$, $p < 0.05$). Therefore, hypothesis 3 is supported.

We also found the squared multiple correlations (R2) values to examine the degree to which the independent variables explain the variation observed in dependent variables. The findings highlighted that DIs credibility components i.e., expertise, trustworthiness and similarity, explain 61.9% of variance in consumers advertising trust and 53.2% of variance in consumers purchase intention. In addition, advertising trust explain 36% of variance in purchase intention.

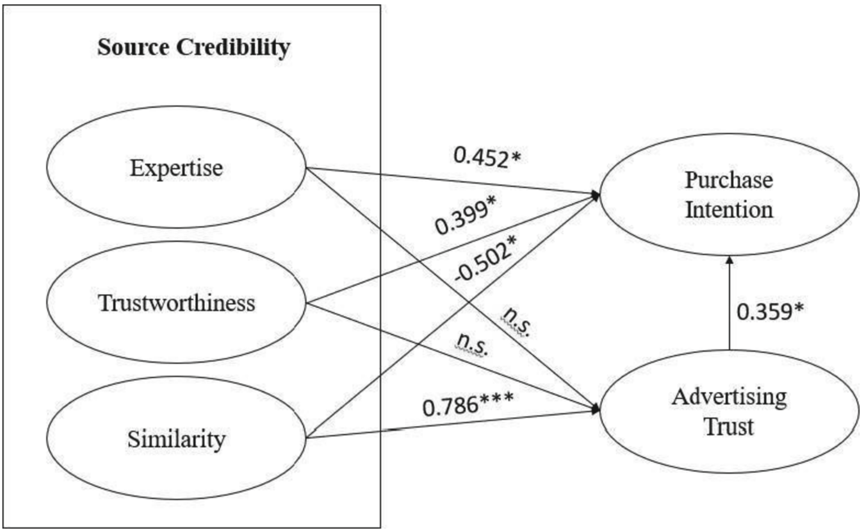

Fig. 2. Hypothesis testing results

5 Discussion

Based on source credibility model, we investigated the mechanism by which DIs influence purchase intention of consumers. By taking the holistic perspective of influencer marketing, we examine the impact of DIs credibility components on consumers perception towards brand (i.e., advertising trust) and intention to purchase.

We also tested the mediating effect of trust in advertising on DIs credibility components and purchase intention. The findings are discussed as follows.

First, we investigated the role of DIs credibility components on consumers advertising trust. Social media users typically choose to follow those DIs to whom they can relate in terms of attitudinal or demographics factors (such as age, gender, occupation, and place). Thus, we found DIs similarity exert positive significant influence on advertising trust of consumers in DIs generated content (H1c supported), it is consistent with the result of previous study [1]. Conversely, DIs expertise didn't influence consumers trust in DIs content related to hyper-local brands (H1a not supported). A possible reason could be in comparison to big brands, in hyper-local market DIs usually promote businesses which they encounter. It may not be related to their niche area; however, they might post stories or reels to make their followers aware about that particular business. Thus, followers don't perceive them as an expert of that particular market and it affects their advertising trust. Additionally, the recent popular discussion and findings on whether the DIs are actual experts or not and consumer awareness in this regard [29], could also be contributing towards these results. Also, result showed that DIs trustworthiness does not affect consumers advertising trust (H1b not supported). This may be because users might hold septical beliefs about DIs motive behind promotion [30] of hyper-local brand and therefore, discredit DIs when making consumption related response like advertising trust.

Secondly, we examine the influence of DIs credibility on purchase intention of consumers. Source expertise and trustworthiness were found positively significant in affecting the purchase intention of consumers (H1a and H1b supported), these results our similar with prior studies [11, 13]. It is reasonable to consider that DIs expertise in certain domains qualifies them to effectively promote specific brands or products and affect purchase intention. Further, DIs through their honesty and credibility affect their audience and thus, perceived trustworthiness was found affecting consumers purchase intention. However, similarity was found negatively significantly affecting purchase intention (H1c supported, negative). This might be because as hyper-local markets can be diverse, with followers having varying preferences and interests. If DIs are too similar to a specific subset of audience within the market, they may not appeal to larger audience base. This lack of appeal to wider audience can have negative impact on purchase intention. For example, if a DI is from specific town in India (e.g., Jaipur) and only shares about hyper-local brands in the city, then the followers who are following the DI from different cities might not find that content similar. However, this unexpected result needs further research.

Furthermore, we also look into the advertising trust of consumers in DIs generated brand related content. Our results support the notion that advertising trust positively affect the willingness of individuals to take action based on the information conveyed in advertisement [17]. In other words, we found advertising trust significantly affect consumers purchase intention. Further, we examined the effect of mediation on advertising trust on DIs similarity and purchase intention and found that advertising trust does not mediates the relationship between DIs similarity and purchase intention. Therefore, the present study contributes in two ways. Firstly, it helps us understanding the consumer perception towards hyper-local brands through DIs generated content.

Secondly, implications of DIs characteristics in enhancing consumer willingness to purchase.

5.1 Implications

This research holds implications on multiple levels. Firstly, it provides insights from the perspective of DIs. Secondly, it sheds light on the implications for hyper-local brands. Lastly, it offers perspectives relevant to social media platforms. For the DIs, it is vital to proactively manage their public image as their characteristics (like expertise, trustworthiness and similarity) will affect the trust and purchase intention of consumers, and hence the effectiveness of the promotion assignments that they take up. The content they provide on social media should showcase their professionalism, sincerity or honesty and relatability to their audience. Achieving a balance between personal content, non-promotional informational content and advertising content is essential. Excessive promotion has the potential to diminish their audience perception about DIs credibility, thereby risking the loss of target audience. Findings also encourage hyper-local brands to engage DIs, who are perceived as experts and trustworthy, to promote their product and services. As it is leading to willingness to purchase, brands could priorities the selection of DIs whose content is widely trusted by their followers. And also, should encourage DIs to make content as relatable as possible as we found a source similarity positively affect consumers advertising trust in brand related content. The results of the present study will help social media platforms to understand the DIs characteristics and manage them. They can invest in aspiring DIs or/and can provide guidance and restraint their behaviour, consequently increasing the level of user engagement and loyalty towards their platforms.

5.2 Limitation and Future Research

The current study has following limitations. First, we only explored the DIs credibility factors in affecting consumers advertising trust and purchase intention. We believe other useful factors may influence the process like brand-influencer fit, entertainment and information quality in DIs content. Second, we have taken hyper-local brands in general, the results may vary for a particular sector like fashion, food etc. Thirdly, the unexpected results of current study (i.e., DIs' similarity negative effects on purchase intention) needs further research. Fourthly, for model testing we have taken Indian users as sample. Previous research, exemplified by Chawla et al. [31], has demonstrated that the source perceived credibility, such as a specific social media platform, influences the perception of information originating from that source. Therefore, conducting the present study by including the specific social media platform would yield a more comprehensive understanding of the platforms on which DIs should engage with hyper-local brands. In future studies, it would also be valuable to examine the impact of cross-cultural determinants affecting the consumption of social media users.

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Modeling the Supply Chain Risk and Barriers to Electric Vehicle Technology Adoption in India

Prasad B. Mane[1], Abhijeet K. Digalwar[1,3](✉), and C. S. Adhithyan[2]

[1] Mechanical Engineering Department, BITS, Pilani, India
akd@pilani.bits-pilani.ac.in
[2] Supply Chain Management, Skema Business School, Lille, France
[3] Symbiosis Centre for Management Studies (SCMS), Symbiosis International (Deemed University) SIU Pune, Nagpur Campus, Nagpur, India

Abstract. The Electric Vehicle (EV) technology is believed to be the most effective to reduce dependency on petrol and diesel vehicles and thereby achieve clean environmental objectives. In pursuit of achieving emission net zero by 2070, central government and state governments are putting substantial efforts to drive the EV technology growth in India. The central and state governments in India through various schemes such as Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME-II), Production Linked Incentive Scheme (PLI), Swapping policy for batteries, Special Electric Mobility Zone, and subsidies such as tax rebate on EVs. Yet the complete switch to the EVs from petrol and diesel vehicles, still has significant technology and supply chain barriers. This research paper identifies the risks and barriers with respect to supply chain, technology, finance, and policy for the growth of EV technology in India. The research paper using an Interpretive Structural Model (ISM) demonstrates the critical supply chain barriers. Based on the analysis carried out in this research paper, the barriers such as availability of battery packs, raw materials, charging network, and interoperability of batteries are the most critical supply chain barriers to implementing EV technology in India. The research findings will enable policymakers to develop a sustainable EV supply chain in India and in similar developing countries.

Keywords: Electric Vehicles · EV industry growth · Risks and Barriers to EV technology · Supply Chain Barriers · Interpretive Structural Model

1 Introduction

In the Paris Climate Conference 2021, India set an objective of a reduction in its emission by 35% by the year 2030. In order to achieve India's commitment, a part of the Intended Nationally Determined Contribution, the country needs to evaluate an alternative to the Internal Combustion Engine (ICE). Therefore, EV technology if used in logistics and transportation can complement India's objective of achieving Greenhouse Gas (GHG) emissions [1].

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In the global context, most policies focused on downstream supply chain activities such as tax incentives and rebates for the customers in European region, has attracted them towards EVs [2]. However, in the Indian context the supply chain of EVs needs attention. There are several barriers such as cost, manufacturing, technology, infrastructure and EV policy, that impacts adoption of EVs in India [3].

The authors reviewed multiple literatures on EV supply chain in India; however most of these literatures are focused on batteries and shortage of lithium-ion for battery manufacturing. There is a research gap observed as very few studies have covered various barriers that would impact sustainability of EV supply chain in India.

The objectives of this research paper are;

1. To identify the barriers to EV technology adoption.
2. To understand various schemes to drive EV technology.

The present study has used an Interpretive Structural Model (ISM) to identify various barriers and interdependency between each barrier to EV technology adoption. Further, by deriving the dependency and driving power of each barrier, the authors have used Matrice d'impacts croisés multiplication appliquée á un classmen (MICMAC) analysis to prioritize the most critical supply chain barriers to EV technology adoption in India.

1.1 Initiatives to Facilitate Implementation of EV Technology

Indian government with an objective of faster implementation of EV technology has launched the following initiatives (Table 1).

Table 1. Initiatives to facilitate implementation of EV technology

S. No.	Initiatives
1	Clean energy ministerial initiative called EV30@30 [4]
2	National Electric Mobility Mission Plan (NEMMP) [5]
3	Faster Adoption & Manufacturing of Hybrid & Electric Vehicles in India (FAME) [5]
4	Custom duty exemption on machines and equipment for lithium-ion cell manufacturing
5	Draft policy on Battery as a Service (BaaS) including battery swap station
6	Standards for safety protocols in battery swapping infrastructure and EV batteries

2 Barriers to Transition to EV Technology in India

Many countries around the world have started implementing EV policies to promote EV technology in transportation [6]. At the same time, there are barriers that do not make the transition to EVs convenient, and these barriers are discussed below.

2.1 Supply Chain Barrier

The inadequate availability of lithium reservoirs in India is the biggest barrier to the domestication of battery manufacturing. Lithium-ion is a non-renewable source of energy and EV batteries are made up of Lithium-ion cells. Currently, China, Taiwan, South Korea, and a few other European countries supply lithium-ion batteries to India. It has significantly increased its imports of the lithium-ion batteries.

2.2 Inadequate Infrastructure for Charging

India does not have enough EV charging stations which invariably deters the acceptance of EVs by customers [7]. The lack of adequate number of charging stations leads to range anxiety amongst the consumers leading to low acceptance of EVs [8].

2.3 Financial Barriers

The battery contributes over 30% of an EV cost, thereby increasing the upfront purchase cost. This makes an EV expensive compared to petrol and diesel vehicles [7]. Adding to this is the higher interest rates prevalent in the retail finance market for an EV. Thus, higher purchase costs and a higher rate of interest for a customer act as significant barriers to considering the purchase of EVs [7].

2.4 Technological Barriers

There are safety considerations too which need to be addressed to eliminate any risk of hazard for the EV user. In case of swappable battery technology, "Interoperability" is a major barrier for data roaming. Data roaming protocol helps in implementing open communication standards and is an important element of the roaming infrastructure. Data roaming is not feasible without interoperability. Lack of standardization of EV battery packs,unavailability of uniform technical standards, and willingness of consumers to pay slightly higher prices to avail of roaming are challenges for interoperability.

Similarly, many researchers have pointed out several barriers/risks to adopting the EV technology. However, for the present study, few select barriers are considered for further analysis. Table 2 below abridged the few select barriers considered from the Indian context for further analysis.

3 Interpretive Structural Model Methodology

Interpretive Structural Modeling (ISM) is arrived at from the judgment and decision of a group of experts. It determines whether and in which way the system's elements are associated [40]. The model is developed based on the relationship of a complex set of variables and their association with each other. In the ISM, the relationship is shown in the hierarchical linked manner [41–44] (Table 3).

Table 2. Citation reference for Barriers/Risks

S. No.	Barriers/Risks	Citations
1	Raw Material Shortage	[9–11]
2	Availability of Powertrain Components	[13, 30]
3	Network/Accessibility	[15]
4	Standardization	[17–19]
5	Pricing Options	[23–25]
6	High Capital Investment	[14, 31]
7	Battery Cost	[9, 32]
8	Credit Availability	[21, 33]
9	Availability of Battery Pack	[12, 34]
10	Battery Interoperability	[8, 20]
11	Data Roaming Standards	[1, 36]
12	Resource Skillset	[28, 35]
13	Safety Standards	[16, 27]
14	Range Anxiety	[21, 28]
15	Charging Infrastructure	[18, 22, 37]
16	Less EV Population	[37, 38]
17	Aftersales Network	[29, 39]
18	Government Subsidies	[26, 37]

Table 3. Steps involved in the ISM methodology

Step No	Description
1	Key barriers were identified
2	Interdependencies between the barriers were determined
3	Self-Structural Interaction Matrix was developed
4	Initial Reachability Matrix was built
5	Driving power and dependency were calculated to get Final Reachability Matrix
6	Level Identification process was conducted
7	MICMAC analysis was done
8	ISM model was derived

3.1 Structural Self-Interaction Matrix (SSIM)

The SSIM as addressed in this section, consists of interdependencies between the barriers. Four academic experts and two statisticians were involved in validating the matrix and there were no disagreements. We have used V, A, X and O to denote the relationships among all the barriers. Table 4 shows the interdependencies as part of the SSIM (Table 5).

Table 4. SSIM

S. No.	Barriers/Risks	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	Raw Material Shortage	A	O	V	O	O	O	O	O	O	V	O	V	V	O	O	O	V	
2	Availability of Powertrain Components	A	V	V	O	O	O	O	O	O	O	O	O	V	O	O	O		
3	Network/Accessibility	O	V	V	V	V	O	O	X	A	V	O	O	O	A	A			
4	Standardization	A	V	V	V	V	X	O	A	V	V	O	V	V	O				
5	Pricing Options	A	O	V	X	O	X	O	A	A	O	O	O	O					
6	High Capital Investment	A	O	X	O	O	A	A	O	A	A	A	A						
7	Battery Cost	A	O	V	O	V	A	O	O	A	A	O							
8	Credit Availability	A	O	V	O	O	O	O	O	O	O								
9	Availability of Battery Pack	A	O	V	O	V	O	O	O	V									
10	Battery Interoperability	A	O	V	V	V	O	A	A										
11	Data Roaming Standards	O	O	V	V	V	O	V											
12	Resource Skillset	O	O	O	O	O	O												
13	Safety Standards	O	O	V	O	O													
14	Range Anxiety	O	O	V	A														
15	Charging Infrastructure	A	V	V															
16	Less EV Population	A	O																
17	Aftersales Network	O																	
18	Government Subsidies																		

3.2 Initial Reachability Matrix (IRM)

In the build-up to ISM, a binary matric is obtained from the SSIM. This binary matrix is addressed as the IRM. This is achieved by replacing the denotation V, A, X and O used in the SSIM by 1 and 0 as required. The following table shows the IRM which is achieved by using 1s and 0s as discussed (Tables 6 and 7).

Table 5. Denotations in SSIM

Denotation	Outcome
V	j achieved by i
A	i achieved by j
X	i achieves j and j achieves i
O	i as well as j are not related

Table 6. IRM

S. No.	Barriers/Risks	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	Raw Material Shortage	0	0	1	0	0	0	0	0	0	1	0	1	1	0	0	0	1	1
2	Availability of Powertrain Components	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
3	Network/Accessibility	0	1	1	1	1	0	0	1	0	1	0	0	0	0	0	1	0	0
4	Standardization	0	1	1	1	1	1	0	0	1	1	0	1	1	0	1	1	0	0
5	Pricing Options	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0
6	High Capital Investment	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
7	Battery Cost	0	0	1	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0
8	Credit Availability	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
9	Availability of Battery Pack	0	0	1	0	1	0	0	0	1	1	0	1	1	0	0	0	0	0
10	Battery Interoperability	0	0	1	1	1	0	0	0	1	0	0	1	1	1	0	1	0	0
11	Data Roaming Standards	0	0	1	1	1	0	1	1	1	0	0	0	0	1	1	1	0	0
12	Resource Skillset	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0
13	Safety Standards	0	0	1	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0
14	Range Anxiety	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
15	Charging Infrastructure	0	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0
16	Less EV Population	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
17	Aftersales Network	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	Government Subsidies	1	0	1	1	0	0	0	0	1	1	1	1	1	1	1	0	1	1

Table 7. Definition of Reachability Matrix Value

If Entry	SSIM	Reachability Matrix Value	
		i, j	j, i
i, j	V	1	0
i, j	A	0	1
i, j	X	1	1
i, j	O	0	0

3.3 Final Reachability Matrix (FRM)

The FRM is an 18x18 [aij] and contents value assigned to each barrier. There are driving power ($^{18}\Sigma_{j=1}\ a_{1j}$) and dependence ($^{18}\Sigma_{i=1}\ a_{i1}$) included in the FRM (Table 8).

Table 8. FRM

S. No.	Barriers/Risks	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	Driving Power
1	Raw Material Shortage	0	0	1	0	0	0	0	0	0	1	0	1	1	0	0	0	1	1	6
2	Availability of Powertrain Components	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	4
3	Network/Accessibility	0	1	1	1	1	0	0	1	0	1	0	0	0	0	0	1	0	0	7
4	Standardization	0	1	1	1	1	1	0	0	1	1	0	1	1	0	1	1	0	0	11
5	Pricing Options	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	5
6	High Capital Investment	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
7	Battery Cost	0	0	1	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	4
8	Credit Availability	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	3
9	Availability of Battery Pack	0	0	1	0	1	0	0	0	1	1	0	1	1	0	0	0	0	0	6
10	Battery Interoperability	0	0	1	1	1	0	0	0	1	0	0	1	1	1	0	1	0	0	8
11	Data Roaming Standards	0	0	1	1	1	0	1	1	1	0	0	0	0	1	1	1	0	0	9
12	Resource Skillset	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	3
13	Safety Standards	0	0	1	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	6
14	Range Anxiety	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
15	Charging Infrastructure	0	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	5

(*continued*)

Table 8. (*continued*)

S. No.	Barriers/Risks	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	Driving Power
16	Less EV Population	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
17	Aftersales Network	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
18	Government Subsidies	1	0	1	1	0	0	0	0	1	1	1	1	1	1	1	0	1	1	11
	Dependency	1	5	15	6	8	3	2	2	5	4	1	6	11	5	3	5	2	1	

3.4 Level Identification (LI)

The LI process consists of; a) Find reachability and antecedent sets. These two sets consist of elements, which may help in achieving the reachability and antecedent sets, respectively. b) Find the top-level element separated from the rest of the elements. c) To establish the level of each barrier, multiple iterations are followed. Once the levels are identified, the development of the ISM is done (Table 9).

Table 9. LI (Iterations 1–5)

Iteration	Barrier	Reachability Set	Antecedent Set	Level
5	1	1, 2, 6, 7, 9, 16	1, 18	V
2	2	2,6,16,17	1,2,18	II
5	3	3,9,11,14,15,16,17	3,4,5,10,11	V
5	4	3,4,6,7,9,10,13,14,15,16,17	4,11,13,18	V
5	5	3,5,13,15,16	5,10,11,13,15,18	V
1	6	6,16	1,2,4,6,7,8,9,10,12,13,16,18	I
3	7	6,7,14,16	1,4,7,9,10,13,18	III
2	8	6,8,16	8,18	II
5	9	6,7,9,10,14,16	1,3,4,9,18	V
5	10	3,5,6,7,10,14,15,16	4,9,10, 11, 12, 18	V
5	11	3,4,5,10,11,12,14,15,16	3,11	V
5	12	6,10,12	11,12	V
4	13	4,5,6,7,13,16	4,5, 13	IV
2	14	14,16	3,4,7,9,10,11,14,15	II
3	15	5,14,15,16,17	3,4,5,10,11,15,18	III
1	16	6,16	1,2,3,4,5,6,7,8,9,10,11,13,14,15,16,18	I
1	17	17	2,3,4,15,17	I
5	18	1,2,4,5,6,7,8,9,10,15,16,18	18	V

3.5 MICMAC Analysis

The barrier's driving power, and dependency is determined by leveraging the MICMAC analysis [45]. The MICMAC analysis is represented by the driver-dependency diagram and is plotted on the x and y axis as shown in Fig. 1 (Table 10).

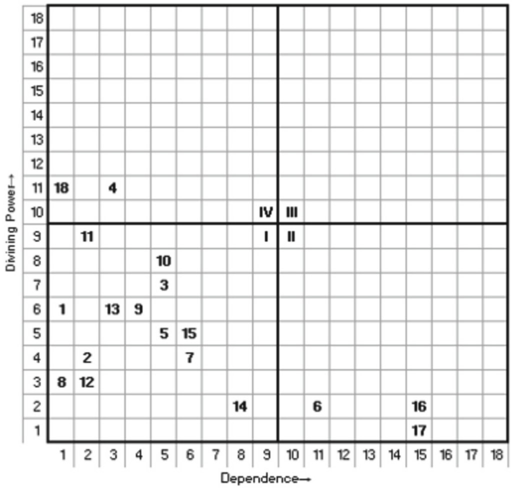

Fig. 1. Driver – Dependence Diagram

Table 10. Description of Quadrants

Quadrant	Description
I	Autonomous barriers with weak driving power and dependency
II	Dependent barriers with strong dependency and weak driving power
III	Linkage barriers with strong driving power and strong dependence
IV	Independent barriers with weak dependency and strong driving power

3.6 Interpretive Structural Model (ISM)

The ISM model is derived from the FRM, as illustrated in Fig. 2 below.

The level I barriers - High Capital Investment, Less EV population and Aftersales Network can be achieved with the help of barriers from the levels II, III, IV and V.

The barriers in level II are Range Anxiety, Availability of Powertrain Components and Credit Availability. The range anxiety is one of the key reasons for less customer preference towards EV. Credit availability can also motivate the customers to purchase an EV. Availability of powertrain components aids in achieving a good aftersales network

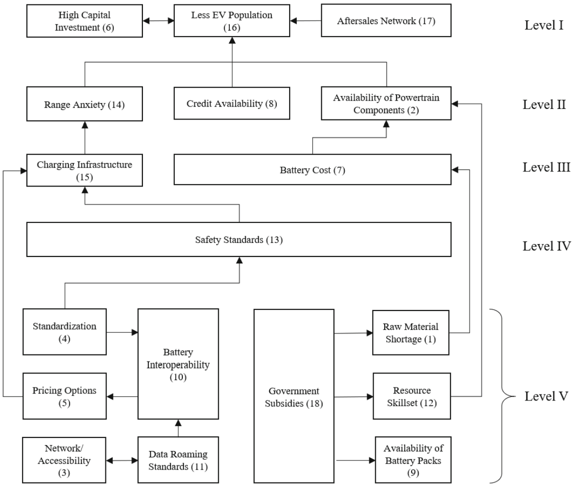

Fig. 2. ISM Model

and also in reducing the high initial cost. Further, the achievement of barriers in the level II, can be aided by barriers from the level III.

The barriers Charging Infrastructure and Battery cost are in level III. A well-established charging infrastructure can aid the range anxiety barrier in level II. Also, the achievement of battery cost barrier, will facilitate the availability of powertrain components barrier in level II.

Further, the establishment of safety standards barrier in level IV, can aid the establishment of charging infrastructure and also influence the battery costs, thereby achieving the barriers in level III.

The level IV barrier can be achieved by the following level V barriers, which includes Network/Accessibility, Data Roaming Standards, Raw Material Shortage, Government Subsidies, Availability of Battery Packs, Standardization, Battery Interoperability, Resource Skillset, and Pricing Option. Government initiatives can aid in achieving the barrier of raw material shortage, resource skillsets and influence the battery pack availability. The Network/Accessibility and Data Roaming Standards help each other for the achievement of the battery interoperability. Standardization also helps in achieving battery interoperability. Such an established battery interoperability can positively influence the pricing option. These nine barriers in level V, together help in the achievement of level IV barriers.

4 Conclusion

Based on the ISM model, developed to analyze supply chain barriers to EV technology adoption in India, it is observed that government subsidies, resource skillset, data roaming standards, battery interoperability, availability of battery packs, network/accessibility, standardization, pricing options and raw material shortage for battery manufacturing should be resolved on priority to enable faster adoption of EV technology in India. The barriers such as safety standards and adequacy of charging infrastructure are equally significant as they are going to impede the transition to EV technology. It can be concluded that, with the government support in terms of incentives for domestic EV manufacturing and localized supply chain, mainly for battery cells/packs, would aid faster acceptance of EVs by consumers. The findings of this research paper will provide guidance to policy makers, EV manufacturers, charging infrastructure service providers, EV components manufacturers, and other stakeholders in Indian EV ecosystem.

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Technological Readiness in the Hospitality and Tourism Literature – A Meta-analysis Review

Nusaiba Begum[1](✉), Nripendra P. Rana[1], and Kumod Kumar[2]

[1] Qatar University, Doha, Qatar
nb1605917@qu.edu.qa
[2] Chandragupt Institute of Management Patna, Bihar, India

Abstract. The hospitality and tourism (H&T) sectors are experiencing a dynamic shift towards adopting innovative technologies under the pretext of Industry 5.0. To gauge users' readiness for these technologies, Technological Readiness (TR) is employed, comprising of four dimensions: innovativeness (INN), optimism (OPT), insecurity (INS), and discomfort (DIS). However, the literature highlights various inconsistencies in incorporating TR while examining user perceptions of technologies in the H&T domain. Thus, to help circumvent the fragmented findings, a meta-analysis is carried out examining TR and its outcome variables by analyzing 56 correlation pairs from 20 studies using CMA V3 software. The findings indicate that TR, conceptualized across its four dimensions, is a significant factor in the technology acceptance model (TAM). Further, the integration of TR with TAM (TRAM) is best complimented by the inclusion of satisfaction in assessing users' intentions towards H&T technologies. Notably, the motivating dimensions of TR (INN & OPT) exhibit stronger effect sizes, while the contrary is true for the inhibiting dimensions (INS & DIS).

Keywords: Technology Readiness · Hospitality · Tourism · Meta-Analysis · TAM · TRAM

1 Introduction

The rapid influx of technological developments post Covid-19 has transformed the service sector with substantial implications for the various industries therein. One such industry is Hospitality and Tourism (H&T), currently revolutionizing its service landscape with Industry 5.0. Unlike its predecessor, Industry 4.0 which emphasized the mere integration of devices [1], this revolution is set to focus on human-technology collaborations [2]. Nevertheless, given the service-oriented nature of H&T, it is of great concern to practitioners and academics alike to assess consumer reactions [3]. Consequently, scholars have sought after tools to assess user readiness towards the adoption of new technologies by segmenting users across groups sharing similar characteristics [4]. The extant literature has further indicated the significance of consumer traits to provide insights on the likelihood of technological acceptance and subsequent use [5].

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Technological Readiness Index (TRI) or simply Technological Readiness (TR) is one such trait variable that has garnered attention of H&T scholars in its ability to assess consumers' propensity and inclination towards use of new technologies [6]. In other words, TR can be defined as consumers' predisposition towards technological acceptance. The conceptualization of TR is explained with the obverse interaction of motivators and inhibitors [5, 7]. Thus, motivators contribute towards increasing TR amongst consumers whilst inhibitors lower the TR levels. In line with Parasuraman [6] and Parasuraman & Colby [8], the motivators of TR constitute two trait features, namely, optimism (OPT) and innovativeness (INN), while the inhibitors constitute discomfort (DIS) and insecurity (INS) highlighting user' reluctance in the adoption and use of new technologies. Definitions of these key terms have been highlighted in Table 1.

Despite the significance of TR in assessing perceptions regarding technological advancements, its comprehension in H&T literature remains limited [9, 10]. For instance, the extant literature reveals inconsistencies in the conceptualization and subsequent use of TR where while some scholars have considered TR as a unidimensional construct [11, 12], others consider it to be multidimensional [13, 14]. In terms of theoretical underpinnings, the literature reveals a general lack of consensus and a haphazard employment of theories to assess the TR. Nevertheless, most studies have examined TR through the lens of technology acceptance model (TAM), as proposed by Davis [15]. The scant literature, however, exhibits lack of coherence and disparity in determining how TR impacts users' intentions (INT) with often contradictory results. Therefore, to help circumvent the fragmented findings, this study consolidated the findings of prior literature through a quantitative review of the literature using a meta-analytical approach. Accordingly, this study aimed to assess the dimensionality of TR and its relationship with the intention to use technology-based services in the H&T literature. Therefore, the following research questions were addressed: 1) How has TR been conceptualized in H&T literature? 2) What are the most frequently examined outcome variables of TR in assessing H&T users' technology-based perceptions? and 3) What theoretical underpinnings best highlight the interaction of TR and its outcome variables in the context of H&T technologies? The purpose of this meta-analysis further stems from its ability to consolidate findings from diverse sources to provide a nuanced understanding of TR and its consequences specific to the H&T domain [5, 16].

2 Literature Review

2.1 Conceptualization of TR

In terms of the conceptualization and measurement of TR, the H&T literature reveals various inconsistencies. For instance, while some scholars have considered TR as a unidimensional construct [11, 12], others consider it to be multidimensional [13, 14]. Even in terms of the multidimensional use of TR, two streams of literature emerge whereby whilst some studies consider TR to be consisting of two dimensions, inhibitors and motivators [10, 11, 17], others have conceptualized it across its four dimensions [18–20]. The four dimensions form the basis of the Technological Readiness Index (TRI) 2.0 as proposed by Parasuraman & Colby [8] and thus include OPT, INN, DIS, and INS. For the purposes of this study, TRI 2.0 is examined as the focal construct to assess users' readiness towards technologies examined in the H&T literature.

2.2 Theoretical Underpinnings

Studies examining TR reveal a haphazard application of theoretical underpinnings to examine its impact in H&T literature. Accordingly, various theories emerge from the literature such as the innovation diffusion theory (IDT) [10], equity theory [19], perceived value theory [21] and self-efficacy theory [22] to list a few. Nevertheless, it becomes apparent that scholars have often resorted to the Technology Acceptance Model (TAM), as proposed by Davis [15], to best compliment TR. This is in alignment with Lin et al. [23] whereby the need to combine TR with TAM had been substantiated [24]. The model thus proposed by Lin et al. [23] has been termed as the technological readiness and acceptance model (TRAM). Although scholars have extensively combined TR and TAM model, only a few scholars have explicitly employed TRAM as the theoretical underpinning [25, 26]. The lack of theoretical consensus in the H&T literature reveals the need to reevaluate how TR can be best used to assess users' intentions towards technologies.

2.3 TR and Interaction Variables

The impact of the four dimensions of TR onto various outcomes can be categorized across its interaction with TAM, INT, and satisfaction (SAT) as the most frequently examined variables. In terms of TAM, studies report conflicting results with little consensus with regards to its key constructs namely, perceived usefulness (PU), perceived ease of use (PEOU), and INT (refer Table 1). For instance, while some studies suggest that all four dimensions of TR direct influence PU and PEOU [12, 27], others report that only the motivating dimensions of TR (OPT & INN) impact PU and PEOU [17, 25]. On the contrary, Yang et al. [26] posit that TR has no impact on either PU or PEOU. Likewise, in examining the impact of TR on INT, while most studies indicate a significant impact of the four dimensions of TR onto intention [9, 11], others postulate that only few dimensions directly impact intentions [19, 28]. On the other hand, some scholars argue that TR has no direct impact on intentions but rather through the mediation of PU and PEOU [13, 27].

With regards to SAT, studies have examined the direct impact of TR on satisfaction [10, 18, 19, 29] as well as the indirect impact through TAM mediators, PU and PEOU [20]. However, the debate on which dimensions remain significant remains inconclusive. For instance, while El Barachi et al. [10] postulate that all four dimensions of TR impact satisfaction, Pham et al. [18, 19] suggest that inhibiting dimensions of TR (DIS and INS) have a non-significant impact on SAT. Given the aforementioned inconsistencies across the three aspects of the literature, a meta-analytical approach is taken which has been detailed in the following section.

Table 1. Key terms and definitions.

Key Terms	Abbr.	Definitions*	Source
Technological Readiness Technological Readiness Index	TR TRI	Measure to assess consumers' propensity and inclination towards use of new technologies. Consumers' predisposition towards technological acceptance.	(Parasuraman, 2000; Parasuraman & Colby, 2015)
Optimism	OPT	Individuals' positive beliefs and expectations pertaining to the potential or actual use of technologies. Characterized by a positive mindset and favorable attitudes towards technology.	(Parasuraman, 2000; Parasuraman & Colby, 2015)
Innovativeness	INN	Individual propensity to embrace technological advancements.	(Parasuraman, 2000; Parasuraman & Colby, 2015)
Discomfort	DIS	Feelings of anxiety, frustration, and unfamiliarity in using technology.	(Parasuraman, 2000; Parasuraman & Colby, 2015)
Insecurity	INS	Feelings of mistrust and uncertainty in using technology.	(Parasuraman, 2000; Parasuraman & Colby, 2015)
Perceived Ease of Use	PEOU	Degree of belief that using a particular technology would require minimal effort.	(Davis, 1989)
Perceived Usefulness	PU	Degree of belief that using a particular technology would be useful in carrying out an activity or task.	(Davis, 1989)
Satisfaction	SAT	Positive perception when using technology-based services.	(Pham et al., 2020)
Behavioral Intention	INT	Intention to use a technology.	(Lin & Hsieh, 2007)

*Note: Definitions have been partially adapted from the above-mentioned sources to fit the context of the study.

3 Methodology

To the best of our knowledge, only one meta-analytical study [5] has attempted to assess and consolidate the findings of the TR literature. Despite its contribution, the meta-analysis has certain limitations whereby the role of TR specific to the service industry, H&T, remains unknown. Secondly, the paper fails to distinguish between the various technological contexts in which TR is being examined. Thirdly, the meta-analysis provides a broader range of TR studies whereby the specific developments and the use of the TRI 2.0 [8] are overlooked. Accordingly, the current study intends to advance literature by providing a service oriented (H&T) examination of TR in light of the rapid technological advancements in the field [2].

3.1 Selection of Studies

To identify articles that empirically examined TR in the H&T literature, the following inclusion criteria were utilized. Firstly, a literature search was carried out across several electronic databases such as Scopus, Science Direct, ProQuest, and EBSCO. This was complimented with triangulation of sources through google scholar and subsequent search of citations. Key words such as technological readiness, technological readiness index (TRI), along with the contextual keyword, hospitality and tourism were examined in the article title, abstract, and keyword sections. Articles were further only included in the meta-analysis only if they were 1) empirical in nature, 2) utilized the technological readiness as key variable in the study [8], 3) had the contextual focus of the hospitality and tourism industry, 4) reported Pearson correlations and sample size, and 5) were published in the English language. The first phase of the literature search resulted in the shortlisting of 89 articles. Nevertheless, evaluation of the articles based on the inclusion criteria resulted in the subsequent removal of 69 articles. Accordingly, the final sample for the meta-analyses included 20 studies.

3.2 Data Coding and Meta Analysis Process

According to Glass [30] meta-analysis is adopted as an alternative to descriptive-qualitative literature evaluation. By combining the statistical results of prior studies, meta-analysis helps integrate the quantitative research findings across the existing literature [31]. To conduct the meta-analysis, the correlation coefficient 'r' is utilized as the primary effect size owing to its dominant use within the H&T literature [5, 16]. Further, the study employed the comprehensive meta-analysis (CMA V3) software to statistically combine the correlation values of variables across different studies [32]. Additionally, rejecting homogeneity assumptions across the studies under consideration [33], the random effect model is considered for the meta-analysis. This is further consistent with prior literature in the field [5, 32, 34]. The 20 studies included for the meta-analyses presented over 73 unique variables. Nevertheless, based on Kirca et al. [35], to conduct a meta-analysis at least three studies should have examined a particular construct, thus, only 10 constructs were shortlisted for further analysis. The next step towards the meta-analysis pertained to the examination of the relationships between the variables that further led to the shortlisting of 8 variables, namely, the four dimensions of TR (OPT, INN, DIS, and DIS), INT, PU, PEOU and lastly, SAT. Consequently, 56 correlation pairs were examined for the meta-analysis. For each correlation pair the sample size, effect size (i.e., Pearson's correlation), and reliability of both constructs from the original studies were coded.

4 Results

The evaluation of the meta-analytical findings is conducted using the Fisher' z statistic for the random effect model. Table 2 provides a summary of the findings highlighting the significance of the effect sizes of the constructs under consideration. Accordingly, the results posit that all effect sizes were statistically significant ($p < 0.05$). Interestingly, it was observed that motivating dimensions (optimism and innovativeness) of TR displayed stronger effect sizes ($r \geq 0.50$) while the contrary is true for inhibiting dimensions. In terms of the heterogeneity tests, the Cochran's Q statistic was significant at 0.05 and thus it was concluded that all studies do not share the same true effect size. In other words, the Q-statistics denoted that correlations were heterogeneous. In addition, the I2 statistics were over 75% (85–98%), with the exception of DIS-SAT and INS-SAT, indicating substantial heterogeneity in effect sizes across studies [36].

Table 2. Meta analysis of correlation pairs and results of heterogeneity test.

Relationship		K	N	r	Main Effect Size Estimates				Heterogeneity Tests		
					95%CI		Z	P	Q	τ square	I square
					LL	UL					
OPT	INT	8	3739	0.557	0.369	0.701	5.113	0	379.922	0.118	98.158
INN	INT	8	3739	0.446	0.281	0.586	4.906	0	240.282	0.074	97.087
DIS	INT	6	3151	-0.188	-0.306	-0.065	-2.974	0.003	61.461	0.022	91.865
INS	INT	6	3151	-0.157	-0.282	-0.026	-2.346	0.019	67.762	0.025	92.621
OPT	INN	15	6855	0.488	0.403	0.564	9.897	0	251.5	0.041	94.433
OPT	DIS	13	5846	-0.232	-0.308	-0.153	-5.645	0	117.838	0.02	89.817
OPT	INS	12	5496	-0.21	-0.275	-0.143	-6.069	0	70.861	0.012	84.477
INN	DIS	13	5846	-0.237	-0.323	-0.147	-5.06	0	153.656	0.027	92.19
INN	INS	12	5496	-0.18	-0.277	-0.079	-3.471	0.001	159.523	0.03	93.104
DIS	INS	12	5496	0.341	0.242	0.433	6.416	0	178.146	0.034	93.825
OPT	PU	6	3250	0.647	0.473	0.772	5.891	0	263.104	0.1	98.1
INN	PU	6	3250	0.544	0.476	0.605	12.997	0	33.309	0.011	84.989
DIS	PU	4	2524	-0.24	-0.375	-0.096	-3.232	0.001	40.435	0.021	92.581
INS	PU	4	2524	-0.264	-0.396	-0.121	-3.559	0	40.543	0.021	92.601
OPT	PEOU	6	3250	0.584	0.467	0.681	8.095	0	104.685	0.039	95.224
INN	PEOU	6	3250	0.554	0.454	0.641	9.072	0	72.504	0.026	93.104
DIS	PEOU	4	2524	-0.221	-0.39	-0.038	-2.358	0.018	63.968	0.034	95.31
INS	PEOU	4	2524	-0.255	-0.435	-0.056	-2.496	0.013	77.279	0.042	96.118
PU	PEOU	8	4222	0.636	0.504	0.739	7.484	0	285.699	0.078	97.55
PU	INT	4	2385	0.594	0.37	0.752	4.535	0	152.41	0.089	98.032
PEOU	INT	4	2385	0.519	0.302	0.685	4.283	0	121.128	0.07	97.523
OPT	SAT	6	2869	0.429	0.235	0.59	4.106	0	170.75	0.072	97.072
INN	SAT	6	2869	0.367	0.185	0.525	3.811	0	139.773	0.059	96.423
DIS	SAT	6	2869	-0.124	-0.187	-0.06	-3.776	0	14.542	0.004	65.617
INS	SAT	5	2519	-0.104	-0.148	-0.06	-4.604	0	4.949	0	19.174
PU	SAT	3	1289	0.465	0.173	0.681	3.006	0.003	54.681	0.08	96.342
PEOU	SAT	3	1289	0.429	0.057	0.697	2.241	0.025	82.159	0.122	97.566
SAT	INT	5	2167	0.648	0.446	0.788	5.172	0	187.958	0.109	97.872

5 Discussion

The present study enhances the understanding of how TR dimensions perform in association with the constructs emerging in the literature. Specifically, the primary aim of this study pertained to enhancing the understanding of TR, its dimensionality, and subsequent interaction with its outcome variables specific to the H&T literature. Accordingly, addressing the first research questions, this meta-analysis reveals that TR is best conceptualized across its four dimensions, namely, OPT, INN, INS, and DIS. Moreover, when evaluating users' perceptions of technology in the H&T domain, in relation to the four TR dimensions, the meta-analysis identifies that customer intentions, PEOU, PU, and customer satisfaction are the variables most frequently examined. Thus, addressing the second research question of this study. Specific to H&T, the findings remain applicable to an array of technologies such as robotics [37], self-service technologies [18, 38], smart devices [21], and virtual reality [39] across hotels, airports, and restaurants alike [13, 14, 28].

Furthermore, addressing the various inconsistencies in the literature pertaining to the impact of TR onto user's intentions, the meta-analytical review highlights the extensive use of constructs from the TAM model or alternatively TRAM. This is evident with the significant correlations between TR and TAM variables in the meta-analysis. In addition, extant literature has also incorporated satisfaction as a key variable in assessing users' perceptions. Consequently, satisfaction has been deemed an essential element in assessing customers reactions in technology use and H&T literature [10, 29].

The interaction of TR with TAM variables indicates weaker correlation of the inhibiting dimensions with PU and PEOU in contrast to the motivating dimensions which provides support for the literature suggesting that only the motivating dimensions of TR (OPT & INN) impact PU and PEOU [17, 25]. Further, TAM strongly postulates that users' intentions towards technology adoption are determined by the PEOU and PU of the said technology. Accordingly, the correlation between the TAM constructs (PU, PEOU, & INT) remains significant and displays a stronger and positive effect size ($r \geq 0.50$). Here, PU and PEOU displayed the highest correlation of $r = 0.636$, which is in contrast to the minimum correlation reported in the prior studies of $r = 0.026$ [27].

The stronger correlation between the two constructs is consistent with the H&T literature whereby PEOU influences PU [12, 17, 28]. Moreover, the incorporation of satisfaction reveals positive and comparatively stronger correlations with the exception of the inhibiting dimensions. Accordingly, the results of the meta-analysis are consistent with prior studies that have indicated a significant impact of the various dimensions of TR on customer satisfaction with various technology-based services [40]. In terms of the motivators of technology use in the TR model, OPT and INN have been found to positively affect technological satisfaction amongst customers specifically in the context of H&T [18, 19]. On the contrary, both inhibiting dimensions, DIS – SAT ($r = -0.124$) and INS – SAT ($r = -0.104$), display a negative and weaker correlation.

Lastly, the interaction of SAT with TAM constructs reveals positive correlations i.e., $r = 0.465$ and $r = 0.429$ for PU and PEOU respectively. Additionally, SAT – INT display a stronger effect size ($r \geq 0.50$), which is in line with the H&T literature whereby scholars have found satisfaction to be a significant predictor of behavioral intentions towards technological services offered [19, 20, 41–44].

6 Implications

This study provides several theoretical implications for the use of TR in the assessment of H&T technologies. Firstly, the fragmented findings in the literature pertaining to the conceptualization and subsequent interaction of TR and various outcome variables have been addressed through the meta-analysis. By examining the aforementioned aspects, a coherent picture of the variables examined are provided in the form of the significance and strength of their associations. Secondly, unlike prior meta-analytical efforts [5], combined effect sizes for each dimension of the TRI are provided, thus, shedding nuanced insights into how each dimension corresponds to the outcome variables. Thirdly, the meta-analysis provides support for the theoretical foundation of the integrated TRAM model with the potential inclusion of satisfaction, hence enhancing the conceptual understanding of the introduction of new technologies in the H&T domain. Overall, this study contributes to the synthesis of TR and various theory driven variables to form the understanding of technological integration in H&T literature.

In terms of the practical implications, this study posits that assessing users' TR could prove useful in assessing their intentions towards the use of new technologies in the H&T sector. Consistent with Victorino et al. [45], it would enable practitioners to classify various consumer segments based on TR levels that would further reflect on the strategic marketing activities. H&T companies can assess customer profiles based on their TR and tailor their marketing activities accordingly. For example, for customers with higher levels of discomfort and insecurity, brands could market new technologies in ways that respond to their concerns. Further, given the importance of PU and PEOU, when customers rank low in terms of their TR, H&T companies can market and promote new technologies in light of their usefulness and ease of use to help overcome negative feelings associated with technologies. Alternatively, when targeting higher TR segments brands can leverage digital channels and tech-savvy means of communication and engagement that could lead to greater customer satisfaction with the H&T services as well as the technologies introduced. Overall, given TR is a tool to assess user perceptions of technologies, companies can leverage this information for the seamless introduction of technologies that are catered to various TR levels.

7 Limitations and Future Research

Although this study helps consolidate prior research findings, there are certain limitations that need to be highlighted. First, the sample considered for the study is small as a vast majority of studies did not meet the eligibility criteria and conditions imposed by the meta-analysis further limited the variables examined across various studies. This is associated with the limited control over the availability of studies and information collected in conducting a meta-analysis [46]. Second, the study only took into consideration quantitative studies while excluding qualitative studies. Thus, future studies could incorporate quantitative and qualitative studies to address the aforementioned limitation. Third, the meta-analysis did not include book chapters, theses, and conference papers which could be included in the future for a more comprehensive overview of the studies. Fourth, moderating variables were not explored in the study due to insufficient number of studies which provides an opportunity for future research. Fifth, given the sole use of coefficient correlation r, causal relationships between variables were not explored. Accordingly, future meta-analysis studies should consider other forms of statistical measures of effect sizes such as a beta coefficient. Additionally, as the literature in the field grows, more studies can be incorporated and detailed insights can be explored with regards to specific H&T technologies and subsequent levels of user readiness towards them.

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Fusing Innovation and Nature: Empowering Forest Fire Detection and Prediction Through IoT Enabled Edge Computing and Deep Learning

Keshav Dhir[1], Prabhsimran Singh[1(✉)], Ronnie Das[3], and Ravinder Singh Sawhney[2]

[1] Department of Computer Engineering and Technology, Guru Nanak Dev University, Amritsar, India
{keshavcet.rsh,prabhsimran.dcet}@gndu.ac.in

[2] Department of Electronics Technology, Guru Nanak Dev University, Amritsar, India
sawhney.ece@gndu.ac.in

[3] Department of Marketing, Audencia Business School, 8 Rte de La Jonelière, 44300 Nantes, France
rdas@audencia.com

Abstract. In the intricate interplay of nature and technology, an imperative arises to synergize innovation with ecological stewardship. This research seeks to harmonize technology and environmental conservation, focusing on improving forest fire detection and prediction by answering three major research questions. The research combines Deep Learning, Edge Computing, and the Internet of Things (IoT) to enhance its applicability in various landscapes. The approach blends Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) to process data from strategically placed sensors, including satellite images, UAVs, drones, weather data, terrain information, historical fire records, and real-time sensor readings. Unlike traditional methods, this study emphasizes edge computing for rapid on-site data analysis to minimize latency. It calls for proactive strategies, empowered by technology, to mitigate devastating fires and protect the environment. The outcomes showcase the potential of this integration, offering a promising solution to combat forest fires and maintain the delicate balance of nature and its ecosystems.

Keywords: Deep Learning · Edge Computing · Forest Fire Detection · IoT · Predictive Analysis

1 Introduction

In an increasingly intricate interplay between nature's intricate symphony and the relentless march of innovation, the realm of forest fire management emerges as a critical nexus. As the world grapples with the escalating challenges of ecological balance and technological prowess, a clarion call reverberates for transformative approaches that fuse these

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realms harmoniously. Understanding and predicting forest fires is a critical endeavor due to their devastating impact on ecosystems, communities, and economies. Traditional methods of fire detection [1] and management often fall short in addressing the complexities of fire behavior. This paper delves into a pioneering synergy, conjoining the prowess of deep learning, the agility of edge computing, and the ubiquity of the Internet of Things (IoT) to forge a novel path in the landscape of forest fire detection and prediction.

In recent years, deep learning has demonstrated remarkable capabilities in image recognition and pattern detection [2, 3]. Extending its potential to predicting forest fires, we capitalize on its ability to discern intricate relationships within data. By integrating diverse data sources, including temperature, humidity, wind speed, topography, and vegetation density, our model gains a comprehensive understanding of the variables influencing fire occurrence. IoT sensors capture vital environmental cues and transmit them to edge computing devices situated within forests.

The escalating threat of forest fires necessitates proactive strategies that transcend traditional methodologies. Recent generative AI advancements [4] have demonstrated the potential of deep learning techniques to unravel complex patterns within multi-modal data streams, including satellite imagery, meteorological data, and historical fire records. However, as the stakes rise, so does the urgency for real-time decision-making. This is where the confluence of edge/cloud computing and IoT becomes paramount [5, 6]. Leveraging strategically placed sensors in forested regions, edge computing expedites onsite data processing. Simultaneously, the integration of IoT facilitates the real-time collection of crucial environmental variables, affording predictive models a more nuanced understanding of dynamic conditions.

The synthesis of these frontiers deep learning, edge computing, and IoT promises a holistic framework that transcends the boundaries of traditional [7, 8] fire management strategies. The significance of this research extends beyond improved prediction accuracy. By harnessing cutting-edge technology and advance the fire management practices, enabling timely responses that mitigate damage and save lives. As climate change intensifies fire risks, this model's real-time capabilities become crucial for adaptive and resilient strategies. This research work reviews the literature concerning utilization of forest fire detection and prediction resulting to its real time management. In doing so, we try to investigate and defend the following research questions (RQs):

RQ1: How can the integration of deep learning, edge computing, and IoT devices be optimized to enhance forest fire detection and prediction?

RQ2: What are the performance and efficiency gains achieved by incorporating edge computing for on-site data processing in the context of forest fire detection?

RQ3: How can the use of satellite imagery, Unmanned Aerial Vehicles (UAVs) and drones equipped with advanced sensors contribute to early-stage forest fire identification and mitigation efforts?

The rest of the paper is organized as following: The theories and ideas given by well-known experts in the same field are covered in Sect. 2. Section 3 describes the proposed model for Forest Fire predictions. The results and findings of this study are demonstrated in Sect. 4 and 5. At last, the conclusions are presented in Sect. 6.

2 Literature Review

Many other researchers who already have done their part in exploring this domain needs to be addressed, before this research can move further. With the phenomenal growth in the field of Deep Learning, much related studies have been performed in respect to implementation and performance analysis on forest fire upkeep.

Several fire detection models have been developed using sensory data to confirm fire incidents in specific regions [1]. Additionally, raw data collected from a range of IoT sensors holds substantial potential for diverse applications and future integration into industries [5, 13]. Deep learning and machine learning models have significantly contributed to object identification, as demonstrated by Guede-Fernández [9], Li [11], and Wang [19] in their respective studies. These researchers employ these methodologies for forest fire detection, highlighting their effectiveness in this context. Moreover, Kang [10] has introduced an efficient forest fire detection model based on geostationary satellite data, emphasizing rapid real-time analysis for swift response. Similarly, Ghosh [8] and Xu [20] have conducted studies employing hybrid deep learning models that integrate multiple diverse neural networks. These models are designed to enhance the early detection of forest fires before they escalate.

In similar regard, the real-time forest fire model, named Fire-Net [14], having the active data analyzing capabilities has been a huge upgrade in this field of research. Also, various alert and assessment based active systems has been established and mentioned in different case studies [12, 15] in order to notify the nearby rescue and firefighter teams whenever there is an early detection of fire in the nearby forests. Recent studies [16, 17] propose innovative approaches involving the use of Drones or Unmanned Aerial Vehicles (UAVs) to enhance forest fire detection. These technologies offer a closer and more accurate monitoring of fires, reducing false alarms for local authorities. Additionally, in the latest research conducted by Vikram and Sinha [18], fog computing is employed, enabling local server analysis of data from IoT-enabled sensors for efficient forest fire management. Smoke monitoring is another crucial aspect, aiding in the identification of forest fires from greater distances, and this has been successfully implemented using Deep Learning methods [21]. Furthermore, comprehensive danger rating systems for forest fires have also been established [22].

From the above literature survey, it is clear that a forest fire can be mitigated before they even start spreading to a much wider distances, destroying the flora-fauna of the nearby locations as well, further harming the locals and the animals prospering inside. However, most of these studies do not consider all latest approaches which can be implemented by combining all the form factors, wherein to better detect and analyze the fire occurrence in vegetation areas like forests and grasslands. Moreover, some studies rely on limited resource availability, and does not capture the packed potential of combining all the state-of-the-art techniques, to better understand the management of forest fire.

Keeping all these facts in mind, the present study suggests an automated solution for the detection of forest fire, using IoT based node sensors, with additional help of edge-based computing factor, alongside the best utilization of Deep Learning approach. This study takes into account the latest parameters which can be acquired from the accurate sensors in a much more resourceful manner. The workings of the previous literature have hugely impacted this study and has also motivated to conduct the proposed methodology, presented in the next section.

3 Research Methodology

To fulfil the research objectives, the entire process is divided into 7 crucial stages or phases, which are described in detail below and visually represented in Fig. 2:

3.1 Data Collection and Integration

In the initial phase of our study, we embarked on an extensive data collection effort to compile a holistic dataset that encompasses various dimensions of forest fire dynamics. Leveraging a network of weather stations, satellite imagery, drones, UAVs and ground-level sensors strategically positioned across fire-prone regions, we sourced real-time environmental data. These sources provided critical variables such as temperature, humidity, wind speed, and historical fire records. The integration of geographic information system (GIS) data enriched our dataset with details about vegetation density, topography, and urbanization patterns. Table 1 outlines the diverse sources contributing to our dataset, encompassing weather stations, remote sensing, historical records, and GIS data. These varied inputs form a rich repository for training and evaluating our advanced forest fire prediction model.

Table 1. Dataset Description Table

Features	Labelled	Size	Source	Metadata
Temperature	Yes	3900	Weather Station Network	Geographic coordinates
Humidity	No	1880	Satellite Remote Sensing	Atmospheric conditions
Wind Speed	Yes	1710	Anemometer Array	Wind direction
Rainfall	No	4300	Rain Gauge Network	Precipitation intensity
Fuel Type	Yes	1090	GIS Data	Vegetation classification
Topography	No	1400	LiDAR Survey	Elevation data
Vegetation	Yes	1990	Remote Sensing Imagery	NDVI values
Ignition Source	No	2100	Historical Records	Source type, location
Fire History	Yes	3170	Fire Department Records	Past fire occurrences
Urbanization	No	1490	Census Data	Population density

To ensure data quality and consistency, robust data pipelines were established that extracted, transformed, and loaded the diverse data streams into a unified format. The resultant dataset not only captured real-time environmental conditions but also factored in historical context and spatial characteristics, painting a comprehensive picture of the fire-prone landscape. This amalgamation of diverse data sources ensured that our model was trained on a comprehensive representation of the complex interplay of variables influencing forest fire occurrences.

3.2 Preprocessing and Feature Extraction

With comprehensive dataset in hand, the next stage involved meticulous preprocessing and strategic feature extraction to enhance the model's predictive capabilities. It undertook a series of steps to ensure data quality and relevance before feeding it into our deep learning architecture. Preprocessing encompassed various tasks, including normalization of numerical variables to ensure consistent scales, and addressing missing values through interpolation techniques validated by domain experts. Given the diversity of data sources, careful attention was paid to handling outliers and anomalies that might arise due to sensor errors or extreme weather conditions. Equation 1 illustrates the function for extracting features from raw data.

$$X_{features} = ExtractFeatures(X_{raw}) \quad (1)$$

where $X_{features}$ is the extracted feature from X_{raw} input data.

Feature extraction was a critical step in distilling relevant insights from the data. Leveraging domain knowledge, we identified key features or sensors, such as temperature, humidity, wind speed, which were expected to exert a significant influence on fire occurrences. To account for complex interactions, we applied techniques like Principal Component Analysis (PCA) to synthesize latent variables that captured underlying patterns within the data.

3.3 Model Architecture Design and Training

Inspired by the inherent spatial patterns in our data, we formulated a combination of deep convolutional neural network (CNN) and Recurrent neural network architecture. This architecture was designed to mimic the human visual system's ability, in order to identify intricate patterns in images. The CNN-RNN combination was engineered with multiple layers, including convolutional and max-pooling layers that acted as feature detectors, capturing local patterns within the data, shown in Eq. 2 below.

$$Y_{CNN} = \sigma\left(W_{CNN} * X_{features} + b_{CNN}\right) \text{ and } h_t = \sigma(W_{hx}x_t + W_{hh}h_{t-1} + b_{RNN}) \quad (2)$$

where Y_{CNN} is the output of CNN layer, W_{CNN} are the CNN weights, h_t is the RNN hidden state and x_t is the RNN input at time t and W_{hx}, W_{hh} are the RNN weights.

The presented op-model architecture in embodies a deep convolutional neural network designed to capture intricate spatial patterns in sensor data and satellite imagery. The model comprises multiple layers, each strategically engineered to extract relevant features, ensuring precise forest fire prediction.

Deep Learning model as presented in Fig. 1, envisioned as a powerful tool capable of learning and synthesizing complex spatial relationships within the data, offering a novel approach to forest fire prediction that aligned with the intricacies of the natural world. Learning rates, which determine the step size in updating model weights, were carefully calibrated to strike a balance between rapid convergence and avoiding over-shooting. Rigorous experimentation with different optimization algorithms, such as Adam and SGD, was conducted to identify the most suitable optimizer for our architecture.

$$Loss = ComputeLoss(Y_{predicted}, Y_{ground\_truth}) \quad (3)$$

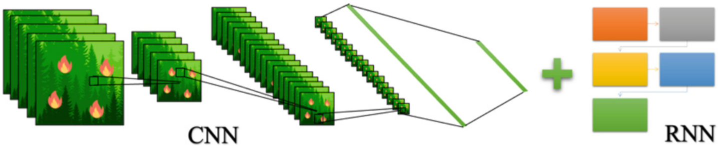

Fig. 1. Proposed Deep Learning Model

where $Y_{predicted}$ are the predicted values and Y_{ground_truth} are the ground truth values shown in Eq. 3, in order to compute the overall loss function. Furthermore, regularization techniques, were employed to prevent overfitting, a common pitfall in deep learning. This stage's meticulous attention to hyperparameter tuning and regularization not only facilitated the model's ability to learn from the data effectively but also fortified its potential to make accurate predictions on unseen instances, forming the cornerstone of our forest fire prediction system.

3.4 Edge Computing Integration

Recognizing the need for real-time responsiveness in forest fire prediction, we integrated edge computing into our system architecture. This pivotal stage marked the convergence of cutting-edge technology and on-the-ground applicability, enabling swift and informed decisions in fire management. IoT sensors like temperature, humidity, wind speed strategically positioned within fire-prone regions collected real-time environmental data. These sensors served as the eyes and ears of our system, capturing crucial information that fed into our predictive model. The edge devices, positioned proximate to the sensors, became the nerve center of our architecture.

These edge devices assumed the role of real-time data processors. As the sensors transmitted data streams, the edge devices took charge of immediate processing, analyzing the incoming data within the forest environment itself. This approach drastically reduced the latency associated with transmitting data to central servers, ensuring that predictions were made in near-real-time. The deep learning model was directly integrated into these edge devices, allowing them to perform on-device inference. This seamless integration between data collection, processing, and prediction significantly expedited response times and enhanced the model's timeliness.

$$Latency = T_r + T_c + T_s \tag{4}$$

where T_r is the time for on-site data processing, T_c is the communication time and T_s is the sensing time, as shown in Eq. 4, calculates the overall time latency. This integration of edge computing brought the power of AI and real-time analytics to the heart of the forests, bridging the gap between data generation and model-driven insights. It represented a convergence of advanced technology and practical on-site implementation, transforming forest fire prediction from a theoretical concept to a practical reality.

3.5 Real Time Data Processing

The infusion of real-time data processing into our forest fire prediction system marked a pivotal advancement, elevating our ability to respond swiftly and proactively to evolving fire dynamics. This stage encompassed the dynamic processing of incoming data streams, translating raw sensor readings into actionable insights in real time. As IoT sensors diligently collected environmental data such as temperature, humidity, wind speed and other alert sensors provide streams of information, which were transmitted to edge devices with minimal delay. At the heart of these edge devices, the data underwent a series of critical transformations.

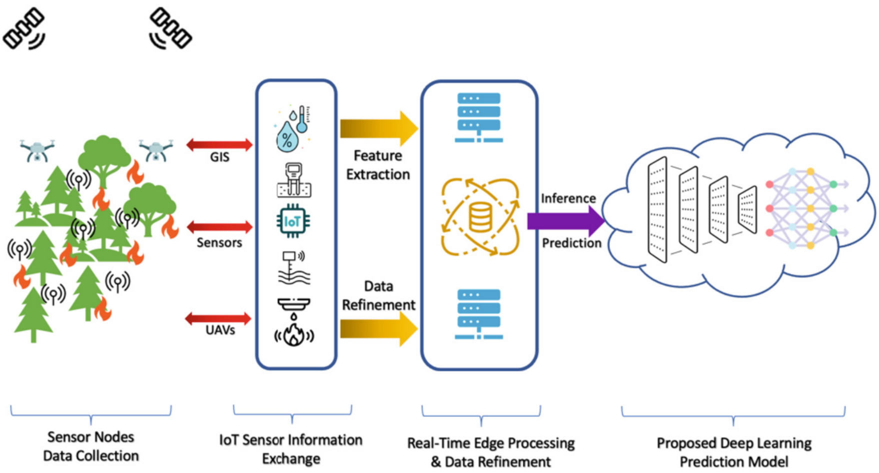

Fig. 2. Proposed Architecture of Fusion Model

The first step involved data interpretation, where raw readings from sensors were converted into meaningful units, ensuring consistency across different aggregation levels. This step minimized the potential for misinterpretation and discrepancies that might arise due to sensor variations. The edge devices factored in variables such as historical fire records, vegetation density, and topographical features to interpret the incoming data within the larger ecological context. This multi-dimensional perspective enabled the system to discern abnormal patterns and anticipate potential fire occurrences.

$$X_{processed} = ProcessedSensorData(X_{raw}) \quad (5)$$

where X_{raw} is the raw sensor data and $X_{processed}$ is the processed data.

These anomalies, if indicative of conditions conducive to fire ignition, triggered the model to initiate prediction procedures. This real-time data processing, illustrated in Eq. 5, acted as the critical conduit between raw environmental readings and predictive insights. By processing data streams in real-time, we transcended the realm of re-active analysis, enabling proactive decision-making and facilitating the timely allocation of firefighting resources.

3.6 Inference and Prediction

This stage transformed raw data into informed foresight, bridging the gap between technology and practical decision-making. By distilling complex data patterns into intuitive predictions, our system empowered forest managers to take timely actions that could potentially prevent or mitigate the impact of forest fires. With real-time data processed at the edge, our forest fire prediction system entered a phase of dynamic inference and prediction, where insights from the data coalesced into actionable intelligence. This stage marked the culmination of our technological advancements, translating complex data patterns into comprehensible outcomes.

$$F_p = w^T . \begin{bmatrix} E \\ D \end{bmatrix} \tag{6}$$

where F_p is the predicted fire spread, E represents environmental parameters, D signifies historical fire data, and w are learned weights, shown in Eq. 6. The model's architecture harnessed the power of deep learning to interpret the synthesized input and generate predictions regarding fire occurrences. The predictions also factored in the temporal aspect, adjusting probabilities based on the current time of day, historical trends, and recent weather changes. This dynamic nature of prediction enabled the system to adapt to evolving conditions, fostering accuracy and relevance.

3.7 Accuracy Assessment and Refinement

This final stage encompassed a comprehensive evaluation, aimed at not only validating the model's effectiveness but also identifying areas for improvement. Actual fire occurrences were compared with the model's predictions to gauge its performance. Precision, recall, F1-score, and other metrics were meticulously calculated, illustrated in Eqs. 7 and 8, to assess the model's ability to correctly classify fire events and non-fire events. By delving into the confusion matrix, we gained insights into the model's predictive behavior, understanding where it excelled and where it fell short.

$$Precision = \frac{TP}{TP + FP} \text{ and } Recall = \frac{TP}{TP + FN} \tag{7}$$

$$F1 - Score = \frac{2 * Precision * Recall}{Precision + Recall} \text{ and } Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{8}$$

This evaluation unearthed the nuanced challenges of forest fire prediction. Instances of false positives and false negatives were dissected to reveal potential blind spots. We scrutinized scenarios where the model failed to predict fires that occurred and instances where false alarms were raised. These findings guided the subsequent refinement phase. A function to refine the model based on the achieved accuracy, enhancing the model's performance is shown in Eq. 9.

$$Refine(Model, Accuracy) \tag{9}$$

In response to these insights, we initiated a targeted refinement process. Misclassified instances were analyzed to un-cover patterns and nuances that the model might have overlooked. This stage encapsulated our commitment to continuous improvement. As our model evolved, its predictions became more aligned with real-world fire occurrences.

4 Findings and Results

The outcome of the comprehensive methodology is now unveiled through an in-depth analysis of our model's predictive performance. The empirical evidence presented here validates the effectiveness of our approach in revolutionizing forest fire prediction. The proposed model's performance is encapsulated through a range of metrics, revealing its ability to accurately distinguish fire occurrences and non-occurrences. These metrics include accuracy, precision, recall, and F1-score.

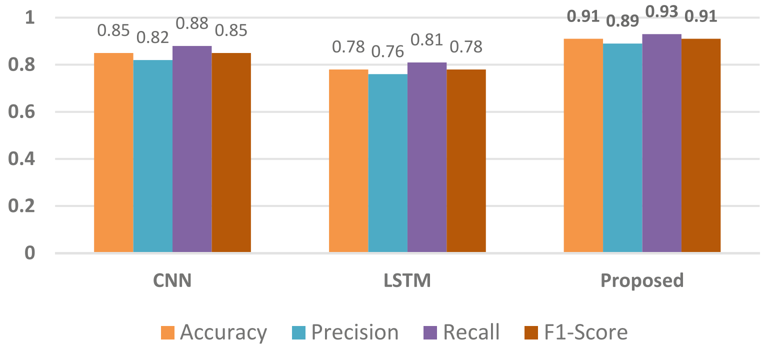

Fig. 3. Model Comparative Analysis.

The model's capacity to surpass existing methods underscores its potential for real-world implementation. The model's performance is benchmarked against existing studies, emphasizing its superiority in accuracy, precision, and recall as presented in Fig. 3. This comparison underscores our approach's advancements in the field, positioning it as a transformative solution. Furthermore, the significance of individual features in shaping predictions is unveiled. This feature importance analysis sheds light on the weightage assigned to variables like temperature, humidity, wind speed, and historical fire data, highlighting their respective influences. Factors such as temperature, humidity, wind speed, and historical fire data emerge as pivotal contributors, illuminating the complex interplay of variables.

Reduced runtime and latency on edge devices underscore its real-time prediction potential, aligning with the practical demands of fire management. The results get fortified through statistical significance tests. ANOVA, t-test, Kruskal-Wallis, Mann-Whitney U, and Chi-squared tests collectively validate the robustness of our findings. These comprehensive results underscore the potential of the methodology in elevating forest fire prediction to new heights. The ensuing discussion delves into the implications of these findings and the broader impact on fire management strategies. As shown in Table 2, each statistic has its own meaningful explanation.

This ensemble of metrics presents a holistic depiction of the model's predictive competence. By quantifying accuracy, the research's outcomes will provide a tangible representation of the model's success in forecasting forest fire occurrences. These equation-derived metrics serve not just as benchmarks but also as the compass guiding the model's enhancement. Quantitative metrics, including accuracy, precision, recall,

Table 2. Statistical Analysis of proposed model

Test	p-value	Effect Size	Confidence Interval
ANOVA	0.003	0.32	0.25 - 0.39
t-test (Group A vs. Group B)	0.017	0.18	0.10 - 0.25
Kruskal-Wallis	0.025	0.27	0.20 - 0.34
Mann-Whitney U (Group A vs. Group C)	0.043	0.14	0.06 - 0.22
Chi-squared	0.001	N/A	N/A

and F1-score, offer a succinct evaluation of model performance across diverse criteria. These metrics collectively showcase the model's proficiency in differentiating fire occurrences.

5 Discussion

The investigation presented in this study underscores the intricate relationship between advanced deep learning techniques, IoT integration, and their collective impact on forest fire prediction. The findings not only validate the effectiveness of the proposed model but also open avenues for nuanced exploration within the domain of wildfire management and eco-logical preservation. The results underscore the transformative potential of combining edge computing, IoT technologies, and deep learning, in the form of CNN-RNN architecture, for forest fire detection and prediction, answers the first research question. The integration of edge computing within the context of forest fire prediction serves as a substantial departure from conventional methodologies, answering the second research question. By enabling real-time analysis at the data collection point using satellite imagery, drones and UAVs, substantially reduces the delay inherent in data transfer to centralized servers, further answering the third research question. This reduction in latency is particularly crucial in the context of forest fires, where rapid detection and timely response are paramount. The collaborative synergy between edge devices and deep learning models establishes a dynamic framework that not only capitalizes on real-time data but also demonstrates the potential to evolve predictive capabilities over time.

6 Conclusions

This study aimed to advance forest fire prediction using a novel combination of deep learning, IoT, and edge computing by predominantly answering all the three research questions. Further, by harnessing sensor data and employing sophisticated deep learning models, this study sought to enhance the accuracy and timeliness of forest fire detection. The accurate prediction of fire occurrences, facilitated by this model's refined precision and recall rates, can enable quicker response times and more targeted deployment of firefighting resources. This, in turn, contributes to the minimization of potential damage to ecosystems and human settlements. While this study has achieved promising results, there remain avenues for further exploration. The integration of more advanced edge computing technologies and a broader array of IoT devices could lead to even more accurate and localized predictions. Ensuring that the benefits of our research reach the communities most vulnerable to forest fires is an integral part of our future efforts. As we navigate the complexities of our changing environment, the convergence of deep learning, IoT, and edge computing holds the promise of a safer, more resilient future.

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Collaborative Robots in Manufacturing MSMEs: Identification and Operationalization of Enablers and Barriers

Pulok Ranjan Mohanta(✉) and Biswajit Mahanty

Indian Institute of Technology Kharagpur, Kharagpur, India
pulok@iitkgp.ac.in

Abstract. In the era of Industry 4.0 the collaborative robots (also known as cobots) are seen to have immense potential to be integrated into manufacturing systems. They demonstrate the potential to revolutionize the way automation is integrated into workplaces through encapsulation of human expertise and robotic precision. However, the deployment of cobots in the Micro Small and Medium Enterprises (MSMEs) are still in the nascent stage. While the extant literature primarily highlights the generic difficulty of MSMEs in adopting the Industry 4.0 technologies due to lack of resource and capabilities, this study specifically explores the contextual requirement of cobots. In the first stage, the enablers and barriers are identified from an extensive literature survey. Subsequently, using structured interviews with domain experts, steps to operationalize these enablers and barriers are delineated. Considering the inputs from the inputs from the domain experts, a stepwise implementation framework is put forward. The proposed framework considers three broad stages: (1) ideation stage (2) implementation stage and (3) review stage. The outcome of this study finds relevance for decision makers involved in managing and consulting the collaborative robot implementation projects.

Keywords: Collaborative Robots · Industry 4.0 · MSMEs

1 Introduction

In manufacturing industry, many Micro Small and Medium Enterprises (MSMEs)[1] are involved in the assembly work having large number of parts, with multiple variants, and shorter cycle times subjected to frequent disruptions in the production process. While traditionally these factors were reasoned for keeping assembly work in MSMEs far from automation, these labor-intensive processes are not able to cope with the challenges [1] in today's scenario of mass customization and globalization. This forms a significant factor for considering industrial automation alongside manual work, referring to a work environment shared by both machines and human being [2].

[1] As per Government of India, MSMEs are the enterprises that has investment in Plant and Machinery not more than Rs.50 crore and annual turnover is less than Rs. 250 crores.

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The fourth industrial revolution has played the pivotal role in augmenting the development and induction of a new generation of robots called "Collaborative robots (cobots)". Contrary to their traditional counterparts, cobots are expected to share the workspace with humans and to collaborate with them to bring in more flexibility, versatility, and safety to the industrial systems. They are designed to support and improve the performance of their human counterpart even in very unpredictable circumstances [3]. The notion is combining the capabilities of humans and machines (Fig. 1). The wider acceptance of this paradigm can be attributed to two main technological advancements: (1) the incorporation of safety features and (2) the use of advanced technology-based interfaces making the interaction with cobots more intuitive and safer [4, 5]. In addition, due to the integration of artificial intelligence, cobots are capable of suitably adapt and deliver desired performance even in unstructured scenarios involving interaction with under-trained users [6]. The wider acceptance of cobots in the industry can be well-comprehended from the observed market growth, which is valued at $1.2 bn in 2023 and is projected to reach $6.8 bn by 2029 [7]. However, the deployment of cobots in the MSMEs are still in the nascent stage.

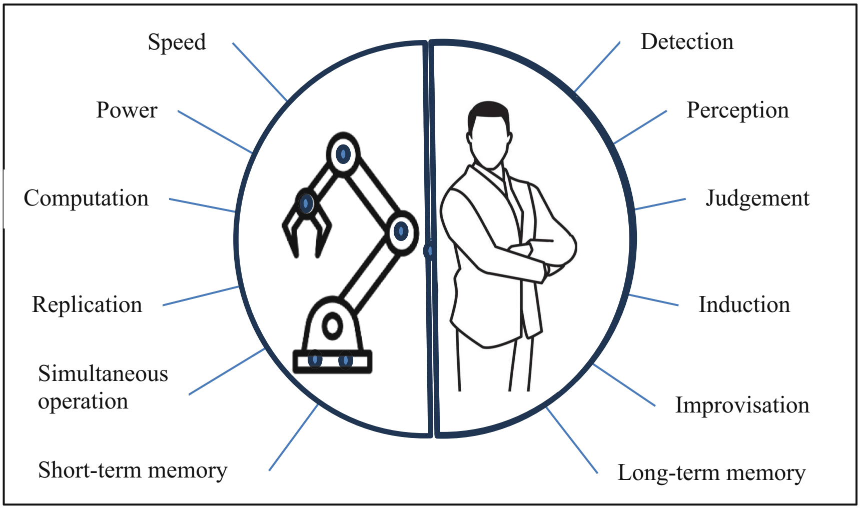

Fig. 1. Comparison of capabilities of humans and machines (adapted from [8])

Despite the significant benefits that cobots offer, their adoption by MSMEs is challenging considering the financial constraints, lack of technical knowhow and challenges associated with integrating new technology into existing workflows [9]. Overcoming these difficulties requires careful planning, targeted investment, effective training, and a clear understanding of the potential long-term benefits. The careful exploration of the extant literature as a part of this study exposed the lack of enough literature addressing the specific aspects of MSMEs and guides them in successful deployment of cobots.

Addressing to this literature gap, this study explores the enablers and barriers for successful deployment of cobots in manufacturing MSMEs. Subsequently, the steps to operationalize these enablers and barriers are delineated. At the end, a stepwise implementation framework is put forward. The outcome of this study finds relevance for decision makers involved in managing and consulting the cobot implementation projects.

The rest of the paper is organized as follows. Section 2 reviews the related literature and Sect. 3 describes the study methodology. Section 4 discusses the enablers and barriers to cobot deployment. Section 5 delineates the steps to operationalize the enablers and barriers. The proposed framework for deployment of cobot is discussed in Sect. 6, while Sect. 7 concludes the paper.

2 Related Literature

2.1 Application of Cobots in Manufacturing Operations

The corpus of literature related to application of cobots in manufacturing operations are seen to report several applications, focusing the enhancement of productivity and safety alongside conforming to regulatory compliances and relieving human labor. Levratti, et al. [10] discussed a cobot for lifting and transferring heavy loads across several workstations thereby reducing fatigue and risk. Peternel, et al. [11] proposed an intelligent cobot that uses an estimated human motor fatigue to deploy cobot for the task beyond a specified threshold, thus helping to avoid risk of injuries. In the same vein Cherubini, et al. [12] presented a cobot that activates itself sensing the requirement of assisting the operator. The aspects of simultaneous working of human and cobot were also discussed by researchers such as Tan, et al. [13], Krueger, et al. [14] and Erden, et al. [15], Magrini, et al. [16]. These contributions primarily focused various aspects of modeling, safety, mental workload, and man-machine interfaces so as to optimize the system design and performance.

Some special cases related to material handling application of cobots included the dampening of undesirable oscillations by Donner and Buss [17], detecting and stabilizing the unstable behavior in human–cobot interactions [18] and handling of a highly deformable material by a cobot using the combination of force and vision controllers [19].

Some cases of deployment of cobots for quality and process inspection were also reported. Typically, such cobots are designed with either 2-D or 3-D vision sensors [20]. This enables them to conduct efficient inspections ensuring all requirements of the respective production stage are met [21].

2.2 Developments in Human-Cobot Interactions

With continually increase in induction of cobots in industries for numerous applications, there is also increase in research focusing on improving performance, safety and collaboration. Some of the focused areas includes control systems, intent recognition system and learning systems [22]. The corresponding development in technologies enables cobots to learn and adapt to the changing conditions in real time. Rosen et al. [23] studied the feasibility of integrating a human arm with a neuromuscular signal (EMG) based powered exoskeleton system as a cobot system. Farry et al. [24] investigated the application of myoelectric spectrum for commanding and controling the cobots. Magrini et al., [25] concentrated on the differentiating the nature of contact i.e., intentional or accidental. Khatib et al. [26] proposed the working of a cobot through a sequence of subtasks namely, (1) differentiating a contact with human as intentional contact or undesired collision, (2) identification of the point of contact on the robot's surface, (3) estimating the force involved in the contact and (4) controlling the robot's reactions according to the desired behavior. For effective human-cobot interactions and execution of desired tasks by cobots, Machine learning techniques are found to be very helpful. For example, application of neural networks and fuzzy logic control for enhanced material handling functions [27] and designing initiative-taking behavior of the cobots for execution of tasks [28].

2.3 Deployment of Cobots in Manufacturing MSMEs

Manufacturing MSMEs often require workers to perform repetitive tasks with high precision and heavy loads. A number of papers discussed such situations involving monotonous, cumbersome and stressing activities that distress the workers, proposing the deployment of cobots to improve the situation. Dimeas et al. [29] discussed the deployment of a cobot to autonomously execute the task of lifting and placing involving repetitive movements. The proposal by Aliev et al. [30] discussed the assembly work where the cobot and worker share the same workspace, focusing primarily on the task sequence planning. In a similar contribution, Michalos et al. [31] proposed a multi criteria decision making method for planning of collaborative assembly tasks. The study by Aliev et al. [32] discussed the application of an integrated camera to identify the job and execute pick and place tasks. Ranavolo, et al. [33] discussed about wearable cobots that can be used to significantly reduce biomechanical risk in the workplace. While explaining the application of cobots to welding operations, Müller et al. [34] proposed a classification of ways the human and cobots can work together, which can be generalized for: (1) non-interactive coexistence, (2) synchronized to work at different timings, (3) working simultaneously on different jobs while sharing the same workspace, (4) performing the same task collaboratively.

Irrespective of the type of interactions, proper coordination between workers and cobots is crucial [35], and integrating technologies like wearable haptic systems [36] and augmented reality systems can greatly assist in this process [37]. To summarize, the applicability of cobots in the MSMEs can be better reasoned for:

1. their capability to work in collaboration with the human operator to increase productivity;
2. reducing the workload of the operator by taking strenuous and repetitive jobs;
3. extending the work duration to increase output;
4. the flexibility and adaptability for different tasks in different workspaces;
5. ability to work in a work environment that is not safe for human operators e.g. high pollution, noise and temperature etc.

The exploration of the existing literature has revealed that most of the contributions discussed the development of the cobots to enhance their suitability for industry applications. Many researchers have particularly focused on job-specific applications and improving collaboration with human operators. However, the literature is scarce that discusses enablers, barriers, and the aspects of their operationalization. This forms the basis of the current work.

3 Study Methodology

Essentially, this study was carried out in three phases as depicted in Fig. 2. The enablers and barriers affecting the successful deployment of cobots in manufacturing MSMEs were gleaned from the extensive review of literature. The findings were then discussed with the subject experts to test their relevance and finalize. Subsequently, through extensive discussion using structured interview technique, the means to operationalize the finalized enablers and barriers were enlisted. By drawing inferences from these discussions, a framework for deployment of cobots is proposed. Five experts were involved in the study. Two of them are academicians, while others are senior executives from industry. The experts were selected based on their (1) relevant experience, (2) familiarity with the research topic and (3) expertise in the research domain.

4 Enablers and Barriers for Cobot Deployment in MSMEs

To identify the enablers and barriers for successful deployment of cobots in manufacturing MSMEs, initially an extensive literature survey was carried out. Subsequently, the identified items were discussed with the experts. The experts individually recommended certain rephrasing and additions to the list. Reasonable consensus was obtained subsequent to two rounds of discussions. The resulting list is presented in Table 1. A brief description of each enabler/barrier follows:

4.1 Enablers for Cobot Deployment

1. *Continuous management support:* Successful deployment of advanced technology such as a cobot in a MSMEs requires the commitment of a visionary leadership to manage the managerial challenges related to implementation strategy, planning, and execution.
2. *Perceived usefulness:* It implies the extent to which a MSME believe that deployment of cobot would bring in the desired improvement to the organization. Higher perceived usefulness would ensure sincerer consideration of such projects.
3. *Smart modular workstation:* A smart modular workstation consists of independent modules with smart tools and technologies, allowing MSMEs to deploy cobots according to requirements without complete technological transformations, enabling pilot projects before large-scale deployment.
4. *Data management capability:* A well-established data management system in an organization gives hassle-free access to data when it is needed. This would augment successful deployment of digital technology such as deployment of cobots.

5. *Availability of a mature IT system:* A mature IT system facilitates efficient information flow, real-time operation synchronization, and enhances coordination with other systems, ensuring desired performance.
6. *Continuous improvement attitude of managers:* Cobots are often integrated into multiple manufacturing projects, requiring continuous improvement attitudes among managers to enhance agility and adaptability to new tools and processes.
7. *Vision for offering mass customization of goods and services:* Cobots' speed, power, and computation make them ideal for mass customization environments, providing organizations with a similar intent a higher degree of certainty to deploy them in their manufacturing system.
8. *Operations technology readiness:* MSMEs need to upgrade their operations technologies to meet digitalization requirements for cobot systems, which require seamless interaction with existing equipment and the use of sensors and intelligent controllers for seamless integration.
9. *Aligning implementation project to business strategy:* The success of cobot deployment projects would primarily be dependent on the organizational strategic visions. Hence aligning the cobot projects to organizational strategies will make the deployment process smooth.
10. *Employees' training and knowledge management:* The deployment of cobots in MSMEs requires proper employee training on their usage and functionalities, as well as well-documented user manuals and troubleshooting guidelines, to facilitate easy adaptation and knowledge management in the new system.
11. *Efficient management leadership:* MSMEs should involve efficient leaders in cobot deployment projects to secure top management support, enhance organizational performance, and deliver transformative projects like cobot deployment.
12. *External Support (from large enterprises, government etc.):* Cobot deployment projects require significant investments and technological expertise, necessitating support from large enterprises and governments in financial grants, resource sharing, and policy intervention to help resource-deficient MSMEs.
13. *Available cyber security measures:* Similar to other Industry 4.0 technologies, cobots involve continuous data generation for optimizing decision-making tools. Cyber security measures are necessary to protect confidentiality and integrity, alongside preventing software, hardware, or network attacks.
14. *Project management competency*: For successful deployment of cobots, it is essential that the right set of tools, techniques and approaches are used to manage the series of tasks. Accordingly, MSMEs need to have a competent project management team to manage such projects efficiently.

4.2 Barriers to Cobot Deployment

1. *High implementation cost:* Deployment of cobots in MSMEs may require a substantial amount of investment to procure cobots, incorporate necessary modifications, purchase necessary safety devices, and impart training to the workforce. This may be prohibitively expensive for them.

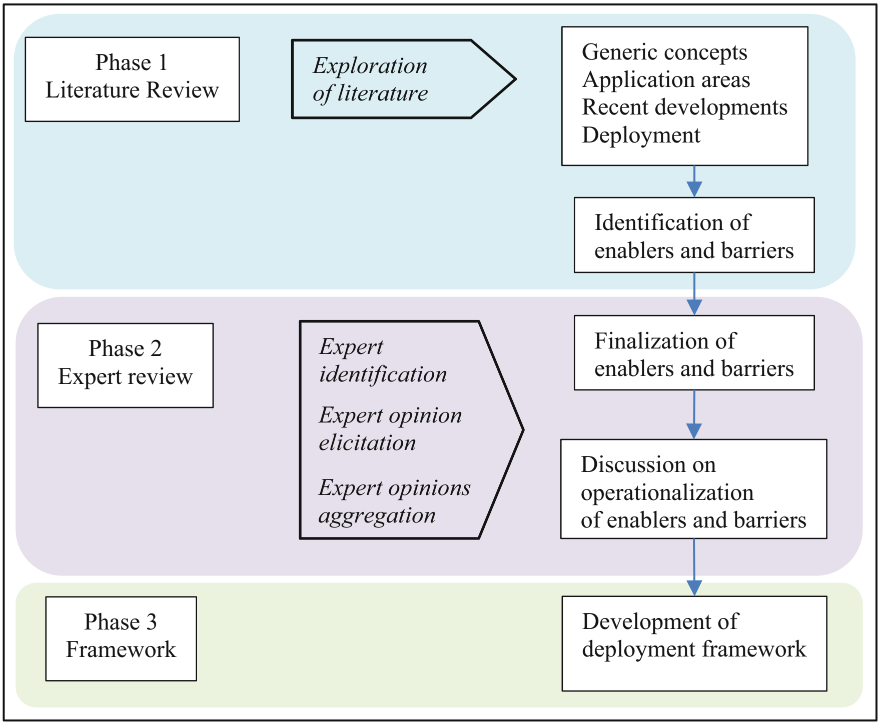

Fig. 2. Study methodology

2. *Lack of long-term vision:* Lack of a long-term vision can hinder the success of cobot deployment projects in MSMEs, leading to a myopic approach that overlooks greater possibilities, underutilization of capabilities, improper integration, and inefficiency.
3. *Unclear economic benefits:* The high implementation cost sometimes overshadows the benefits that can be accrued from implementation of advanced technologies such as cobots. Hence the MSMEs, amidst the uncertainties, may find it a risky affair to invest in cobot deployment projects.
4. *Challenge in integrating to the existing value chain:* Integrating cobots with the production system of MSMEs can be a challenging affaire considering the setting up communication with other equipment, process and software. It may also be challenging considering the requirement of process redesign, and adapting to the legacy systems.
5. *Concern for security infringements and related risks:* Since cobots are conceptualized for integrating to a broader network of equipment and other digital infrastructure, there is a concern for cyber-attack targeting the operations, data and intellectual property. The MSMEs may find the potential breaches and malicious activities as limiting factor for cobot deployment.
6. *Lack of competency in change management:* Improper change management can significantly hamper the cobot deployment project in MSMEs. This may lead to

Table 1. Enablers and barriers to cobot deployment in manufacturing MSMEs

Sl. No	Enablers	Barriers
1	Continuous management support	High implementation cost
2	Perceived usefulness	Lack of long-term vision
3	Smart modular work station	Unclear economic benefits
4	Data management capability	Challenge in integrating to the existing value chain
5	Availability of a mature IT system	Concern for security infringements and related risks
6	Continuous improvement attitude of managers	Lack of competency in change management
7	Vision for offering mass customization of goods and services	Deficiency of a proper digital strategy
8	Operations technology readiness	Scarcity of required resource
9	Aligning implementation project to business strategy	Fear of interference to existing jobs
10	Employees' training and knowledge management	Lack of adequate digital skills
11	Efficient management leadership	Lack of conducive digital culture and training
12	External Support (from large enterprises, government etc.)	Employee's resistance to change
13	Available cyber security measures	Lack of adequate infrastructure
14	Project management competency	Lack of trust and understanding from operators and industrial parties

employee resistance, improper integration to existing systems and disruptions in workflows resulting in reduced productivity.

7. *Deficiency of a proper digitalization strategy:* The complex nature of cobot deployment projects demands careful delineation of short-, medium-, and long-term vision of the organization. As such many digitalization projects are required to be executed prior to (or alongside) the deployment of cobots. Accordingly, if the digitalization strategy is not properly defined aligning to the business strategy, it may risk the success of cobot deployment.
8. *Scarcity of required resources:* The MSMEs are known for their scarcity of resources. Typically, it hinders cobot deployment by constraining the financial, human, and technical assets essential for success of such projects. Resource scarcity impedes the procurement, implementation, and optimal utilization of collaborative robots in manufacturing, limiting their potential benefits.
9. *Fear of interference to existing jobs:* The notion of deploying cobots may induce concerns among the employees about job displacement and changes in job-roles.

This may lead to skepticism and stem misconception about replacement of human workers entirely. This may attract strong resistance from employees.

10. *Lack of adequate digital skills:* Deployment and operation of cobots require a specialized skills and knowledge. While MSMEs may not have workers with such competencies, hiring and training to meet the requirement may be expensive, further increasing the overall deployment cost.
11. *Lack of conducive digital culture and training:* The lack of a conducive digital culture that embraces technology and innovation, may lead to employee resistance to cobot deployment. Further, inadequate training on cobot operation, programming, and collaboration can exacerbate this issue, limiting the proper deployment and functioning of the cobots.
12. *Employee's resistance to change:* The deployment of cobots into the production systems may witness resistance from employees who are accustomed to the traditional way of product manufacturing. Overcoming such resistance requires effective change management and clear communication about the benefits and implications of cobot integration.
13. *Lack of adequate infrastructure:* Inadequate infrastructure refers to the absence or insufficiency of the physical, technological, and organizational components necessary for successful deployment of cobot. This deficiency can hinder cobot deployment in causing space constraint, power deficiency and compatibility issues thus making the implementation project's difficult to execute.
14. *Lack of trust and understanding from operators and industrial parties:* The lack of trust and understanding from operators and industrial parties creates barriers to acceptance, establishing collaboration, and effective utilization of cobots. This lack of trust and understanding can impede the successful deployment of cobots in various ways such as resisting the change, spreading misconception and fear, deter the effectiveness of collaboration and lagging proper control.

5 Operationalization of Enablers and Barriers

Subsequent to identification and finalization of the enablers and barriers, the next step was to discuss with the experts and delineate the steps for operationalization. The opinions of all the experts were synthesized to yield the following operationalizing steps:

1. Develop a comprehensive deployment plan for cobot deployment, aligning with the organization's growth and industry trends, outlining tasks, responsibilities, timelines, and key performance indicators.
2. Develop effective communication channels with stakeholders to understand concerns, gather insights, and address misconceptions about cobot deployment, involving operators, technicians, managers, and IT personnel.
3. Offer comprehensive training programs for operators and workers on cobot operation, safety protocols, programming, and collaboration, fostering familiarity and confidence in cobot technology and best practices.
4. Enhance the organization's technology infrastructure for cobot integration, ensuring seamless integration with existing systems and collaborating with IT professionals for power supply, network connectivity, and compatibility.

5. Conduct a controlled pilot deployment of cobots to evaluate their performance, workflow impact, and operator interaction, gather feedback, and use insights to refine processes and optimize applications.
6. Conduct a comprehensive risk assessment to ensure that cobots are integrated safely into the workspace. Implement necessary safety measures, such as barriers, sensors, and emergency stop buttons, to minimize potential risks.
7. Establish a mechanism for collecting and analyzing data from cobots to monitor their performance, efficiency, and impact on productivity. Use data-driven insights to optimize cobot operations and identify areas for improvement.
8. Establish a feedback loop with operators and stakeholders to assess cobot performance, address challenges, and regularly review and refine applications based on operational feedback and business needs.
9. Customize cobot applications to fit your specific manufacturing processes, tasks, and operational requirements. Collaborate with cobot manufacturers or integrators to tailor solutions that align with your organization's needs.
10. Develop a strategy for scaling up cobot deployment based on initial success and evolving business needs, planning for additional cobots, applications, and new processes as the organization grows.

6 Proposed Implementation Framework

Taking into consideration the identified enablers and barriers as well as the steps to operationalize them, a comprehensive cobot deployment framework is proposed (Fig. 3). The purpose is to serve as a reference material that can be used by the MSMEs as a guideline while planning to deploy cobots.

6.1 Ideation Stage

In this stage, a proper strategy for cobot deployment should be developed. This involves brainstorming, conceptualizing, and outlining the key aspects of the cobot deployment initiative. In particular, the existing infrastructure should be assessed for feasibility considering the technological and functional requirements. Further, the communication channels are to be established for effective data capture and information sharing. After completion of the deployment, the strategies for scaling up are to be taken into consideration, keeping in mind the customization requirements.

6.2 Implementation Stage

Ideally, the implementation stage should begin with the execution of a pilot project. The potential risks related to the cobot deployment should be comprehensively assessed. The need-based training and development programs should be organized to make the workforce conversant with the new technology. Upon satisfactory outcomes, the full-fledged implementation can be pursued taking into consideration the customization aspects.

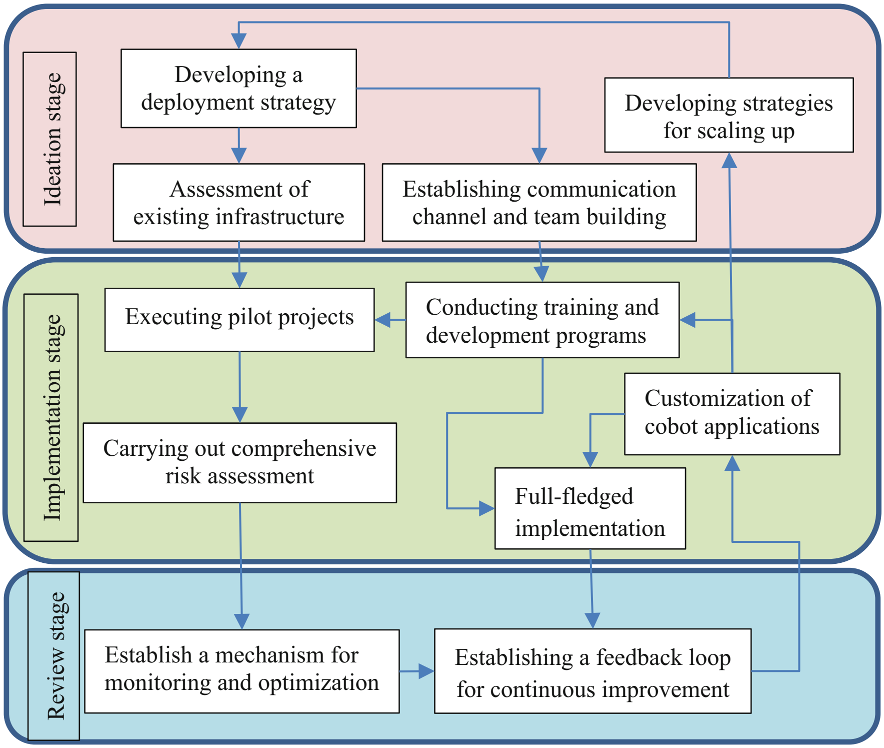

Fig. 3. Proposed comprehensive cobot deployment framework

6.3 Review Stage

The review stage should have critical consideration of continuous improvement of the emergent system. A proper mechanism should be established for monitoring the performance and identifying the optimization opportunities. Further, it should provide input to the customization and scaling up programs related to the cobot deployment projects.

6.4 Validation of the Proposed Framework

The developed framework was sent to all the experts for refining (if necessary) and validation. The experts analyzed the proposed framework and given their feedback remarking it to be satisfactory for this nascent stage of cobot deployment. The excerpts of the feedback follow:

1. There is a concern related to the required digital infrastructure and internet networking due to the low availability of the internet in many areas.
2. The aspect of reskilling the existing employees should be effectively dealt with so that there is a smooth transition to the emergent system.
3. The implementing MSME should carefully plan for cybersecurity measures and the integration of the cobots to the existing system.

7 Conclusion and Way Forward

In this study, the enablers and barriers to the successful deployment of cobots in manufacturing MSMEs were identified from the extant literature. They were finalized with the consultation of the domain experts, from both academia and industry. Using structured interview, the steps to operationalizing the enablers and barriers were delineated and finally a comprehensive framework for successful deployment of cobots in manufacturing MSMEs was proposed. This study distinctively contributes to the existing literature by proposing a cobot deployment framework for MSMEs, considering operationalization of both enablers and barriers.

This study can be considered as primer to the researchers and practitioner working in the domain of development and deployment of cobots for manufacturing applications. The research can further be extended to include more number of experts so that the validity of the proposed framework can be improved.

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Why do Consumers Believe in Brand-related Fake News? Insights from a Methodological Juxtaposition of QCA and Meta-Synthesis

Pramukh Nanjundaswamy Vasist(✉) and Satish Krishnan

Information Systems Area, Indian Institute of Management Kozhikode, Kunnamangalam, Kerala, India
pramukhn02phdpt@iimk.ac.in

Abstract. Fake news poses a severe threat to brands in the digital era. Despite an escalating crisis, the combination of factors that dictate belief in fake news remains unclear. To this purpose, we evaluate the expanding corpus of fake news articles that discuss the impact on brands and deliver crucial insights through a first-of-its-kind methodological fusion of meta-synthesis and qualitative comparative analysis. Preliminary analysis reveals a set of four themes that induce belief in fake news. The envisaged plan for qualitative comparative analysis seeks to unpack the combinatorial effect of factors driving belief in brand-related fake news. This would serve as the basis for formulating propositions to guide empirical advancements in the field.

Keywords: Fake News · FsQCA · Meta-synthesis

1 Introduction

Fake news refers to news articles that are deliberately produced by individuals to disseminate inaccurate or false information [1]. The term has been used interchangeably with misinformation and disinformation, with the former referring to unintentionally shared false information while the latter involves an intent to deceive [2]. Fake news can adversely impact brands, causing irreversible damage [3]. Past instances of fake news concerning the safety of self-driving cars, for example, have had a negative impact on consumers' acceptance of self-driving cars [2], while food brands are beginning to recognize the need for more transparent communications with their consumers, given the negative impact of fake news on brands [4]. Fake news has also ushered in a crisis for political brands by contaminating democratic discourse [5] and has led to an existential threat to journalism brands with a lack of trust in factual reporting [6].

Fake news as a phenomenon is increasingly garnering attention in the marketing discipline [7]. The fragmented nature of brand-related fake news literature has instilled researchers to analyze the varied perspectives and organize the literature to drive future research. However, research on the reasons behind people's belief in fake news remains

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largely under-researched, and scholars advocate for deeper analysis of the underlying causes [8]. Recent studies indicate the possibility of asymmetrical relationships in this domain, which motivates further investigation using novel methods such as qualitative comparative analysis (QCA) to elucidate the multiplicity of solutions to a particular outcome [e.g., 9], which is the belief in fake news. As the field evolves, the scholarly contributions tend to advance in a piecemeal fashion, necessitating a review that not only critiques the growing body of knowledge but synthesizes it and offers new perspectives on the phenomenon of interest [10]. Such is the case with research on fake news as a phenomenon.

Meta-synthesis as a research design delivers significant insights and a holistic understanding of the phenomenon of interest [11]. However, the focal phenomenon, the belief in brand-related fake news, is rarely influenced by a single factor but rather by multiple factors [12]. This crucial aspect positions configurational analysis as an apt setting for the current study. Hence, we utilize a combination of meta-synthesis as a research design and QCA as a method to ascertain the combination of conditions that establish belief in brand-related fake news. Per this objective, our research question (RQ) is as follows:

RQ: Which combination of factors determines consumers' propensity to believe in brand-related fake news?

The rest of the study is organized as follows. Section 2 discusses the key constructs to set the background for the study. Section 3 describes the search protocol and list of conditions and outcome of interest. Section 4 describes the envisaged plan for data analysis. Section 5 outlines potential implications before concluding in Sect. 6.

2 Background

2.1 Fake News

Fake news in the context of marketing can have far-reaching consequences. Firms may end up as a target of fake news intended to alter consumers' perceptions about their products [13]. As firms increasingly focus on online advertising campaigns, it incentivizes fake news creators to publish more false content online [2]. Believability and sharing of fake news are influenced by multiple factors such as online trust [9], confirmation biases [14], emotions [15], partisanship [16], media literacy [17], and critical thinking [18]. However, it is widely acknowledged that fake news is not a monolithic phenomenon [19], and it remains unclear which combination of constructs determines why people believe in fake news. Individuals' susceptibility to fake news online is driven by a complex concoction of biases and a dynamic interplay of technological and societal variables. Hence, we seek definitive answers to the factors driving belief in brand-related fake news through a QCA-led meta-synthesis.

2.2 Meta-synthesis and QCA of Qualitative Case Studies

Meta-synthesis is widely recognized for its effectiveness in interpreting qualitative research studies [20]. In formal terms, it is defined as "an exploratory, inductive research design to synthesize primary qualitative studies for the purpose of making contributions beyond those achieved in the original studies" [21, p. 527]. In addition, the qualitative approach offers crucial insights into how people engage with fake news content and captures the diverse interpretations underpinning the process of forming a belief in false information. Towards this, we synthesize qualitative research to elaborate on the study phenomenon and aim to offer a rich interpretation of the causal complexities underlying the belief in brand-related fake news by employing QCA which helps measure such complex causal configurations effectively [22].

In contrast to quantitative studies that control for specific variables, qualitative studies analyze and monitor all variables to understand their interactions and the contextual elements that influence the phenomenon of interest [23–25]. In line with this purpose, QCA provides an abductive approach for establishing propositions and determining causal pathways to the outcome [26]. It overcomes a fundamental problem with cross-case analyses in which the integrity of individual cases must be preserved while accounting for differences and similarities in causal factors across cases. It offers a promising alternative to narrative synthesis in the context of literature reviews, and its use in literature reviews is limited but expanding [27, 28].

3 Methodology

3.1 Designing the Search Protocol

Our search protocol was driven by previous reviews on fake news in the marketing context [e.g., 2], including a typology of fake news [29]. We included additional keywords in line with prior reviews in the marketing and branding literature [e.g., 30, 31]). We added a third set of keywords to narrow our selection to qualitative studies and leveraged three databases, namely Web of Science (WoS), EBSCOhost, and Scopus, to locate relevant articles. A preliminary search yielded a total of 54 WoS listed, 176 EBSCO-host-listed, and 265 Scopus-listed English-language articles published in conference proceedings and journals till 2022. We compared the studies across the databases to arrive at 329 unique studies. Subsequently, a set of criteria was established to ensure that the selected studies aligned with the research purpose. The criteria for inclusion were studies with (a) qualitative research design, (b) primary data or data from social networks as focus, (c) belief in brand-related fake news as a dominant theme, and (d) elaborate descriptions of sampling approach. Research designs that were either (a) quantitative or (b) non-empirical were excluded.

First, we conducted a thorough review of the 329 studies, examining their titles by applying inclusion criteria (a) and (c) while also implementing exclusion criterion (a). The assessment process led to the identification of 144 studies. Subsequently, the abstracts of these studies were assessed to ascertain whether they employed a qualitative research methodology and were thematically situated within the realm of brand-related fake news. Through this process, 57 articles were chosen for full-text evaluation, all inclusion and exclusion criteria were applied, and 19 studies were identified as suitable for the study's context. As a concluding measure, we conducted a supplementary search through manual searching, and two articles congruent with the objective of our review were incorporated into the final corpus of 21 articles.

3.2 Data Extraction and Coding

An essential aspect of meta-synthesis involves conducting an analysis specific to each study [21] to extract and categorize evidence [32]. We employed content analysis wherein the authors independently examined and coded the chosen studies to investigate various factors contained within the articles and influencing belief in brand-related fake news. We utilized an iterative method, switching back and forth between the data and emergent categories while comparing the codes simultaneously. In the event of a disagreement, the authors discussed the reasons for the differences until a consensus was formed. Examples of first-order themes that emerged from this process were "fear-mongering," "Herd behaviors," and "Raising awareness."

Based on prior literature's conceptualization of factors driving belief in brand-related fake news and the content analysis, we began to establish a connection between the categories. As recommended by Hoon [21], we categorized related concepts into theoretical categories to determine second-order themes and develop case-specific causal networks. For instance, "anxiety," "anger," "pride," "stimuli to evoke emotions," "fear-mongering," and "sense of surprise" were collectively condensed into "Emotions" as a first-order category. Through this process, the first-order categories were condensed into a set of four second-order themes, namely (a) Groupism, (b) Cognitive reflection, (c) Emotions, and (d) Media literacy, with the outcome being belief in brand-related fake news. Each of these factors has been extensively recognized in prior branding literature as core elements influencing brands [33–36].

3.3 Configurational Approach to Factors Driving Belief in Brand-Related Fake News

At this stage, our study departs from conventional approaches to meta-synthesis. While meta-synthesis traditionally seeks to integrate the emergent themes and synthesize concepts from each case through a cross-case analysis, our approach is guided by QCA to identify configurations influencing the outcome of interest. The second-order themes derived from meta-synthesis constitute the conditions, and belief in fake news forms the outcome for QCA analysis. QCA guidelines suggest that one needs at least five observations per condition [37, 38], and our sample of 21 cases is deemed sufficient for the current analysis comprising four conditions.

4 Envisaged Plan for Data Analysis and Next Steps

Fuzzy set QCA (fsQCA) turns qualitative data into a fuzzy set with values ranging from 0 to 1 based on qualitative anchor points [39]. We choose a four-value fuzzy set, and Fig. 1 displays the calibration scale for the conditions and the outcome. Based on this calibration scale, we plan to engage in coding the articles for scores across the conditions and the outcome, ensuring high inter-rater reliability and consistency throughout the process. We then plan to assign membership values to each case. Before embarking on the fsQCA analysis, we plan to analyze contrarian cases in the sample, which helps identify cases not explained by the main effect. Next, we use fsQCA 4.1 software to analyze necessary and sufficient conditions that serve as the basis for formulating propositions to guide empirical advancements in the field. Lastly, as a test of robustness, we plan to vary the calibration anchors and choose a five-value fuzzy set to validate the findings.

		Calibration values			
		0 (Fully out)	0.33 (More out than in)	0.67 (More in than out)	1 (Fully in)
Conditions	Groupism	Groupism is not visible	Low level of groupism is demonstrated	Moderate level of groupism is demonstrated	High level of groupism is demonstrated
	Cognitive reflection	Cognitive reflection is absent	Low level of cognitive reflection is present	Moderate level of cognitive reflection is present	High level of cognitive reflection is present
	Emotions	Emotional intensity is absent or not discussed	Low intensity of emotions is present	Moderate intensity of emotions is present	High intensity of emotions is present
	Media literacy	Media literacy is not discussed or absent	Low level of media literacy is demonstrated	Moderate level of media literacy is demonstrated	High level of media literacy is demonstrated
Outcome	Belief in brand-related fake news	Propensity to believe fake news is absent	Propensity to believe fake news is low	Propensity to believe fake news is moderate	Propensity to believe fake news is high

Fig. 1. Calibration Scale for Conditions and Outcome

5 Potential Implications of the Study

The findings from this study have several implications for theory and research. Firstly, a multitude of factors have been discussed in the context of belief in fake news [40–42] while the body of literature researching fake news remains fragmented and several questions surrounding fake news remain unanswered [2]. Our research breaks through this clutter by focusing particularly on individuals' belief in fake news in the context of brands and the causal factors underlying this belief. In doing so, the review takes an exploratory approach to establish key causal configurations that determine belief in brand-related fake news. Secondly, the study introduces a first-of-its-kind methodological fusion of meta-synthesis and QCA to deliver crucial insights into factors driving belief in brand-related fake news. Unlike traditional approaches, this juxtaposition allows themes identified through meta-synthesis to be subject to fsQCA analysis, resulting in a set of configurations influencing belief in brand-related fake news. Collectively, we contend that this would serve as a foundation for future empirical research on belief in fake news while also motivating future studies combining meta-synthesis and QCA. Lastly, our study aims to provide vital insights for information systems practitioners who are constantly engaged in combating a deluge of fake news that poses a threat to businesses and brands worldwide.

6 Conclusion

Despite the growing menace of brand-related fake news, the causal factors influencing consumer belief in such news remain largely unclear. The complexities underlying belief in fake news as a phenomenon serves as an incentive to seek a novel approach involving a first-of-its-kind fusion of meta-synthesis as a research design and QCA as a method. The meta-synthesis helps identify a set of emergent themes through theoretical and substantive knowledge. These themes serve as conditions relevant to the outcome of interest. Based on this fsQCA-led data analysis, we aim to identify configurations influencing belief in brand-related fake news and formulate a set of propositions for future exploration. We contend that our findings will motivate further investigation at multiple levels of analysis to curb the menace of fake news.

However, the study's findings must be viewed in light of two limitations. Firstly, although our choice of keywords was driven by past reviews on fake news and marketing and branding literature and sought to capture as many relevant publications as possible, the possibility of excluding close-match keywords may have resulted in the exclusion of certain publications. Future research may broaden the scope and include a wider range of keywords to include more works in future reviews. Secondly, although our study seeks to discern factors driving belief in brand-related fake news, prior fake news literature highlights a substantial disconnect between what people believe and what they share [43]. Consequently, future research may seek to differentiate combinations of factors that drive the dissemination of fake news from those that drive belief in brand-related fake news.

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Big Data Analytics Adoption Framework and its Verification Using a Case Study

Shivam Tyagi[1], Veena Bansal[1], and Deepak Saxena[2](✉)

[1] Department of Industrial and Management Engineering, Indian Institute of Technology, Kanpur, Uttar Pradesh, India
veena@iitk.ac.in

[2] School of Management and Entrepreneurship, Indian Institute of Technology, Jodhpur, Rajasthan, India
saxenad@iitj.ac.in

Abstract. Many organizations are in the process of adopting big data analytics (BDA) to make data driven decisions. In this work, we have used a variant of CRISP-DM and broken-down processes into sub-processes, meanwhile also integrating critical success factors in the framework. We have validated our framework to understand BDA adoption via a case study of a big data analytics firm, referred to as ABC in this study. ABC helps large farmers to make farming decisions based on BDA. We conducted in-depth interviews with the Data science team of ABC to validate our framework. In terms of critical success factors, costing, project planning, adoption strategy, identification of business problems, project team formation, data management, training, change management and final preparation were identified as important by ABC for BDA projects. In addition, ABC also considers maintenance, evaluation of business objectives and overall project management critical that were not part of our model. We have incorporated these in our framework. Our research contributes to the growing body of knowledge on BDA adoption, offering valuable insights specific to the agricultural sector and emphasizing the challenges and opportunities posed by the substantial volume and variety of data in this domain.

Index Terms: Big Data Adoption Framework · Critical Success Factors · Big Data in Agriculture · Big Data Planning Phase · Big Data Implementation phase

1 Introduction

Today, many organizations produce, obtain and store data about their business and transactions, clients, suppliers etc. These organizations want to extract valuable knowledge about business from this data using big data analytics. The knowledge may be used for prediction or explanation [12].

Organizations must start thinking and deploying big data analytics for decision making to compete and survive [2]**.** However, organizations struggle with big data projects as around 85% projects are never completed or fall short of their objective [5, 9, 29]**.**

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There are many challenges that a BDA project encounters [15, 38]. The challenges that are critical for the success of the project are termed critical success factors. Inadequate attention to critical success factors could be a key reason for such failure rates [30].

There are two popular frameworks for data mining projects CRISP-DM and Scrum [23]. Since data mining is an integral part of big data analytics, in this paper we propose an integrated framework for Big Data Analytics projects, that is an adaptation of CRISP-DM. We have carefully associated Critical Success Factors (CSFs) across various phases in BDAA. A big data project may involve an external agency. We have also identified the roles and responsibilities of various teams involved in a project. Presently, most of the research papers seem to use a case-based approach for identifying CSFs [4, 30]. We have validated our integrated framework through a case study of a firm in the agriculture domain.

The remainder of the paper is organized as follows. In the next section, we review relevant literature including CSFs and their categories identified over the years. Thereafter, we present the proposed framework and CSFs in Sect. 3. Section 4 presents the case study and findings. The paper ends with conclusions and directions for future work in Sect. 5.

2 Literature Review

2.1 Characteristics of Big Data Analytics

McAfee and Brynjolfsson observe that big data is much more than *a lot of data* due to three key properties – Volume, Velocity and Variety – properties originally suggested by Laney [12] in relation to e-Commerce data management. It was later realized that three Vs do not fully capture the nature of big data. Subsequently, two more Vs- Value and Veracity were added [24].

Big Data Analytics (BDA) refers to a set of techniques based on data mining, artificial intelligence, neural network, predictive analysis and more. BDA can help firms in data driven decision making to create value for the organization [10, 16]. In the agriculture sector, BDA can help farmers in enhancing their efficiency, improve profitability and competitiveness via smart agriculture [14], meanwhile also contributing towards sustainable development. BDA is extensively used to discover genetically modified seeds that provide better yield and are less susceptible to diseases.

However, developing BDA capability is not an easy task and requires significant effort [17, 26].

2.2 Adoption of BDA in an Organization

Big Data Analytics Adoption (BDAA) in an organization starts with the identification of business problems and culminates with deploying a data analytics solution in the organization. However, accurate identification of business problems itself is a big challenge [32, 33, 38]. We need a framework that includes all phases, processes, and events of a Big Data Analytics Adoption project [22, 33]. Due to underlying similarity, data mining frameworks may be useful for BDA adoption projects. CRISP-DM [28, 35, 37] by far is the most popular framework**.** CRISP-DM stands for CRoss-Industry Standard Process for Data Mining. This framework is for data mining projects and consists of the following six stages **-** Business Understanding, Data understanding, Data Preparation, Modeling, Evaluation and Deployment.

CRISP-DM is a very high-level framework that is only partly suitable for BDAA [23, 36]. This is because a BDA project is also closer to an Enterprise Resource Planning project that impacts the culture and structure of the host organization [31]. Thus, an integrated framework that considers business, technology and people dimensions is more suitable for a BDA project. One problem with these frameworks is that no attention has been paid to different models of executing a BDA project. There are three possibilities, namely in-house team, outsourced and a combination of the two. The role of the client changes according to the model. None of the frameworks specify the roles and responsibilities of various parties involved in the project. It is where this paper seeks to fill the gap.

2.3 Critical Success Factors for BDA Projects

Critical Success Factors (CSFs) are factors that must go right for a business, an organization, or an individual executive to succeed [25]. CSFs have been defined as the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organization [20].

Because of high investment and expectations from BDA projects, CSFs are important for managers to help them understand what needs to be done to accomplish objectives and targets. CSFs identified in literature are summarized in Table 1.

It may be noted that the classification shown in Table 1 is not straight jacketed and the categories may have some overlap. Some authors have merged people and process into one [30]. A distinction between a factor and what is critical about the factor is important. Management support is a factor as a project cannot take off with their support. However, once a project has been conceived and taken off, what is critical about the support of the management is their availability and commitment to resolve issues in a timely manner.

Another common problem is that no distinction is made between factors that are critical and must be resolved before the project can commence and the ones that are critical for the project to succeed.

Table 1. CSFs for BDA project and their categories

Category	CSF	Reference
Organization	Alignment of BDA strategy and Business strategy	[21]
	Adequate resources: Financial & Human Resources	[15, 27]
	Project Management: Scope & Timeline	[8, 22, 23, 39]

(*continued*)

Table 1. (*continued*)

Category	CSF	Reference
	Change management	[8, 17]
	Top management support	[15, 19, 30]
Process	Clear identification of business problem	[6, 10, 39]
	Information sharing	[8, 30]
	Project Methodology	[8, 23]
People	Multidisciplinary team: Domain, BDA solutions, Hardware knowledge, Data scientists	[4, 5, 8, 15, 19, 26, 27, 30]
Technology	Availability of BDA solutions	[15, 22, 23, 30, 34]
	Integration of BDA with existing systems	[15]
	Data Ecosystem	[6, 15, 30, 34]
	Infrastructure Readiness	[1, 34]

For instance, data quality that is part of the data ecosystem [6, 15, 30] is a factor that is non-negotiable and must be in favor before the project can commence. On the other hand, Integration of BDA with existing systems is a factor that needs attention after the project commences.

3 Proposed Framework for BDAA

Big data analytics adoption consists of four phases – pre-planning, planning, implementation and deployment. During the pre-planning phase, a high-level business problem is identified, and the readiness of the organization is checked. The business problem may be identified by a functional head such as sales, marketing, operations with an objective of reducing cost or making future strategies based on data analytics. CXO may also take the initiative and identify a broader canvas for data analytics. A small team may be formed by the management to study the feasibility of adopting data analytics. Team may ask and answer questions such as, "W*hy do we need to adopt BDA?", "*W*hat are the business needs of the organization?", "*D*oes our big data strategy align with the business strategy?"*. The objective of this phase is to answer the question- "A*re we ready to adopt BDA?"*. The organization may discover that it is not ready to adopt BDA due to the presence of various barriers [1]**.**

Once an organization ascertains its readiness for DBAA, objectives of the BDA project are clearly defined before the project commences. At this stage, a sales department may define the data analytics problem as "*increase sales through cross and up selling across multiple channels"*.

The planning phase (shown in Fig. 1) overlaps with strategic groundwork proposed by [7]. The planning phase commences after it has been established that the organization is ready for adopting big data analytics. The planning phase starts with identifying a project manager by the management. The project manager assembles an in-house team. We refer to this team as Team A in Fig. 1. Team B [7] consists of functional heads of relevant departments (functional team) and technology experts (technical team) and is headed by the project manager. Team B refines the problem and translates it to a corresponding big data analytics problem. The objective "*increase sales through cross and up selling"* may translate to create a model to *identify potential customers for cross and up selling. The* project team is not responsible for increasing the sales. Team B makes a strategy for the project. While strategizing, team B may feel the need and extend team B to team C by adding an external consultant. If no consultant is added, team C is the same as team B. Team C identifies and evaluates viable solutions. The existing infrastructure is also examined for its suitability for the project. Team C creates a detailed project plan. The project plan includes tasks, cost**,** timeline and a risk analysis, mitigation and management plan [22]**.** The team needs to formalize processes for selecting big data analytics solutions, vendor, implementation partner and technology to be used**.** The team also identifies project methodology such as agile methodology. All the planning done should be documented properly [30]**.** The document created in this phase is used as reference for the rest of the project by the team. As soon as the project objectives are decided, a part of team B may start working on exploring the data ecosystem and establish a data pipeline.

The next phase, namely the implementation phase, is like any other project involving IT and business such an ERP implementation. Team C may select and add an external implementation partner to create team D. A vendor for additional hardware, if required, is selected. Most suitable big data analytics solutions, amongst all solutions identified and evaluated in the previous phase, are implemented by the team D. Data pipelines for required data are established. Once the implementation is complete, it is tested and integrated with existing systems. Finally, the newly created big data analytics solution is deployed. In parallel, a separate team may start training sessions for stakeholders [6]. Another team may create a change management plan and execute it to handle issues of employees.

4 Critical Success Factors for BDAA

We discussed CSFs in Sect. 2. In this section, we will associate CSFs with phases of a big data analytics project. There are certain factors that are critical for the entire project while others are phase specific [30]. This distinction is important for managing the project successfully. A project manager can focus only on relevant CSFs as the project progresses. A factor may play differently during various phases of the project. Consider *top management support*, this is a factor that is relevant for the entire project. However, during the pre-planning phase, the management should extend its support for the project. During the planning phase, top management should extend its support by allocating the required funds and resources. During the implementation phase, the management should support stakeholders by allocating funds and resources for managing changes.

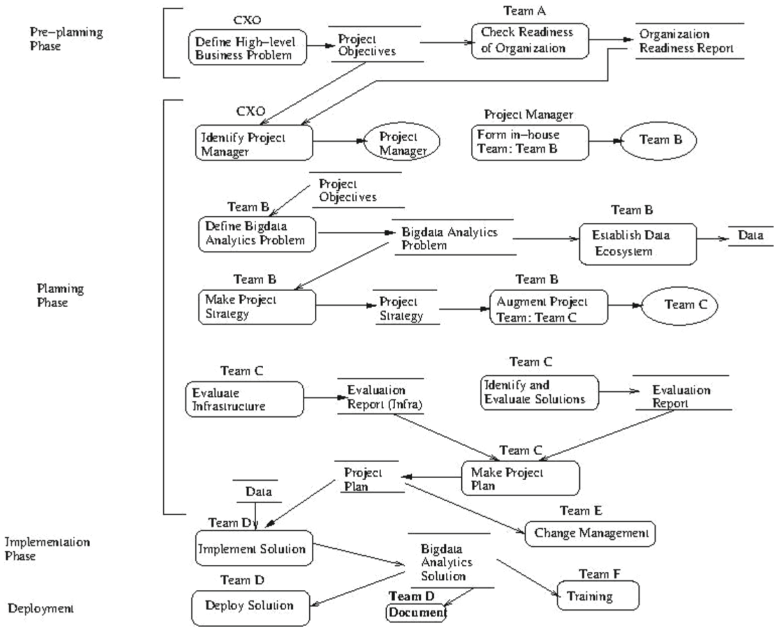

Fig. 1. Different phases of Big Data Analytics Adoption.

There is one factor that is critical throughout the project and that is sharing information about the project with all stakeholders. Another factor that is critical throughout the project is the support of the top management. The manifestation of top management support varies across various phases of the project. CSFs that need to be taken care of during the pre-planning phase are included in Table 2. CSFs that need to be taken care of during the planning phase are included in Table 3. CSFs that need to be taken care of during the implementation phase are shown in Table 4. CSFs that need to be taken care in the deployment phase are included in Table 5.

Table 2. CSFs related to the processes mentioned in the PRE-planning phase

Activity	CSFs	Managerial Action
Define business problem	Clear identification of business problem to be solved by big data analytics problem	Quantitative Measure of success of business problem
Readiness of organization	Alignment of business and big data strategy	Figure out how big data will support business
	Top management support (Organization)	Ensure that top management is supportive of the project

Table 3. CSFs related to the processes mentioned in the planning phase

Activity	CSFs	Critical Component
Identify project manager	Project methodology	Project manager should be well versed with project methodology
Form in-house team	Multidisciplinary team	Business domain knowledge
		Big data solution experts
Define Big Data analytics problem	Clear identification of big data analytics problem	Quantitative Measure of success of BDA
Establish data ecosystem	Access to data IT infrastructure	Ensure availability of required data
Make project strategy	Project Methodology	Project methodology should be suitable for big data analytics adoption
Augment project team	Multidisciplinary team	If in-house team feels the need, add an external consultant
Evaluate Infrastructure	Flexible and appropriate technological framework	The existing IT infrastructure should either support or should be extendible to support BDA
Identify and evaluate BDA solutions	Multidisciplinary team	Team should have expertise and knowledge of existing big data solutions
	Top management support	Ensure availability of adequate funds
		Relieve team members for the project
Make Project Plan	Project methodology	Establish scope of the project
		Estimate cost
		Risk mitigation and management plan
		Defined processes for various procurements
	Top management support	Establishing processes to legitimize the project hierarchy and leadership

5 Validation of Proposed Framework: A Case Study

We validated our proposed framework with the help of a case study with an Agri-Business Corporation (ABC) whose BDAA we explored in this study. In 2012, agriculture didn't even feature as a possible domain for analytics [3] but some companies had already started BDA implementations in the sector. Our objective is to understand- why an

Table 4. CSFs related to the activities mentioned in the implementation phase

Activities	CSFs	Critical Component
Big Data Analytics Implementation	Multidisciplinary team	Utilizing and retaining people with domain knowledge, hardware, BDA solutions and statistical and analytical skills
	Data ecosystem	Data pipelines
		Data quality
	IT infrastructure	Testing and making sure that there are no issues associated with technology stack
	Project management	Scope of the project must be contained
Change management	User oriented change management	Users are informed and involved throughout the implementation so that they consider themselves stakeholders of BBAA

Table 5. CSFs related to the activities mentioned in the deployment phase

Processes	CSFs	Critical Component
Deployment	Integration with the existing system	Input/output channels should work smoothly
Documentation	Shared	Controlled access and modification
Training	System Training	Organization-wide training programs are conducted on the new system
	Statistical and analytical skills	A data-oriented culture and analytics-based decision making is promoted in the organization

organization adopts BDA, how it carries out a BDA project, and to identify the challenges faced by the organization in implementing and adopting BDA in the agriculture sector. We conducted in-depth interviews of the data science team of ABC. We interacted with the data science team of the organization including data scientist, data science team lead, and data stewardship and analytics lead. The findings are discussed in this section.

ABC is in the domain of smart farming and focuses on improving yield. ABC adopted BDA in their organization 10 years ago. The organization works in trait discovery using genomic information. They also work in precision agriculture which is a management strategy that gathers, processes, and analyzes temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production [11]. Predictive analytics software uses the data to give farmers advice on crop rotation, optimal planting times, harvesting times, and soil management. They also predict infestation in the field. f there are satellite images or drone images that are analyzed to identify an infestation and the farmer is warned, the farmer can take care of the infestation and can prevent its spread to the rest of the field.

ABC adopted BDA for trait discovery using genomic information 10 years ago. They subsequently started providing services to farmers using BDA for precision agriculture and predicting infestation in the field. We focused on adoption of BDA by the organization. Data from ABC was collected using a structured questionnaire. The organization validated our framework and made some observations.

5.1 Few observations and Discussion

The data science team of ABC observed that the project strategy and plan will implicitly bring in many processes. Some of these are as follows.

1. Project management is an implicit part of the Implementation phase.
2. If agile methodology is adopted for the project, evaluation is an ongoing activity. The project is evaluated regularly and not only at the end of the implementation phase. Hence a separate test phase is not required.

The team strongly felt that documentation is very important for a big data analytics project and it should be added as an activity. We have added this activity to the framework. The documentation may be done during the implementation and deployment phase. They also emphasized on adding a maintenance phase right after the deployment phase. We agree with the team but we have not added a maintenance phase to the framework shown in Fig. 1. Our framework got validated through this case study based upon participants' responses. It is established that BDA is not a monolithic activity. It has four phases, each with clear objectives. Breaking up the adoption into phases and activities makes a project manageable.

After adopting BDA for developing GM seeds, ABC started providing services to their clients for precision farming and infestation detection. Both these services involved big data analytics. Most of their clients are owners of large farms and do not have IT capability. ABC builds solutions for them. Teams A, B, C and D are constituted by ABC. A farm owner and ABC work together to identify a business problem and from there onwards, ABC teams carry out the project.

6 Conclusion

We used the case study approach to validate our proposed framework of BDAA. Our results reveals that out of all the Critical Success Factors (CSFs) of our model**,** clear identification of business problem, adequate resources, access to capital, flexible and appropriate technological framework, creation and dissemination of documentation, IT infrastructure, multidisciplinary team, statistical and analytical skills, project scope management, project leadership, technical support from vendors, data quality, data integration, user oriented change management, training and development of employees, alignment of the business strategy with the big data strategy were important CSFs for the organization while executing any BDA project. Based on the interaction with the organization, we discovered that maintenance, evaluation of business objectives, project management and documentation are also deemed important. We need to validate the proposed framework using case studies in other environments.

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Diffusion and Adoption of Information Technology

Preferred Level of Servitization in Select Industrial Services

V. T. Rakesh[1,2](✉), Preetha Menon[3], and Ramakrishnan Raman[1,2]

[1] Symbiosis Institute of Business Management (SIBM), Pune, India
vtrakesh@hotmail.com

[2] Symbiosis International University (Deemed University) (SIU), Pune, India

[3] FLAME School of Communication, FLAME University, Pune, India

Abstract. The purpose of the research was to study what ails Servitization. It was also an endeavor to study if there is an optimized level of servitization for which customers tend to pay maximum price premium. A thematic literature review, followed by qualitative research involving in-depth interviews, adopting an inductive approach was used as methodology. It was found that servitized products command a price premium, but the preferred level of servitization is 20–40% at which the price premium peaks (10–20%), beyond which customers do not prefer servitization. Brand Equity of service provider, Location of service provider and Quality of service provider, emerged as the three salient attributes that contributed towards willingness to pay for servitized products.

Keywords: Servitization levels · Brand Equity · Price Premium · Industrial Services

1 Introduction

Manufacturing companies the world over were reeling under the pressure of increasing costs and excess capacities in the market. It is at this juncture that some of them ventured into offering services alongside the products thus adding value to the customer and commanding a better price. This process, which later came to be known as Servitization, was adopted by many companies looking at the success of some of the pioneers of it like IBM.

Kamp and Perry (2017) states that Servitization has immediate effects and profits increase till the companies start investing on building up the facilities and manpower to further enhance the results. Kastalli and Van Looy (2013) say that as the companies stay put further, the profits again start increasing due to economies of scale. But Servitization was a mixed bag and many companies failed in it. Such extremities wherein some cases of Servitization became runaway successes and others became utter fiascos brought in a new term called Servitization paradox. Chaudhary et al. (2022), defines Servitization paradox as three different paradoxes (paradoxes of organising, performing, and learning). They also cited the research gap when it comes to failure of Servitization and the various

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anomalies that could be causing such failures. They also substantiate that the most daunting thing about Servitization was that firms were not able to be successful when they entered a new market altogether. The solutions offered by Chaudhary et al. (2022) were change management, open communication, training programmes and digitalisation. Most of these firms who failed were the ones with high brand equity. This points to the fact that they were not able to capitalize the brand equity through price premiums. This aspect remained a research gap and had to be found out on why firms with high brand equity failed while they entered new markets. Chaudhary et al. (2022) points out the lack of research to substantiate the paradoxes ailing Servitization and the remedies thereafter. Is there a particular level of Servitization which fetches the maximum price or is it proportional to Servitization level, i.e., more the level of Servitization, more the price premium will be paid?

2 Methodology

A thematic literature review was done covering the topics of Servitization, brand equity and pricing models. Journals of repute were covered like Industrial Marketing Management.

Qualitative research was conducted which involved in-depth interviews. For the research, an inductive approach was selected. Twenty open-ended questions were asked. The number of interviewees was twenty-five, since saturation was observed by the time 25 interviews were conducted. The Interviews were transcribed, and content analysis was conducted to find the outcomes.

2.1 Thematic Literature Review

The literature review was conducted covering the three topics of Servitization, brand equity and pricing models. Under Servitization, the sub-topics of Services marketing, theory of Servitization, pro-Servitization arguments, critical of Servitization arguments, problems and solutions for Servitization were covered. Sub-Topics of concepts of brand equity and brand equity models were covered under the topic of Brand Equity. Whereas pricing theory and pricing models were sub-topics covered under the topic of pricing models.

Bendixen et al. (2004), echoes what Aaker and Equity (1991), and Firth (1993) had been stating earlier that brand building activities and a strong brand equity result in better price realisation. Casidy et al. (2019) added to it when they said that a customer has always made up his or her mind to pay a price premium much before the purchase is physically done, and for this he or she is always swayed by the brand equity of the customer.

Keller and Lehmann (2003) explicitly state that brand equity is a relative term and is measured with reference to other brands. When it comes to the highly competitive and price sensitive services sector, brand equity plays a key role in tilting the table towards success (Casidy et al. 2019). Nam et al. (2011) also counted this as one of the foremost ways to expand in the market. Ohnemus (2009) and Persson (2010), both believe that building a good brand would help the company to improve profitability by commanding a price premium. Panda et al. (2019) also bet on investing in a brand, positioning it well and thereafter reaping a premium. Qorbani et al. (2021) echo the same when they state that brand differentiation is what does the customer acquisition for companies. Yeniaras et al. (2021), talk about the paradoxes that are preventing Servitization from being a success and list the failure of companies entering a new market as a proof of such paradoxes. They further say companies must choose between either modifying their products and services or coming out with altogether new products and services and cannot do both. Chaudhary et al. (2022) state that the freedom given to employees enhances their performance but excess of it could divulge the focus and maintaining the right balance remains a bottleneck. Gabor-Granger (GG) indirect pricing model (Wu et al. 2021), Van Westerndrop (VW) price sensitivity model (Ceylana et al. 2014), Product/price mix models or Conjoint and Discrete Choice Models (DCM) (Lipovetsky et al. (2011), are some of the models, researchers have brought up, but none of them considers brand equity as a factor. Lee et al. (2016), considered factors like Service Dependency (v), Substitutability (w), Quality sensitivity (x), Market Base (y), Quality cost coefficient (z), Price (p), Quality of goods (q) and Demand for goods (D) in their pricing model. Xia et al. (2021) came out with a pricing model for aftermarket services considering price sensitivity and market size. Here again, brand equity of the service provider was conspicuous by its absence buttressing the research gap in finding why companies fail while entering new markets.

2.2 Qualitative Study

A qualitative study was thus needed to understand the customers' perception about effect of brands on price, to check if Servitization is a welcome move for the customers and is there an optimum level of Servitization from the point of view of willingness of customers to pay. A geographical area had to be chosen where it had a cross section of all kinds of industries and under a particular industry vertical had many companies. Surat in Gujarat turned out to be a right place which had heavy, medium, small industries and had many variations under these categories as well. It also had a diaspora of manufacturing, heavy engineering, power, chemical, textiles, and defence industries. Hence Surat in Gujarat was chosen as the geographical location of research.

The questions which were asked included twenty open-ended questions. Since it was an inductive approach, no kind of guiding or probing was extended to the respondents. Respondents were asked about their opinion on servitised products, and fuzzy-set qualitative comparative analysis (fsQCA) was done to generalize the factors and identify attributes and services (Das et al. 2022).

3 Summary of Findings

Industries have three kinds of services. Basic services, Intermediate services, and Advanced services. Basic services are routine in nature but are critical to the operations. Intermediate services are the ones which are not routine services but are critical to some extent for day-to-day operations. Advanced services are sparsely taken and not critical for day-to-day operations but need advanced skills.

Table 1. Kind of Services

Kind of Services	Examples of services	Percentage share
Basic Services	Overhauling, break-down, and fire and safety	40%
Intermediate Services	Logistics, inspection and condition monitoring	40%
Advanced Services	Efficiency enhancement, extended warranties	30%

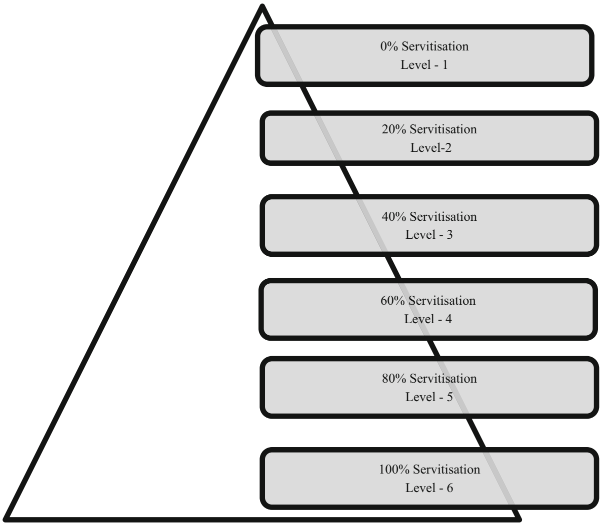

Fig. 1. Servitization Levels

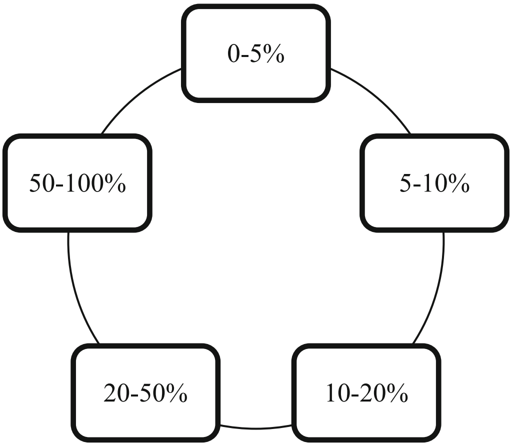

Fig. 2. Price Premium bands

Table 1 gives further clarity on kind of services with examples and percentage share in the total gamut of services. Customers of industrial services welcome Servitization with open arms. They are therefore ready to pay a price premium for such servitised products. But the customers being technocrats and engineers themselves, they would like to limit this extra money they would be paying for servitised products. This they want to ensure by limiting the kind of services they would take from manufacturers. Customers prefer to take only the basic services from the manufacturers. Figure 1 gives the details of Servitization levels considered and Fig. 2 the details of price premium bands considered in the research. Customers going for servitised products had the apprehension of whether the premium they pay for the Servitization of the product is justified. Hence one out of five customers still preferred to go for level-1 or unservitised products. The rest were ready to pay a premium as they in-principle welcomed the idea of Servitization and appreciated the benefits of it. And 75 percent of customers thus preferred a Servitization level-2 or level-3 at the most. This preference was mainly because this was the Servitization level for which they were ready to pay maximum premium. For any increase in the level of Servitization beyond level 2 and 3, customers had two apprehensions. One was that any premium they would be paying for these increased levels of Servitization, they would not get the proportionate value addition. Second apprehension was that such high levels of Servitization would be binding the customer to the supplier fully and this would give way for a monopoly. Customers wanted the freedom of choice and therefore to keep the options open. Also, the apprehension included the fact that in case of the supplier quitting the market or stopping to serve, then customers would be left with no alternative. All these reasons prompted the customers to gravitate towards 20% to 40% of Servitization, when it came to paying maximum price premium. The three attributes that customers valued the most, when it comes to paying a price premium were 1) Brand Equity of Service Provider 2) Location of Service Provider and 3) Quality of Service. These three services were highlighted by all customers as the ones they consider while ascertaining their willingness to pay for the select services.

As far as price premium bands are concerned, customers considered 10–20% (highest premium they were ready to pay) when it came to Servitization levels of 20% to 40%. They never went to the higher extremes of the price premium bands. Since customers prefer the Servitization level to be limited to 20–40% of the total services, this insight would help the managers who are implementing Servitization.

4 Managerial Implications

Managers who were implementing Servitization were confused on to what extent the services should be included in the servitized products. Without a clear roadmap from researchers, managers resorted to trial-and-error methods which proved to have very high opportunity costs. This research gives a clear verdict to the managers that “more the merrier” approach will not work in case of servitization. This research, by pointing out the 20–40% bracket as the optimal level of servitization, helps the managers in their implementation strategy of servitization, thus making such ventures more successful.

5 Future Scope of Research

This research was limited to the state of Gujarat in India. Pan-India research would be helpful to give more accuracy and reliability to the findings. This research was cutting across many industries. Industry specific research can give more accurate results for those respective industries.

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Three-C Framework for Social-Aware Resource Sharing

Pramod C. Mane(✉) and Praveen Ranjan Srivastava

Indian Institute of Management Rohtak, Rohtak, India
{pramod.mane,praveen.ranjan}@iimrohtak.ac.in

Abstract. This article presents a communication-cooperation-collaboration (Three-C) based framework of social cloud that incorporates a socio-technical perspective. One might look at the variety of reported views and perspectives on the social cloud and see that it can serve as a special kind of computing paradigm. But, the overall concept of the social cloud is muddied by so many divergent perspectives discussed in the literature. Therefore, there is no clarity and unified view of the social cloud. Our effort unifies the concept of social cloud, making it easier to see its promise and offering a path towards its continued development and deployment in enterprise and academia. Further, this article discusses social cloud implications in business settings.

Keywords: Social Cloud · Cloud Computing · Social Network · Resource Sharing · Conceptual Framework

1 Introduction

Patrick Gelsinger, then the Chief Technology Officer of Intel, spoke with David A. Light of HBR in 2001 [5], emphasized the importance of finding ways to put idle computers to productive use. He recommends using distributed computing, in which tasks are assigned on numerous machines scattered across the network, as opposed to centralized computing, in which tasks are assigned to a single system. During the course of the discussion, he also mentioned that huge businesses could save millions of dollars by making complete use of the computing capacity that is sitting idle on personal computers, servers in their organizations, or users at the edge of the Internet.

In the realm of academic discourse, numerous attempts have been made to integrate and make use of the unused computing resources that are available at the edge users of the Internet who are socially connected. The term "social cloud" encapsulates these developments and the concept of social-aware resource sharing. Hagel III and Brown[1], Hamalainen and Karjalainen [6], and Kaganer et al. [8] explore the power of the social cloud and connect it to businesses by discussing how enterprises might leverage the potential of the social cloud.

1 https://hbr.org/2010/10/the-power-of-the-social-cloud.

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1.1 Social Cloud Framework: Motivation

Mane et al. [14] demonstrate that academics disagree on social cloud. The literature's definition of a social cloud is ambiguous and can take several shapes, which raises questions regarding its uniqueness. These many definitions and perspectives on social cloud do not provide answers to issues such as: what is the scope of social cloud? who are the social cloud's stakeholders? what sharing mechanisms govern resource sharing among users? how will users and organizations trade resources? why do users and organizations want to trade resources with each other? how will users and organizations trade resources? and who will provide support and for what purposes? Further, the definition [3] ("A Social Cloud is a resource and service sharing framework utilizing relationships established between members of a social network") is inadequate to develop the theory of social cloud. Agents' active or passive engagement in resource-sharing alliances is ignored in this definition. It also doesn't address who uses social cloud connections-participants or third parties. To develop the theory of social cloud, in our view, in addition to the above notion, we need to shed new light on the notions such as limit sharing [3] (for example, social network users share their resources with only friend or friends), and explicit partner selection [16] (where social network users select their partners). Thus, a general framework of social-aware resource sharing is needed to: 1) address the above issues, 2) guide its application, 3) provide a starting point for developers and practitioners to reflect on how the concept of social-aware resource sharing can be applied to social cloud systems, and 4) connect social cloud to businesses.

1.2 Towards Framework

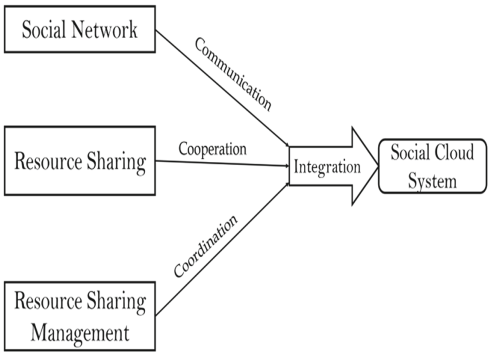
The idea of social cloud arose to take advantage of the social connections between users in order to overcome problems inherent to different computing paradigms (such as security, trust, free-riding or social loafing, etc.). We believe that the above concerns can be answered by examining social cloud from three different perspectives: communication, cooperation, and coordination. This will result in a more comprehensive view of social cloud.

According Kim et al. [9], 'highly qualified' collaborative systems needs 3C, that is, Communication, Cooperation, and Coordination. Kim et al. [10] states: Communication: is the community linkages where the exchange of information takes place. Cooperation: is the sharing of information, activities, and service integration, while working to achieve the same goal between two or more organizations. Coordination: is operating autonomously while coordinating information, activities and resource sharing.

As shown in the figure given below, the social cloud system we broke into three parts after decoding the definition [3]: social network, resource-sharing activity, and resource-sharing management.

Communication: as social network facilitates exchange of information, resource sharing and in negotiations among socially connected users and organization
Coordination: as a resource sharing management consists of autonomous operation or functionalities that support users or organizations while coordinating information, activities and resource sharing

Cooperation: Share of resources and information while performing activities between two or more organizations to achieve a common goal.



1.3 Our Contribution

Our research is one of the first attempts to establish a theoretical framework for the social cloud, which is based on the concepts of cooperation, coordination, and cooperation. We consider a wide range of perspectives on topics like "limit sharing or partner selection" and "use of pre-established social relationships" that have been discussed in the literature (but missing in [12]). We model 3C-Social-Cloud-Theoretical-Framework using a network-based approach. This approach is logical for modelling the proposed framework because social networks are central to most social cloud research. We see a social network as the basis for agent communication. A virtual cooperative overlay on a social network can conceptualise cooperation among social network agents. A group of agents shares resources to perform tasks (different from the tasks they perform in the underlying social network). A coordinating mechanism supports the cooperation of these agents. We belive the suggested framework will be useful for the creation of a thorough theory of social cloud, the improvement of various social software systems, and the education of businesses about the advantages of social cloud.

2 Social Cloud: Theoretical Framework

This section presents the 3C-Social-Cloud-Theoretical-Framework (see Fig. 1). We view Social Cloud as a cooperative computing framework that stands on notions: communication, cooperation, and coordination, where cooperation and coordination are at the center. More precisely, cooperation and coordination constitutes a social cloud system.

2.1 Communication

Internet and other technologies enable agent-to-agent communication. Offline agents can build their social network using an online platform. An online social network platform can be captured as follows.

Definition 1. *An on-line social network system a_g=(A, A^g, F^g) is a tuple of three sets; a set A of agents {a_1, a_2 ,... a_n} in the offline world, a set A^g of activities {$a_1{}^g$, $a_2{}^g$, ..., $a_n{}^g$}, and a set F^g of functionalities (or entities) {$f_1{}^g$,$f_2{}^g$,..., $f_n{}^g$}*

An agent $a_i \in A$ performs an activity $a_i^g \in A^g$ with other agents in **A** with the help of a functionalities set F^g. An activity $a_i^g \in A^g$ could be sharing of profile (consist an individual's information like an individual's pictures, work experience, education, etc.), content (consist music, videos, etc.) or computational resources (e.g., storage, bandwidth, processing power, etc.).

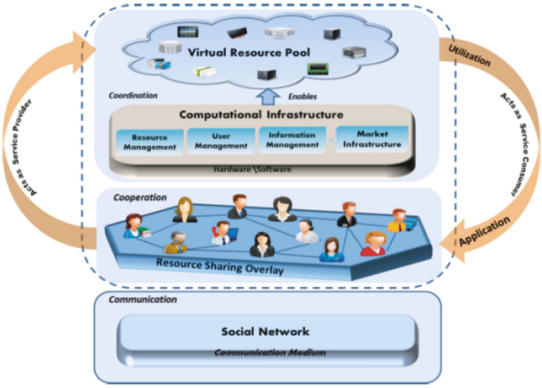


Fig. 1. 3C- Social Cloud Framework

The functionalities set F^g consists of several entities and functionalities, which provide a way for agents to share their profile, visual contents, or computational resource with their social relatives. Note that, a social network platform a_g consists of a set of functionalities F^g supports all activities in g. Hence, an agent can perform all types of activities in A^g with other agents. Now onwards in this paper, we assume an activity set A^g as a singleton activity g. A social network system enables an agent to engage in activity with other agents, regardless of whether or not the agent and the other agent have any kind of social contact with one another in the physical world.

Facebook, for instance, facilitates agents with profile, audio, and video sharing. Instagram, Pinterest, and Flickr are other content-based social networks offers content-based sharing where agents share visual content with their social relatives. Buddy Backup and CrashPlan are social network systems where agent's backup data with their friends. Wikipedia is a social network that lets its editors share content and vote for administrators. Specifically, social network platforms enable agents to articulate their online social connections, which can be represented as a social graph and modelled as follows.

Definition 2. *A social network (graph) $g = (A, L, a^g)a^g$ is a tuple of two sets; the set **A** of agents, a set **L** of links, and the activity.*

A social network g reflects the social structure of these agents, i.e., how agents are involved in activity a^g. In fact, who perform the activity a^g with whom determine the social structure of g. A link $\langle ij \rangle \in L$ between agents $i \in A$ and $j \in A$ represents their direct involvement activity a^g, , otherwise they are indirectly involved. Facebook social graph is an example of g which represents the social structure of the Facebook participants and the activity (with whom they perform profile sharing, like comment, audio, video sharing, etc.) they perform in Facebook.

2.2 Cooperation

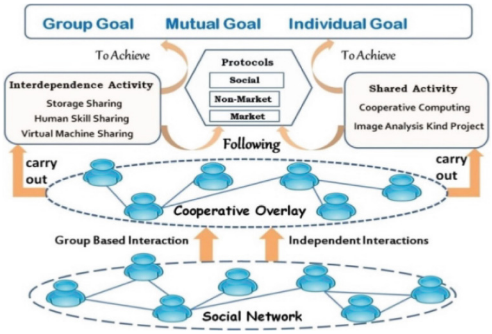


Fig. 2. Cooperative Overlay

A cooperative overlay $\overline{g}$ evolves on top of g, when either,

- *A $\overline{A}$ (where $\overline{A} \subset A$) number of agents forms a group to achieve a shared goal or a mutual goal, or*
- *An agent $i \in A$ takes decision independently with whom s/he wants to cooperate and with whom s/he do not want in g, then a mutually agreed pair of agents $i, j \in \mathbf{A}$ cooperates each other to achieve a mutual goal*

Cooperation among a set of agents ($\overline{A} \subset A$) in carrying a set $A^{\overline{g}} = \left\{a_1^{\overline{g}}, a_2^{\overline{g}}, \ldots, a_n^{\overline{g}}\right\}$ of activities can be perceived as a cooperative overlay (see Fig. 2) and captured as follows.

Definition 3. *A cooperative overlay $\overline{g} = (\overline{A}, \overline{L}, A^{\overline{g}})$ is a tuple of three sets; a set $\overline{A} \subset A$ of agents, a set $\overline{L} \subset L$ of links, and a set $A^{\overline{g}}$ of activities.*

On one side, a few studies suppose social cloud as a resource (physical or virtual entities of limited capacity including people, information, computational resources, etc. [3]) sharing framework, on the other side, a few studies look social cloud as a distributed computing framework where agents perform a computational task [15]. Instead of looking at social cloud as either resource sharing or distributed computing framework, we consider that a set $\overline{A}$ of agents perform the set of activities $A^{\overline{g}} = \left\{a_1^{\overline{g}}, a_2^{\overline{g}}, \ldots, a_n^{\overline{g}}\right\}$, which are different than those set of activities (A^g) they perform in the underlying social network g, i.e., $A^{\overline{g}} \cap A^{g} = \varnothing$. As like previous, we consider, the set $A^{\overline{g}}$ as a singleton and represent it as $a^{\overline{g}}$, whereas $a^{\overline{g}} \neq a^{g}$.

An activity $a^{\overline{g}}$ can be an interdependence activity [11] (refers to exchange/share/trade information, computational resources, human skill as a resource, etc.) or a shared activity [2] (refers to do something together, for example, resource pooling, or performing a computational task, etc.). A shared activity $a^{\overline{g}}$ further divided into a few numbers of sub-activities (or tasks) (e.g., $a^{\overline{g}} = \hat{a}_1^{\overline{g}}, \hat{a}_2^{\overline{g}}, \ldots, \hat{a}_m^{\overline{g}}$). A sub-activity, say, $\hat{a}_i^{\overline{g}}$ is assigned to an agent (say, $i \in \overline{A}$), and then, each agent $i \in \overline{A}$ brings its result (of the assigned sub-activity) to the table.

A set $\overline{A}$ of agents cooperates with each other to obtain either a common goal, an individual goal, or an individual's goal by carrying out an interdependence activity or a shared activity. A set $\overline{L}$ of links provides an abstract view of the social structure of cooperative interaction (who cooperates with whom) of a set $\overline{A}$ of agents who are involved in the activity $a^{\overline{g}}$. As we stated earlier, a cooperative overlay $\overline{g}$ evolves on top of an underlying social network g through a group-based interaction or independent interaction between a pair of agents in g.

Cooperative Overlay as Group Interactions. A cooperative overlay $\overline{g}$ can be seen as group interactions. A set $\overline{A} \subset A$ of agents in the underlying social network g constitute a group to perform activity a $\overline{g}$ (could be a shared or an interdependence activity) to obtain a common goal, individual's goals or goal of each member of the group. A virtual organisation [4], for example, is a group of individuals or/and organisations that share resources available at their end) in a controlled manner to achieve a common goal.

Group members define the activity they want to do (e.g., shared or independent activities) and set the group's goal (e.g., a shared goal, individual's goal or goal of one of the participants). They establish a set of guidelines for how group activities are to be conducted, as well as rules for group membership, social protocols, and market protocols. How the group takes place defines the structure of cooperative overlay $\overline{g}$, and thus cooperation pattern.

Strongly Connected: If each group member has direct contact with all other members, we can observe that the group is tightly connected.

Loosely Connected: A loosely connected group has few members in direct contact with one another. A loosely connected group forms when either one agent (say, $i \in g$) invites its social relatives in g, and then added members also invite their social relatives, or a set of agents forms a group and then invites their social relatives as group members. These procedures may create a loose group, where, two group agents may not have direct contacts in g.

Cooperative Overlay as Independent Interactions. A cooperative overlay $\overline{g}$ could be an outcome of independent interactions between a pair $\langle ij \rangle$ of agents in g. A cooperative overlay $\overline{g}$ takes place when agents in g take decisions independently with whom they want to cooperate to perform activity $a^{\overline{g}}$ and with whom they do not want. A pair $\langle ij \rangle$ of agents in g mutually agrees to perform activity $a^{\overline{g}}$, and then we can say, agent i and j become members of set $\overline{A}$ and a link $\langle ij \rangle$ becomes a member of link set $\overline{L}$. The set $\overline{A}$ of agents and the link pattern $\overline{L}$ encompass cooperative overlay $\overline{g}$.

Cooperation in a Group

A Shared Activity and A Shared Goal: When a few agents form a group and are involved in a shared activity to obtain a shared goal, they accomplish the shared activity collectively. As stated earlier, a shared activity is divided into multiple sub-activities and assigned to group members; each member puts efforts into accomplishing the assigned sub-activity. Their combined efforts yield the group's goal. Let us consider the following example.

Example 1. A group $\overline{g}$ carried out an activity (say $a^{\overline{g}}$) like performing a computational task τ to achieve a shared goal (or joint benefit). The computational task τ is divided into multiple tasks (e.g., $\tau_1, \tau_2 \ldots \tau_n$). A task τ_i is assigned to an agent $i \in \overline{g}$, and then each agent $i \in \overline{g}$ cooperates by submitting the result of the assigned task to produce the final result. The combined individuals' effort yield the group benefit.

Example 2. Another illustration is when group members works together for a shared goal. They can use a third party Cloud provider's computational infrastructure to perform computing task together, or they can develop it themselves by pooling their resources. Building computational infrastructure can be seen as a shared activity (say, $a^{\overline{g}}$) where agents pool their resources to build the infrastructure. Let us consider the computational infrastructure requires r amount of resources. Then each agent $i \in \overline{A}$ shares r_i amount of resources to construct the coordination system, such that $r = \sum_{i \in \overline{A}} r_i$.

In most cases, group members perform a shared activity to benefit a third party. Agents collaborate to do computational tasks for scientific programmes like ATLAS@Home, Einstein@Home, etc. These initiatives may give them computational credit (social recognition in multi-team environments).

A Shared Activity and Individuals' Goal: Unlike the previous scenario, where the group's collective action provided a mutual benefit, the group now cooperates accomplishing a shared activity to attain their individual goals. Let's review Example 1. As seen in the example, computational task τ is split into many tasks. These many tasks are then assigned to group members, thereafter each member executes the assigned task to produce the final result. In the earlier situation, they helped the group. In this scenario, they're seeking personal gain. Each member receives a portion of the benefit after finishing the work. For instance, the group can complete scientific project computational tasks and gain prize money, which they can share.

Another example, where one member of the group might outsource a computational task to members of the group, who would then do the task for the outsourcer. In this scenario, the group perform a shared activity together for one member, then another. The group may execute a shared activity to help one agent attain its goal. Thus, the shared activity benefits one person.

An Interdependence Activity and A Mutual Goal: It was not always the case that agents collaborated to accomplish an individual's objective through a shared activity. Whether a joint endeavor necessitates or does not necessitate it depends on the type of activity performed by group members. A set ($\overline{A} \subset \widehat{A}$) of agents form a group in which they engage in interdependence activities (e.g., trading/sharing resources such as processing power, human skill, etc.) in order to attain their individual objectives. Specifically, in a group, pairs of agents engage in an interdependence activity in order to achieve a common objective. For instance, agents may share storage devices to store their data on one another's storage devices.

An Interdependence Activity and An Individual Goal: In a group in which agents engage in pair cooperation, one agent facilitates the other agent in achieving its objective. For example, if one agent offers its partner free storage space, the partner can store data on the offered free space. There is no expectation of reciprocity in this form of cooperation; the agent assisting its partner expects nothing in return.

Cooperation in a Pair of Agents. Cooperation between two agents is unlikely if one agent is opposed to the other cooperating. Therefore, mutual agreement is required for agents to cooperate to achieve an individual's objective.

A Shared Activity and Mutual or Individual Goal: When two agents participate in a shared activity, they divide the task and work together to attain the shared objective. For instance, a pair of agents collaborating on a project may contribute their unique abilities or efforts to the task at hand in order to accomplish a common goal. In another situation, one agent achieves its goal with the help of the other agent.

An Interdependence Activity and a Mutual Goal: A pair of agents mutually agree to perform an interdependence activity $a^{\overline{g}}$ to obtain their individual goals. For example, a pair of $\langle ij \rangle$ agents (i and j) agreed to share storage space (available at their end) to store their data on each other's storage devices. In $\overline{g}$, agents might be benefited from indirect relationships, if in $\overline{g}$ each agent agreed to perform an activity $a^{\overline{g}}$ for those agents with whom s/he indirectly connected. Let us say, agent i and $j(\langle ij \rangle)$. The agent j and $k(\langle jk \rangle)$ are involved in a direct relationship (meaning these pairs ($\langle ij \rangle$ and $\langle jk \rangle$) are directly involved in performing an activity $a^{\overline{g}}$), and agent i and j are indirectly involved. If agent k is ready to perform an activity $a^{\overline{g}}$ for agent i, then i is benefited by indirect relationship thanks to agent j. Similarly, agent k is also benefited if i agrees.

An Interdependence Activity & An Individual Goal: As discussed earlier, in a group, a pair of agents involved in an interdependence activity, one partner helps its partner for no gain, and in a cooperative overlay (which is a result of agents independent decision about cooperation), one partner helps others altruistically. Agent i lets agent j store its data on its storage device, and vice versa. Here, agent i cooperates by letting agent j store its data on its storage device.

2.3 Protocols

Social Protocols: Human communities have explicit social codes. A social protocol expresses a person's ability to form relationships, organisations, and partnerships. Social and cooperative interactions generally follow preset behavioural paradigms. Agents' benevolence and reciprocity facilitate cooperation. These traits can guide agents' cooperation. Agents undertake shared or interdependence activities for others selflessly or in hopes of future assistance. Social rules are therefore essential for regulating shared or interdependent activity. Data (information) can be shared in three different social protocols, namely, community sharing, and closed and open associative sharing. Community sharing is known as closed communal sharing, and it is founded on a feeling of belonging. Associative sharing is called closed associative sharing, and it involves people acting in accordance with an agreement. Open associative sharing, and it's based on something called "institutional imperatives" as well as formal regulations.

Market and Non-Market Protocols: An interdependent or shared activity can be carried out through a market or non-market method like an auction or posted price. In a shared activity, a procurement auction can outsource a task. A publicized pricing technique can be used for resource trade. Trust- or reputation-based non-market-based systems can carry out joint or interdependent activities. A group of agents choose whether to use a market or non-market mechanism.

2.4 Coordination

Definition 4. *A coordination system is a set* $F^{\overline{g}} = \left(f_1^{\overline{g}}, f_2^{\overline{g}} \ldots, f_n^{\overline{g}}\right)$ *of entities or functionalities that manages or supports an activity* $a^{\overline{g}}$ *that the participants perform in* $\overline{g}$.

Malone and Crowston define coordination as "coordination is managing dependencies between activities" [13]. This concept leads us to think of coordination as a hardware-software system that performs complex functions (activities) and manages dependencies between them to help agents cooperate. On an online social network platform, agents can carry out tasks like sharing profiles and information. Some agents in given online platform may want to carry out interdependence or shared activities (such sharing computational resources or outsourcing tasks) to achieve common or individual goals with aid of their defined social and economic protocols. These shared or interdependent activities differ from those users do with the online platform. Online social network platforms do not support these activities or group-defined social and economic protocols. A coordination mechanism is needed to support interdependence, shared activities, and social and economic protocols set by a group of users.

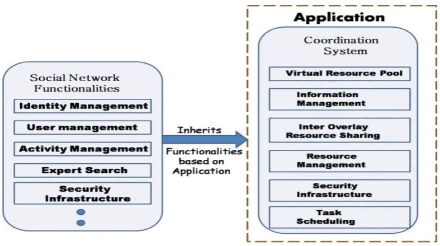


Fig. 3. Coordination System

A cooperative overlay $\overline{g}$ consists of autonomous agents that cooperate to achieve individual or group goals. However, an efficient coordination system is essential to assist agents in cooperating. In fact, it's worth mentioning that a coordination system plays a key role in achieving such goals. A coordination system consists of computational infrastructure (hardware and software) facilitating agents to carry out the activity efficiently. The coordination system consists of different functionalities such as user management, resource or service management, marketplace, etc. A set of functionalities that a coordination system consists, of depends on which kind of activity (whether the activity is shared or interdependence) that agents carry out to achieve a specific goal. In other words, the set of functionalities is an application (activity) specific.

A coordination system is not a sub-system of an online social network platform, i.e., $F^{\overline{g}} \subsetneq F^{g}$, a coordination system consists a few numbers of functionalities that are different than an online social network system (see Fig. 3). Nevertheless, a coordination system and an online social network system may have some functionalities in common, i.e., $F^{\overline{g}} \cap F^{g} \neq \emptyset$, if this is the case, then we can say that the functionalities of the online social network platform are inherited in the coordination system. In another case, a coordination system consists of a different set of functionalities than the online social network platform, i.e., $F^{\overline{g}} \cap F^{g} \neq \emptyset$.

Functionalities. A coordination system includes features such as a resource pooling mechanism, information management, inter overlay resource sharing, a resource management mechanism, security infrastructure, and job scheduling.

Virtual Resource Pool: Agents can share/trade resources, for example, storage [16], virtual machines, blogs, skill, computing power [3], at their ends, or they can share/trade a part of hired resource from third party vendor (e.g., Amazon AWS). It is possible that agents share/trade either homogeneous or heterogeneous resources. The coordination system needs to support both homogeneous and heterogeneous resource pooling.

Information Management: An agent may need to know about the group's members, the sort of resources (like storage), the service provider, resource properties (like storage capacity), resource availability, group policy, etc. Information management must support agent accounting, user auditing, resource advertising, group membership accounting, etc.

Inter Overlay Resource Sharing: A social network may have several cooperative layers where agents trade resources. An agent may belong to many cooperative overlays in such a case. A coordination system support for inter overlay resource sharing.

Resource Management: Resource management sets policies for resource authorization, authentication, audit, and allocation. As mentioned, market or non-market methods like lotteries and posted prices can be used for resource allocation and exchange. Agents can choose a resource exchange scheme. For instance, resource allocation can be governed with or without price (matching, auction), reputation, trust, etc. To discover, advertise, and allocate resources, a marketplace is needed. In a nutshell, resource management supports marketplace, and service-level agreements between agents.

Security Infrastructure: Distributed resource sharing poses data and computational security risks. Even if users share resources in a trust-based social connection, these concerns exist. Data confidentiality, integrity, consistency, and reliability are threats. Shared storage or virtual images may be hacked. Security rules (access restrictions) and techniques (authorization, authentication, encryption, etc.) help users securely access and share resources.

Task Scheduling: The functionality of task scheduling consists of a scheduling algorithm that divides a shared activity into sub-activities (sub-tasks) and distributes them to the participants. A scheduling algorithm also manages the execution of interdependence tasks. The information management functionality offers details on each person's abilities and resources that are available to them. The task scheduling functionality uses this information for the assignment and distribution of sub-activities.

Design and Implementation. The design and implementation of a coordination system $c^{s(\overline{g})}$ depends on the activity $a^{\overline{g}}$ that agents want to perform in $\overline{g}$. Hence, resource, service, user, information management, and other entities take various forms system to system to facilitate specific activity (or activities) $a^{\overline{g}}$ in $\overline{g}$. In other words, the coordination system $c^{s(\overline{g})}$ is $a^{\overline{g}}$ specific. For example, let us say there are two different cooperative overlays $\overline{g}_1$ and $\overline{g}_2$ exists on top of $\hat{g}$. The coordination system $c^{s(\overline{g}_1)}$ and $c^{s(\overline{g}_2)}$ manages the activity (or activities) in $\overline{g}_1$ and $\overline{g}_2$, respectively. If both $\overline{g}_1$ and $\overline{g}_2$ are likely in terms of the aim these groups want to achieve and the activity these groups perform, then it is likely that $c^{s(\overline{g}_1)}$ and $c^{s(\overline{g}_2)}$ are same. However, if these groups $\overline{g}_1$ and $\overline{g}_2$ are different and are involved in the two different activities (say $a^{\overline{g}_1}$ and $a^{\overline{g}_2}$, respectively, and $a^{\overline{g}_1} \neq a^{\overline{g}_2}$) then it is likely that both $c^{s(\overline{g}_1)}$ and $c^{s(\overline{g}_2)}$ are different and serve different activities. The design and implementation of a coordination system depend on how the activity (or activities) are carried out in the overlay $\overline{g}$. In a broad sense, two design and implementation models are relevant here: the first is centralized, and the other is decentralized.

Centralized Model: is appropriate when agents are structured in a group. The centralized Model is suitable when agents in $\overline{g}$ cooperate in carrying out an activity with the help of a central system. The central system coordinates activities and different functionalities to serve the corporation.

Decentralized Model: is appropriate when each agent has a partial view of the overlay $\overline{g}$, and each agent is involved in the activity with only a few numbers of agents. A decentralized works well when $\overline{g}$ emerges due to each agent's decision about with whom they want to cooperate.

3 Social Cloud: Implications

3.1 Resource Sharing Based Coopetition

Social cloud may be vital to resource sharing-based coopetition [1]. By sharing resources, social cloud may help competing companies achieve a goal. Companies can establish social clouds to produce value by combining resources, talents, and expertise. Collaboration can save money, boost efficiency, or improve capabilities. For instance, competing companies can collaborate on R&D projects. By sharing resources and information, firms can speed up innovation, cut research expenses, share risk, and get access to knowledge they may not have. This is typical in drugs, aeroplanes, and technology. Software companies collaborate and share computing resources to develop industry standards and open-source software. Through social cloud, software companies can reduce development costs, improve interoperability, and accelerate innovation.

3.2 Social Cloud: Digital Commons

A social cloud is a digital common where individuals exchange computer power, experience, and knowledge to benefit the community. Digital commons are user accessible resources generated utilising digital technologies. It departs from private property rights, when a few people own and control most resources. A community shares knowledge, skills, digital, and other resources to produce and maintain most of these resources.

Digital commons have laws or conventions that everyone agrees on, which makes them unique. These regulations ensure everyone may use the resource and that it benefits the group. In the information era, data and skills are valuable resources, making digital commons important. They enable individuals and companies to pool resources to produce new value not available in the current economic system.

3.3 Social Cloud: Applications

Social cloud can improve collaboration, consumer engagement, and productivity. Social cloud benefits organisations in various ways, including:

Collaborative tools: Collaboration solutions in the social cloud can boost teamwork. Cloud-based project management enables resource and knowledge-sharing, and allows team members to work together in real-time.

Social listening tools: Social cloud makes social listening technology available, allowing businesses to monitor consumer feedback, reply to comments, questions, and complaints, and learn how to improve their products and services. It helps organizations swiftly address client inquiries, complaints, and feedbacks.

Data Analysis: A social cloud can analyse social media data to assist organizations make data-driven decisions by revealing customer behaviour, preferences, and trends. A social cloud can help create a federated machine learning model. Users contribute knowledge and resources to train the local model in this federated model. The trained model can be used for brand management, marketing, etc.

3.4 Social Cloud: Plaformization and Network Effect

Platformization [7] is a process of transforming a firm or organisation into one that runs on a platform. Using a uniform protocol and software architecture, a platform allows several parties to communicate. Servers and networks that run a website or mobile app allow users to transact business, hold discussions, and communicate in other ways. The 3-C architecture offers a method for creating a social cloud platform where several beneficiaries can communicate with one another. The following are a few beneficiaries of social cloud platforms.

Users: are those who make use of social cloud services for the purposes of communicating, collaborating, networking, and engaging in other types of social activities.

Developers: Individuals or teams responsible for creating social cloud applications, software, and platforms.

Investors: Individuals or organizations that invest in social cloud businesses or initiatives.

Regulators and Advocacy groups: Government agencies or other regulatory entities that supervise the usage of social cloud services to guarantee compliance with applicable laws and regulations. Advocacy groups encourage the ethical use of social cloud services and advocate for the rights of social cloud users.

Educators and Researchers: Social cloud systems let educators share knowledge. Educators can create virtual learning spaces. Virtual learning environments are a set of interconnected tools for managing online learning that allow instructors to communicate with students and track their progress and provide real-time feedback.

4 Conclusion

Because the social cloud notion is delivered in many contradicting ways. These paradoxical views inhibit social cloud potential exploration and exploitation. We unify these varied perspectives on social cloud and present a three-C conceptual framework based on concepts of cooperation, cooperation, and coordination. We will better comprehend the social cloud concept and be guided in connecting it to business, research, and academia by using this scio-technical three-C framework.

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How the US Financial Market Embraced Automation

Jonathan Seddon(✉)

Audencia School of Management, 8 route de la Jonelière, B.P. 31222, 44312 Nantes Cedex 3, France
jonathanseddon1@gmail.com

Abstract. This paper is part of a funded research grant into how financial regulation in the US has evolved. For almost one hundred years the regulators have attempted to manage evolving trading activities and security types. Ever since the Wall Street crash of 1929 rules have been defined and then changed as the Global Recession and World War 2 constrained market growth. Change can be seen following the introduction of computers in the 1960's, as trade volume and order types grew. Not only did automation require new controls, it also required a paradigm shift in how these new products could be traded. This paper explains how the market has changed to provide the foundations on which today's trading systems operate. This now poses real problems, as regulators argue whether crypto-assets are securities or derivatives, and who should govern them. The absence of clear mandates has fueled criminal behavior by some crypto firms.

Keywords: SEC · CFTC · Regulation · HFT · Automated trading

1 Introduction

The system of financial regulation in the U.S. is complex and fragmented [1], shared between federal and state agencies, and numerous industry-sponsored self-governing associations. Regulatory jurisdictions overlap, with financial firms sometimes reporting to multiple regulators. Overlapping standards, federal and state laws, and private jurisdictions increase regulatory complexity. Lack of clarity about who regulates whom, what rules apply, and to whom, is confusing to market participants. Rapidly changing financial technology allows firms and investors to 'fly under the radar' and benefit from regulatory arbitrage [2, 3]. Against this backdrop, regulatory decision-making is fraught with legal, institutional and technical challenges.

Prior work shows how financial innovation and technology has transformed the financial services industry. Insightful studies emerge on mortgage securitization [4], computerization of the U.S residential mortgage industry [5, 6], the rise of online investment banking [7], the impact of the Internet on financial market trading [8], and FinTech [9]. Building on this work, we ask the question: *How do government agencies develop policies and practices to regulate information technology in financial markets.* His question will focus on the technology that facilitates trading, not the financial outcomes of

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trading strategies. Embedded in the technology is algorithmic software. The interaction between regulator and financial firm plays center stage in technology's role in performing the market [10]. Regulators face a dilemma as relentless technological change forces them to balance ex-ante (forecasts) and ex-post (retrospective) decision criteria. Studies on algorithmic trading provide examples of regulatory challenges. For example, systemic and firm-specific risk profiles are different for low frequency and high frequency traders (LFTs and HFTs) since they operate in two separate markets. Unlike LFTs, HFTs have advantages of low latency (the time taken to capture changes in market events) [11], co-location of their equipment (close to the exchange) [12], and more sophisticated technological infrastructure and applications [13]. These factors increase the heterogeneity of financial market firms and, by extension, the variables for regulatory oversight [14].

Traditionally, with uniform rules to measure outcomes regulators adopted command-and-control behavioral mandates. Eventually financial firms develop internal risk-management processes. Against a background of financial events, such as the 2010 Flash Crash, the scale and complexity of contemporary financial transactions processed by information technology makes '*policing the markets*' a significant regulatory challenge [15, p.550]. Emerging from the literature, albeit discussed in isolation of each other, three interrelated concepts impact regulatory decision making on oversight mandates on information technology in financial markets: market fragmentation, technological complexity, and information asymmetry.

High profile financial market events of the 2008 financial crisis and the 'Flash Crash' of 2010 generate questions about whether automated trading is a causal or contributory factor in disruptive market events [16]. Other studies, mainly from the management and financial literature, look at how information technology performs the financial markets [10]. With the growth of algorithmic trading, replacing humans with machines [17], and crypto-assets offering virtual speculative products, we developed a second research question: *What are the decision-making criteria of regulators to oversee the use of information technology in financial markets*?

We organize the paper as follows. First, the literature review explores three dimensions of the markets structure. Next, we present the analysis of the US financial market and identify regulatory actions across four intervals. Finally, in the discussion section, we explain how this work is used in our current research which looks at the absence of regulation in the crypto asset world.

2 Literature Review

Market fragmentation, information asymmetry and technological complexity are discussed individually in literature. However, in this paper their combined effects will be discussed.

First, fragmentation in financial markets is a perennial topic receiving attention from policymakers, market participants, media and academics [18]. Diverse financial market participants interaction in cross-jurisdictional environments [19]. In algorithmic trading, market fragmentation influences financial technology regulation. Over six decades, institutional environments enabled by technology have shaped financial regulation. For example, the 1960s saw a shift from concentrated to differentiated financial markets, opening up opportunities to trade in multiple geographical locations and venues. As financial markets evolved, trading venues invested in technology, further increasing fragmentation. In 1975, Congress enacted Section 11A of the Exchange Act, directing the Securities and Exchange Commission (SEC) to establish an administrative system to regulate the nationwide clearance and settlement of securities transactions. In April 1976, executed trade data (stock, quantity, and price) was recorded using a tape system. By January 1978, the prices of the same stock at different exchanges became available (on the consolidated quote system). As competition between regional exchanges developed, fragmentation failed to improve the competition of individual orders for securities. To enable best execution, the SEC introduced Regulation National Market System (Reg NMS) in 2005. Fragmentation in algorithmic trading further exacerbated latency arbitrage, with more opportunity for dislocation across trading venues [20]. By 2017 only 50% of equity trading was done at the NYSE or Nasdaq, with the rest across 10 other equity exchanges, 50 alternative trading systems, dozens of large bank trading desks, 13 equity derivative trading options exchanges and many equity-linked futures markets [21]. This now offered a single virtual fragmented market [22] changing efficiency, execution speeds, cost, and the stability of financial services.

Second, financial markets and trading have been revolutionized by technological complexity [23]. Technology has completely transformed the complexity of financial instruments [24]. Strategies require complex calculations completed at speeds beyond human capability. Technology also offers new risk oversight where regulators require firms to deploy technology to calculate and mitigate risk showing compliance with regulatory mandates [25]. Delegating this activity allows compliance teams and programmers more scope to deploy technology in ways that mask the interests of regulators. This scenario, described as an 'automation bias,' privileges firm self-interest over meeting the conditions of legal mandates. Reduced transparency thus undermines regulatory oversight and accountability [26]. Technological complexity further obfuscates how regulators evaluate systemic risk to prevent financial market events, such as, flash crashes. Regulators face the '*perennial struggle to keep up, or rather, to not fall too far behind*' relentless change [15, p. 555].

Third, information asymmetry has grown over the decades as automated trading replaced humans. In the 1960's, it was common to experience delay and error due to ticker tape issues. The solution - the computerized Market Data System (MDS) - had different outcomes. Whilst increased availability benefited the investor, the NYSE used the tool to increase surveillance on staff efficacy. Kennedy [27, p. 890] commented, '*computerized finance and electronic telecommunications reproduce material politics of access and social asymmetries of information*'. Today, algorithmic traders (HFT), need advanced systems to gain advantage over competition, locating their systems at an exchange, utilizing the latest located solid-state technology. Timeliness is important. In 2010, spread networks reduced the round-trip time between Chicago and New York by 2.6 μs, with customers paying ten times more for the service [28]. Such strategies focus on capturing price differences on economically identical assets [18].

3 Automation of the US Financial market: Data and Analysis

The regulation of US financial markets developed from the statutes introduced by Congress, following the disruptive 1929 Wall Street crash. The SEC was formed in 1934 with the mission of protecting investors, maintaining fair, orderly, and efficient securities markets, and facilitating capital formation. Before its creation, two major acts were introduced: The Securities Act of 1933 (concerned with the distribution of new securities) and the Securities Exchange Act of 1934 (SEA) (which paid attention to trading securities, brokers and exchanges). The role of the SEC was to regulate the securities industry, using civil charges if necessary, on companies or individuals who broke security laws. Additional acts were passed by congress, but the growth of the market was slow due to the Great Depression and then World War II. Created several decades later in 1974, the Commodity Futures Trading Commission (CFTC) served as an independent federal regulatory agency. The CFTC's mandate was renewed and expanded in 2000, with Congress passing the Commodity Futures Modernization Act, instructing the SEC and the CFTC to develop a joint regulatory regime for single-stock futures to start trading in 2002.

Four stages reveal changing regulatory policies and practices. Each phase marks an inflection point by which distinctive technological change impacts regulatory decision making and mandatory outcomes. The regulatory mix incorporates ex-ante and ex-post responses to complex market structural changes and fragmentation, the impact of financial technologies in the form of software products and services that shape trading practices, and how information is created, accessed and manipulated by financial intermediaries.

3.1 Stage 1: 1960–1974

This period witnessed a fundamental change in financial trading as stock exchanges transitioned from almost no technological infrastructure and applications to the beginning of a technological revolution. Following a two-year review of the securities industry, the SEC released the Special Study of the Securities Markets in 1963 [29]. The document was the first and only in-depth review of US financial markets, providing guidelines for reforms planned over fifteen years. Financial firms hired traders on their past performance. Most financial activity occurred on the NYSE, with open outcry trading integral to the process [30]. Amendments to the securities act (1964) strengthened the SEC's ability to remove structural asymmetries on price between investors and the trading floor [27].

Towards the mid-1970s, the Commodity Futures Trading Commission Act of 1974 proposed sweeping changes to the Commodity Exchange Act (CEA) of 1936. The SEC's Chairman, declining jurisdiction over the commodity futures industry, led to the creation of the CFTC. Its mission was '*…to strengthen the regulation of futures trading, to bring all agricultural and other commodities traded on exchanges under regulation, and for other purposes*' [31, p. 1389]. From this point, two separate bodies regulated the US financial market.

3.2 Stage 2: 1975–1989

Amendments made in 1975 to the Securities Exchange Act had the objective of establishing a national market system (NMS). This stated that '*The linking of all markets for qualified securities through communication and data processing facilities will foster efficiency, enhance competition, increase the information available to brokers, dealers, and investors, facilitate the offsetting of investors' orders, and contribute to best execution of such orders*' [32, p. 112]. How this was achieved was not specified. The NYSE proposed its Intermarket Trading System (ITS) connected to other exchanges via the communications network provided by SIAC. Suggestions for a separate nationwide trading facility to replace exchange floor activities was further proposed [33].

Automation increased the speed and volume at which transactions occurred. By 1987, two days trading on the NYSE was equivalent to the annual volumes for the year of 1964. Recognizing the growing impact of technology to change financial markets, the SEC issued its first Automated Review Policy (ARP) statement in 1989 [34]. This offered voluntary guidelines on the best practices to mitigate system risks by assessing vulnerabilities. To support this policy, the Office of Automation and International Markets (OAIM) was created to ensure the integrity of exchanges' electronic data processing. Independent bodies would carry out reviews, supported by the OAIM.

3.3 Stage 3: 1990–2005

This period saw a wholesale change in financial trading with the acceleration of information technology influencing financial market structure and reshaping how regulators engage with financial firms and intermediaries. Significant technological developments occurred during this phase, notably the commercialization of the Internet in the mid-1990s and day trading. Financial markets became further fragmented. Trading decisions radically shifted from floor based to server based execution.

Rapidly advancing technological change spawned further risk mitigation guidance, with the SEC issuing ARP II [35], again based on voluntary compliance. In 1998, the SEC introduced Regulation Alternative Trading Systems (Reg ATS) [36]. Here, some of the guidelines presented in ARP and ARP II became rules, again with the goal of allowing ATS to compete with the traditional exchanges. By 2000, regulation contained in the Commodity Futures Modernization Act [37] represented the most significant reform to the CEA since the creation of the CFTC. Whilst it eliminated overlapping jurisdiction between the SEC and the CFTC, excluded from regulatory oversight were OTC derivatives executed on electronic platforms. Automated trading created new types of instruments in a high-speed interconnected market. A report by the US General Accounting Office (GAO) two years later [38] raised fears that the SEC was no longer able to fulfil its mission. It claimed the SEC had not kept pace with the growth, complexity, and international operation of the market it was regulating. In a later report GAO raised concerns that despite earlier recommendations, the SEC had not imposed mandatory rules on the market [39].

3.4 Stage 4: 2005–2020

One of the most significant changes to US financial market architecture occurred when Regulation National Market System (Reg. NMS) was introduced in 2005 [40]. The underlying philosophy of the NMS is open competition between private agents to produce a stronger and more resilient market than one using dictatorial mandates and aggressive enforcement [41]. With increased market fragmentation, these rules intended to give the investor optimal trading prices [42]. This required an increase in automation for a market structure dominated by HFTs, leading to claims of unfair trading practices [20]. Driven by technology, whoever had the best would win each order (at the best price) by using the fastest tool. Speed was important, but so too was the strategy being run. Millions of dollars could be spent each day on research to try and gain an edge over competitors. The SEC did not anticipate any of these effects and responded by re-evaluating the substantive content and efficacy of Reg. NMS rules [43].

Limited regulatory oversight, a consequence of financial innovation and technology, characterizes the period leading up to the Global Recession of 2008, with the burgeoning derivative market implicated in this seismic market event. Between October 2007 and 2008, over $8 trillion was lost on the US stock market [44]. These events implicated financial software as a major contributory factor presenting regulators with even greater risk oversight challenges. Automation not only fragmented financial markets, giving rise to increased diversity of intermediaries, it also transitioned trading from the domain of brokers and dealers to one dominated by quants and programmers. Technology created new strategies, as HFT became driven by data. It was not just being able to farm and process vast volumes of data – vast increases in trading activities were required just to cover the increased costs of business (e.g. colocation, microwave towers).

4 Discussion and Conclusion

Regulators, by virtue of rational choice, make trade-offs between alternative choices made explicit in their policy mandates, exemplified, for example, by choosing either rules-based or principles-based regimes. Findings show, however, that constraints on decision choices are much more complex in evolving regulatory and technological landscapes.

Prior to the 2008 financial crisis, deregulation enabled freedom to develop new financial products with reduced administrative controls to prevent financial failure [24]. The absence of regulation drives financial innovation and new products [45], for example in derivatives [46]. One consequence of allowing firms to develop without regulatory mandates meant a dilution of the controls needed to provide market integrity. No longer was the regulator able to manage risk generated by self-interested parties.

We find that information asymmetry dilutes the effective monitoring of any regulated asset. Trading firms obfuscate their actions, benefiting from strategies and market knowledge which is never shared with the regulator. Arguing that this represents their competitive strategy prevents any scrutinization. This clearly increases asymmetry, driven by decisions embedded in code. Even if such information (code) was to be shared with the regulator, the complexity of what is being done may be beyond their skill set. Strategies are driven by statistical analysis (e.g., Bayesian probability) not just market events and 'if-then' code. Replacing humans with robotic trading has undermined traditional methods of coordinating and controlling behavior [47].

Following the 2008 Great Recession, crypto-assets have evolved. Nakamoto's paper which spearheaded this phenomenon asserts, "*What is needed is an electronic payment system based on cryptographic proof instead of trust, allowing any two willing parties to transact directly with each other without the need for a trusted third party*" [48, p. 1]. An asset generated using cryptographic techniques falls into three broad types: virtual (crypto) currencies; virtual coins (or tokens); and tokenized traditional equity and debt securities. Definition is critical for regulatory interpretation, but turf wars exist about which agency should be the lead federal regulator. The existing rules and controls are applied when fraudulent activity occurs, but no control exists on how these private crypto companies should operate. Deregulation has created multiple interpretations on what a crypto product is and how it should be managed. Future research work will look at how existing rules can be applied to those companies trading in the crypto markets as well as the types of products that need to be defined and regulated. The crypto asset market has created a process governments are, as yet, unable to control.

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Discovering the Journey to Success of Research Productised Startups

M Srinath Nair(✉), Ramesh Loganathan, and Nimmi Rangaswamy

IIIT Hyderabad, Gachibowli, Hyderabad, India
srinath.nair@research.iiit.ac.in,
{ramesh.loganathan,nimmi.rangaswamy}@iiit.ac.in
https://www.iiit.ac.in

Abstract. Research productisation is a critical process that aims to transform innovative research outcomes into marketable products or services, bridging the gap between academia and commercialization. This study focuses on tracing the journey of four research-based startups and identifying the factors contributing to their success. Drawing on literature review and collaboration with the Technology Transfer Office (TTO) of IIIT Hyderabad, several hypotheses are formulated, including the impact of founders' educational background, the reputation of the educational institute, the co-founding team's network and experience, sources of support received, market understanding, and the involvement of stakeholders. Through interviews with startups, primary data is gathered and carefully analyzed, leading to interesting observations. Thirteen factors contributing to the success of research-based startups are identified, categorized into TTO and enabler support, Technology and Product, Market Validation, and Founder's Background. Additionally, the study highlights the role of different stakeholders in the startup ecosystem and identifies distinct phases in the research productisation journey. While these phases may not always be sequential or present in every startup, they provide valuable insights into the overall process. This research provides valuable knowledge for promoting innovation, entrepreneurship, and knowledge transfer from academia to industry, ultimately fostering successful research productisation.

Keywords: Research Productisation · Entrepreneurship · Technology Transfer · Startups

1 Introduction

The goal of research productisation is to bridge the gap between research and commercialization, by taking an innovative idea or technology from the lab and turning it into a viable product or service that can be released and use in the real world [3]. Google, one of the most successful companies to ever exist is an example of a very successful research productisation. The co-founders Sergey Brin and Larry Page met at Stanford University where they worked on a search algorithm

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that eventually went on to become Google [2]. The work done by OpenAI including the Generative Pretrained Transformers (GPTs) [14] and image generation tools like DALLE [15] that have been driving the excitement around Artificial Intelligence (AI) in present times are testaments of why research productisation is important and exciting.

Research productisation is both a technical and a social capital fostering innovation, promoting entrepreneurship, and enabling knowledge transfer from academia to industry. In this study we attempt to trace and understand the journey of four productisations from laboratories initiating the beginnings of research to the launch of a product . A company is formed around product research once there is product validation from customers deeming the product to hit the market and generate revenue. Once formed, our study identifies factors that contribute to the success of these commercial entities.

1.1 Hypothesis

Based on initial literature study and through our interaction with the Technology Transfer Office (TTO) of IIIT Hyderabad, we formulate a hypothesis and narrow down to the following factors. One of our main foci is on the stake holders of productising companies such as the co-founding team, enabler support, research standing of the educational institute among others. Our hypothesis includes,

- The founder's educational background will have an impact on the productisation journey
- The reputation of the educational institute and technology standing of the institute needs to be good in order to engage in a successful research productisation process
- The network of the co-founding team matters
- The experience of the founders in running a startup or a business, the corporate experience of the founders contribute to the success of research based startups
- The sources of support received will have an impact on success
- The cofounding team needs to have domain knowledge in order to run a research productised startup
- Market understanding contributes to success
- The number of programs the startup has been a part of matters
- The co-founder's involvement in the research and the support the team receives from these labs post productisation will contribute to success.

As part of the study, we interviewed 3 research-based startups from IIIT Hyderabad and the Technology Transfer Office for information on a fourth startup while also being able to discover the process behind research productisation from an enabler's point of view. The motive was to understand the journey of research productisation and what is it that makes certain startups run successfully.

We were able to come up with a good amount of primary data which through careful analysis, we were able to make some interesting observations, both from the perspective of tracing the journey of these startups and in order to understand what contributes to the success of these startups. From the observations we made through the study, we were able to come up with 13 factors that contribute to the success of research-based startups. The factors were organized into 4 categories including TTO and other enabler support, Technology and Product, Market Validation, and Founder's Background. We were also able to highlight the ways in which different stakeholders of the startup ecosystem could contribute to the success of research productisation. The observations made also pointed out to the fact that the entire journey of research productisation can be divided into different phases. These phases have been identified and labelled for each startup that we interviewed. Interestingly, we saw that these phases need not always be sequential in nature, or the phases need not appear in every single research based startup. But it is very likely that a majority of these phases identified will appear in any research productisation journey.

2 Background Study

2.1 Literature Study

Current State of Research. There has been considerable attention on the commercialisation of science since the Bayh-Dole Act of 1980 in the United States. The act allowed contractors to take ownership in inventions that arise out of Federal Government funded institutions [4,8]. Research productisation falls under the same concept of commercialisation of science. While there have been works on technology transfer process and academic entrepreneurship from a developing country's perspective [5], our research is targetted particularly at the state of research productisation in India.

Indian universities have not traditionally worked on research with an aim of commercialisation. The approach was with a mindset focused on solving a problem that looks interesting. There is minimal research on this subject as well. But given the government's push in the field of technology transfer from academia to the industry, there has been some focus on trying to understand the process. The focus has been on understanding the awareness of patenting practices and technology productisation in the academic community of India, comprehending productisation strategies and understanding the barriers in academia-industry technology transfer [1]. It goes without saying although that technology transfer through formation of commercial ventures is something that still remains unprecedentedly unexplored, especially given the Indian government's policies pointing towards their ambitions in developing the startup ecosystem of the country.

The structures and institutions that support startups and productisation efforts remain the same across countries. That is, enablers including Technology Transfer Office (TTOs) and educational institutions, incubators, accelerators, funding firms like VCs, angel investment groups, etc. are essential and contribute to the success of entrepreneurial ventures [12]. A quick look was done into understanding how the bodies within the startup ecosystem that constitute as enablers, with a special focus on TTOs, measure their own success. The internal structures and the business models adopted by these bodies inadvertently impact the success of these bodies and the success that these bodies create in startups or products that they support. The offices that run for profit turned out to be better in terms of output when compared to not for profit TTOs [13].

Some effort has been put into understanding the journey of a scientific innovation being commercialised, right from the research to the formation of the product [9,10,16]. An example that is seen is that of a neuromodular device, the market demand and size, licensing, spin offs and funding opportunities made available to the original technology and spin offs that have later taken off [9]. These works provide a first person look into how managing a venture feels like in actual.

From the TTO's perspective, entrepreneurial success is defined in a completely different way. The structure and competency of the TTOs in educational institutions are vital for influencing success of startups that come out of productising research in these institutions [7]. The funds directed from the institution or government bodies help these enablers tackle problems for startups in a much efficient way by letting them serve startups with a backing of good infrastructure and mentorship support.

One thing to be noted here is that this work describes what happens in a start-up ecosystem of a developed country with good financial resources to back start-ups. The case with developing countries like India might be entirely different and worth exploring and documenting. From the work that has been done, what we see is that there are a few studies done on the role of TTOs in start-up success and so forth. But there is a lack of effort made to understand what defines success for research productized start-ups. Most research fail to talk about how success can be measured and what contribute to the success of startups that come out of research productisation. Also, there are non-physical parameters like leadership style, network of the founders and professional support that these founders have sought which aren't being discussed here but contribute effectively to startup success. Besides these, the research that is currently done does not differentiate research productization from regular entrepreneurship. There is a need to study and publish a methodology of research productization that would increase the probability of success while productizing research. That is basically creating a scientific framework for research productization.

2.2 Background Work with IIIT Hyderabad

IIIT Hyderabad has had several years of efforts to actively create products from research. At the Product Labs in the Technology Transfer Office and the DeepTech Incubator that comes under the Centre for Innovation and Entrepreneurship, IIIT Hyderabad (CIE or CIE-IIITH). CIE is the largest and one of the oldest academic incubators in India with an experience of incubating and supporting startups from 2008.

From its 14 years of experience guiding and supporting startups, CIE and IIIT Hyderabad have come up with a "Three-way-cocreation model", where they have identified three pillars of innovation - Startups, Industry and Academia. The Industry determines the use cases, Academia does the research to build solutions and Startups innovate and make products out of the research to serve the use cases defined by the industry. Picking on their experience, the following are the factors that IIIT Hyderabad has identified which contributes to the success of research-based startups:

- Team Composition: It is essential to have 3 important figures, one co-founder who can take care of the core technology, one co-founder who can engineer the product, and one co-founder who can handle the business.
- Tech differentiator: There needs to be a core technology that can't be replicated and has a strong quality to attract customers to it.
- Support Received: It is important that startups, in their nascaent stage get sufficient support from the TTO, incubator in the form of availability of grants and seed fundings, Infrastructural support, office space, etc. Other support like CA, Legal, Finance, Banking, are also equally important.
- Market and domain exposure: It is important to understand the technology for startups. But if the founders are unaware of the problems faced by the domain where their customers lie then it is of no use. Founders must know how to apply their solution to the domain that they are targeting and understand how to ease the pain points for them.
- Access to customers and access to end-users: Support in terms of routing startups to customers. It is also important for these customers to stick with the startups.
- Continuous innovation post building the startup: Startups coming out of a laboratory initially had several brains working and thinking over how to make the product better. Once it gets converted to a product and moves out of the laboratory setting, it is difficult to apply the same level of upgradation to the product. This makes innovation important just so that the product remains relevant.
- Culture within the team: Most of the fouders are first-time founders who do not know much about handling people. It is important to build a good culture within the team to ensure success.
- Other ethical aspects: Inexperience comes with a tendency to take risks. Unawareness of rules and regulations surrounding money, technology proves to be factors that kill startups right before they take off.

3 Experimentation: Interviews as Case Study for Understanding the Journey of Research Productisation

The research methodology involved documenting case studies of startups. The mode of doing this was through first hand interviews. Interviews were chosen as the preferred method of investigation because they allow in-depth exploration while allowing the flexibility to extract contextual information since the interviewees are answering questions based on their real life experiences. The journey was traced and specific observations were made on the stages of the journey and the actions that entrepreneurs take in order to drive the startups to success.

3.1 Case Studies

The candidates for the interview were selected based on their profile and how they have contributed to the creation and development of the startups. The candidates were selected across several stakeholders including startup founders, researchers and Technology Transfer Offices.

Dr. Manish Srivastava - Subtle AI. Dr. Manish is the co-founder of Subtle AI, a startup focused on retrieving information from documents with a chatbot interface. He is also a professor and a researcher with an interest in Natural Language Processing (NLP). The CEO of the company, Mr. Vishnu Ramesh was an intern working on the project that eventually became Subtle AI's product. The commercial viability of the product had become apparent after Dr. Manish's discussion with the CTO of an important pharmaceutical company in helping them speed up the process of filtering complaints about their products from the internet. The solution was able to reduce the human efforts by 80% which led to the CTO calling it a solution they would pay for to use. The current CEO started talking to customers to understand further requirements of potential clients and the product was rolled out.

Prof. Prakash Yalla - Technology Transfer Office, IIIT Hyderabad. Prof. Prakash Yalla heads the Technology Transfer Office (TTO) at IIIT Hyderabad. He has overseen multiple research productisation. The importance of TTO in the research productisation process comes from the fact that TTOs are means of educating the students about scientific entrepreneurship. With the success of these offices being directly attributed to the outcome of entrepreneurial ventures from these, this could prove to be an effective mechanism to invoke interest in this domain among the student community of an institution [11].

At IIIT Hyderabad, the TTO has a catalogue that lists out research happening at IIIT Hyderabad for the industry to take interest in. Other than doing a matchmaking between academia and the industry, the TTO is also responsible for doing market research on whether or not the research is worth productisation and possible use cases of research. One of the productisation he oversaw, Matchday AI was the core subject of this discussion. The company works on sports analytics with Star Sports, a television channel headquartered in India and owned by the Walt Disney Company. The company gained a lot of attention through news articles and eventually with Mr. Pullela Gopichand, the Chief National Coach for the Indian national badminton team, joining in as a co-founder of the company.

Pawan Reddy - NeuralSync. NeuralSync is home to the product Wav2Lip, a technology that helps make lip synced videos for several languages. The technology gained traction through connections and licensing requests they received through LinkedIn. Between Auguest 2021 and January 2022, the co-founders of Neuralsync spoke to 100 customers and made close to $75,000 in revenue. The validation for the technology eventually lead to the birth of the company Neuralsync.

Rajat Aggarwal - DreamVu. Rajat Jain is the founder of DreamVu, a startup that makes products in the domain of omnidirectional 3D vision systems. The first product of the company was a portable 360-degree camera. The research was published at the Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR) 2016. They used the camera for XR use cases which made them incorporate the company in the United States where the market seemed more ready for XR technologies. Eventually, as they realised that the solution that they have taken up does not have a market to cater to, which made them pivot to a different use case. They moved on to building depth perceiving eyes for robots which sowed the seeds to the company that they are presently.

4 Findings of the Study

The case studies were analysed to understand what contributes to a successful startup where the core product came out of research. An attempt was made to understand what are the key activities undertaken by these founders and stakeholders to drive their startup towards growth. These findings have been grouped under 4 categories including Technology and Product, Market Validation and the Founder's Background. These have been discussed in detail in the following sections.

4.1 Factors that Contribute to the Success of Research Based Startups

The following are the success factors that were identified through the interviews and case study that was done. Following is the list grouped under 4 categories:

TTO and Enabler Support Is Important

The right stakeholders need to identify productisable research The TTO and those enabling research productisation need to identify specific sub domain use cases in broad research fields and do a matchmaking with the industry.

Identifying the right market use cases for research sub domains Enablers of research productisation need to understand what industry needs and map it back to academia.

Support from the TTO or Incubator to build a quick demo able prototype There must be an active support to build a prototype of the product that can be used by the startup team to demo in front of prospective customers.

Strong Technology and Product Attracts Customers and Success

The ability of the system to reduce human efforts is important while thinking about building a product Subtl AI's product was able to reduce human effort by 85% which attracted the customer that they first spoke with. This was the pivotal moment when they realized that the research could make a good product.

Publication in reputed conferences/journals gives a validation that the tech is interesting and powerful Reputed conferences show that the technology is strong or unique enough. It does not guarantee that it would make a product that would be loved by customers though.

Market Validation Is Key to Building a Successful Venture

Customer validation and iterating over the product based on the feedback received It is important to understand what the customer needs and how the product can be designed to satisfy that.

Building a relation with the customer Having a relation with customers prior to productisation would help in piloting the product and acquiring paid customers.

Having users who pay for the technology is the most important form of validation Neuralsync had people paying for the product even before they formed the company. That shows that the technology is worth making a product out of.

Getting people to talk about the technology through proper visibility It is important to make sure that people know about the technology and create an excitement about the same. It is easier talking to customers who are familiar with your tech already. The visibility should ideally happen from the research stage.

Validation from industry experts or individuals who are renowned in the domain that your product lies Matchday AI for instance got Pullela Gopichand as a co-founder. Gopichand's reputation would go a long way in adding credibility to the startup.

Lack of a clear leader in the market the product is placed in The lack of a clear leader in the market makes it easier to capture market and lesser resources to climb up the ladder.

Background of the Founders Matter

Having a Co-Founders with a good domain expertise and complementary skills is important Domain expertise makes it easier to navigate through the product making process and to deal with customers. If there is an absence of such a person in the team, it is important to gain this experience as soon as possible.

Serial entrepreneurs add value to the team Serial entrepreneurs who have worked with stakeholders add credibility when they return to the same people/organizations which makes it important to have such people in the co-founding team.

The above factors were identified through the interview process. These are made from observations made in the interviews and also by observing the change in status of each of these startups post these critical moments.

5 Discussion

The previous section identifies the factors that contribute to why a startup that arise out of research would become successful. Here, we discuss certain variables outside these that enable startups. Careful observations have also been made on the startup journey which have been discussed in this section.

5.1 Supporting Productisation Better - Role of Stakeholders

The current support received by research productised startups is the same as that of a regular startup. This is not ideal for these startups that may not have a traditional market. There is a need to communicate their work better to the intended audience.

The institutions that work towards supporting research productisation are also limited. There are Government supported institutes including the Indian Institute of Technology (IITs), the Indian Institute of Information Technology or privately funded International Institute of Information Technology (IIITs) that support research productisation efforts in India. Let us look at the role of the stakeholders in detail.

Researchers. The role of researchers is primarily to produce core technology for people to consume. It is the efforts made by these individuals that eventually become products through research productisation. A collaboration with industry is necessary to understand what part of research can help ease pain points of potential customers.

Technology Transfer Offices (TTOs). The TTOs are responsible for identifying use cases from the industry and doing a matchmaking between industry and research. The lack of experience of researchers in understanding markets can be filled by these bodies. Cold calls to understand what problems technology can solve for the industry can go a long way. The ideas or use cases that they receive from these calls need to be documented to understand what kind of technology is shown value by the market.

TTOs are responsible for cataloguing of technology based on the domain of research that happens at the research institute. This public document becomes a handbook for entrepreneurs who wish to take up interesting use cases to productise. TTOs can also support in creating demo able prototypes for these entrepreneurs. TTOs also play a key role in helping get IP protection support for the technology that these startups end up productising.

Incubators. The incubators are regular enabler bodies whose activities are independent of whether or not the startup is from research to a large extent. Incubators are supposed to help setup these commercial entities with support ranging from registration of the company to getting them mentorship support for go-to-market (GTM) strategies and start making revenue. These organisations are expected to handhold the startups in their initial phases.

Entrepreneurs. Entrepreneurs play a key role in research productisation by taking action. They identify interesting technology and make successful businesses out of them. Once the startups are formed, they are supposed to play the key role of connecting the dots to bring in revenue and raise funding and investments when necessary.

5.2 Framework - Phases in the Journey of Research Productisation

Every research productised startup are seen to have gone through most of the phases that have been listed out in the following subsection.

What Are the Phases?

- Identifying of pain points in the industry that can be addressed by the broad research problem.
- Identifying the specific solution within a broad research problem that can be applied to solve the pain point.
- Verbal validation from potential customers. This could be through an increase in the number of unpaid users for the technology as well.
- Identifying the right product and getting a demo able product built.
- On-boarding entrepreneurs who can run the company
- Paid customers start getting on-boarded
- Company is formed with a proper structure

Why Are the Phases Not Serial in Nature? Every startup has their own journey and are unique in how they achieve milestones. For instance, some have had paid users prior to the formation of the company, some have verbal validation and look for paid users post formation of the company.

5.3 Phases of Product in "Land" in Research Productisation

There are two such phases as follows:

– Product is made and there are users for the product. Could be paid or unpaid.
– Company is formed and users now become customers.

Why Are These Phases Different? Like mentioned earlier, research is mostly not done with an aim to productise it. Researchers usually look at interesting problems and try to solve them from an academic point of view. When solutions exist, people use them either by paying to the researchers or without paying when the technology is made available for open use. Now, when the company gets incorporated, these individuals become users or customers to the company based on whether or not they are paying. And when startups are formed, they define a revenue model for the use of the technology and payment is sought from customers accordingly.

6 Conclusion

In conclusion, research productisation is pivotal in bridging the research-commercialization gap, allowing innovative ideas to transform into real-world products. This study identifies critical success factors for research-based startups, including founders' education, institute reputation, team experience, support sources, market understanding, and stakeholder involvement. Through interviews and investment thesis analysis, we unearthed thirteen key factors grouped into TTO and enabler support, Technology and Product, Market Validation, and Founder's Background categories. These factors shed light on the core elements driving research productisation success.

Furthermore, our research underscores the vital role played by stakeholders in the startup ecosystem, emphasizing academia-industry collaboration, innovation, entrepreneurship promotion, and knowledge transfer facilitation. Distinct, but non-linear, phases emerged in the research productisation journey, serving as reference points for understanding the process, challenges, and opportunities.

In sum, this research enriches the understanding of research productisation, benefiting researchers, entrepreneurs, and policymakers. By grasping these success factors, stakeholders can refine strategies and support structures, fostering an ecosystem that encourages innovation and research translation into impactful products and services.

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Try and Fail, But Never Fail to Try – A Study on the NFT Investments Through the Theoretical Lens of Trying

Vijayakumar S Bharathi(✉), Kanchan Pranay Patil, and Dhanya Pramod

Symbiosis Centre for Information Technology, Symbiosis International (Deemed University), Pune, India
{svkbharathi,kanchan,dhanya}@scit.edu

Abstract. Non-fungible token (NFT) trading has gained prominence; hence, determining whether people are interested in investing in NFTs is critical. The current study expands on the theory of trying by considering two significant elements when discussing adopting new technology in emerging economies: general self-confidence and cynicism. Primary data was collected from 281 respondents who had experience exploring NFT marketplaces. Structural equation modeling was applied to analyze data collected through structured questionnaires. The findings reveal that NFT investments are determined by trying attitude toward NFTs, which in turn is determined by attitude toward success and attitude toward failure. Both attitudes are significantly influenced by general self-confidence and cynicism. However, the attitude towards the process was found to be insignificant. The study can significantly contribute to investment strategies, providing essential guidelines to facilitate NFT exchange and allowing investors to diversify their portfolios.

Keywords: Trying theory · Non-fungible tokens · self-confidence · cynicism · NFT investment · attitude

1 Introduction

Web 3.0 and extended reality technologies have opened the path for introducing the Metaverse. This multiverse platform has resulted in a new era of online shopping, digital investments, entertainment content creation, and content consumption (Marr 2021). In the Metaverse, a shared virtual environment, users can interact with one another and digital objects naturally (Mahmoud 2023). NFTs (non-fungible tokens) are essential in the Metaverse because they give a mechanism to represent distinctive digital goods like in-game items, collectibles, virtual real estate, art, and music. NFTs (non-fungible tokens) are unique cryptographic tokens that can only be found on blockchains and cannot be replicated. These tangible assets can be "tokenized," which increases trade efficiency while reducing fraud risk (Belk et al. 2022).

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The inception of Non-Fungible Tokens (NFTs) may be traced back to the year 2014, when Kevin McCoy pioneered the design of the inaugural NFT named “Quantum” (Khan et al. 2022). In the year 2017, global awareness regarding non-fungible tokens was established with, a multitude of unique non-fungible token (NFT) collections emerging on the Ethereum blockchain. At the same time, Ethereum network congestion caused by the CryptoKitties collection made news. The origins of non-fungible tokens made it possible to envision the creation of brand-new, individually owned blockchain-based assets. As a result, the advent of NFTs sparked fresh ideas that helped decentralize asset ownership. Digital assets currently held on multiple Metaverse platforms like Decentraland, Roblox, and SecondLife are not transferable.

With the easing of regulatory restrictions worldwide and more support for the ownership of virtual objects, the acceptance of NFT and cryptocurrencies may expand (Murray 2021). According to the available research, the NFT market is comparable to the cryptocurrency market, and there are rumours that investor perceptions of future worth may influence investments. People invest in NFT to make money and future investments, but other studies show that people do it because they want to be immersed and think it is fun. The effects of NFT on metaverse communities were investigated, and it was discovered that consumer intention to utilize NFT is significantly influenced by psychological aspects like self-efficacy (Ho and Song 2023).

Therefore, understanding self-confidence can help us understand how people with different levels of self-assurance views interact with NFTs. Skepticism regarding the worth and validity of NFTs is one way that cynicism can appear and not be explored much. Because NFTs are a new and unproven asset class and because the market can be very unpredictable, investors must determine whether to accept or reject NFT investments. Consumers consider both the success and failure of their choices. As a result of their lack of knowledge of NFTs, many consumers may find it difficult to learn about NFT investments. There needs to be more research on the connections between attitude towards success, attitude towards failure, attitude towards process, social influence, willingness to try, and investment. Therefore, this paper explores by means of “The Theory of trying”, the effect of general self-confidence and cynicism in understanding consumers’ investment trials in non-fungible tokens. The research objectives stated are:

- To develop a model to validate the factors impacting NFT trial investment decisions
- To examine the impact of the general self-confidence and cynicism on the trying attitudes of NFT investments

2 Literature Review

Here, we explain the relevance of the proposed theory, develop a conceptual model, and enumerate the research hypotheses.

2.1 Underpinning Theory

According to the literature, The Theory of Trying focuses on evaluating trying to act (Bagozzi and Warsaw 1990). An attitude towards trying and an intention is restricted to an “intention to try” in the theory of trying. Success, failure, and striving to achieve a goal are three separate goal-directed attitudes that correlate to three different outcomes that influence the establishment of a goal intention. When pursuing a goal and accomplishing it effectively or when pursuing a goal and failing to achieve it, an individual may create different opinions. Similarly, a person may generate various assessments of the process that achieves either goal.

According to Bagozzi et al. (1992), the try-theory theorizes attitude as a multifaceted phenomenon. It assumes that three sub-components of attitudes—towards success, failure, and acquiring new skills—relate to how people feel about adopting new technologies. Previous studies have used theory in adopting mobile banking technology (Chaouali et al. 2017) and information technology use (Ahuja and Thatcher 2005).

2.2 Conceptual Model and Hypothesis Development

Drawing from Subsect. 2.1, we propose the conceptual model in Fig. 1.

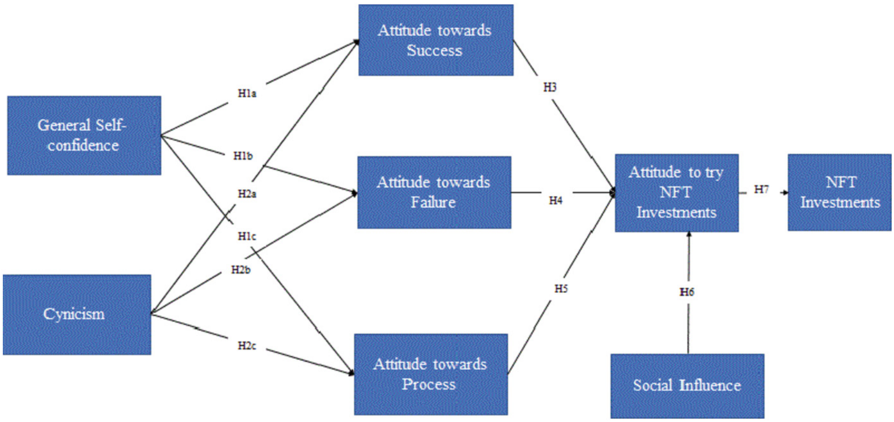

Fig. 1. The conceptual model for trying NFT investments

Agarwal et al. (2000) define general self-confidence as "a positive or negative attitude towards a product/service, of non-users: those who have not yet experienced or tried the product or the service." According to the literature, general self-confidence fosters risk-taking behaviour, learning behaviour, self-efficacy, and certainty, increasing the attitude towards success and learning and decreasing failure. People with high levels of overall self-assurance exhibit high self-esteem and improved self-image (Chuang et al. 2013). Someone with solid self-confidence will undoubtedly be able to use new technologies. Conversely, persons with low self-confidence will find it challenging to make decisions, hesitate, worry, and believe they will fail. Such persons need more assurance to intend to use cutting-edge equipment and technologies. Therefore, those with high confidence levels will have a good outlook on success, a negative outlook on failure, and a positive outlook on picking up new skills. Hence the hypotheses we stated are, H1a. General self-confidence favorably influences the attitude toward success. H1b.

General self-confidence adversely influences the attitude toward failure. H1c. General self-confidence favorably influences the attitude toward learning the process.

According to Gerber (2019), cynicism is defined as “a lack of belief in the sincerity or goodness of human motives” and can be expressed as anything from “distrustfulness, doubt, to contemptuous and mocking disbelief.”. Cynicism significantly influences consumers’ decisions to use or not utilise relatively new technology products or services (Chylinski and Chu 2010). Research has also shown that when consumers are unfamiliar with new technology products or services, they are more likely to generalise their unfavourable opinions about such items to survive.

Cynicism is the lack of faith in the sincerity of other people’s actions and motivations (Ketron 2016), which can positively influence one’s attitude towards failure but a negative one towards achievement and learning. Therefore, skeptical consumers may perceive new technological products/services and organizations as unreliable while casting doubt on the organisations’ integrity. It has a beneficial effect on their attitude towards failure but a negative effect on their attitude towards achievement and learning. Therefore, we hypothesize that H2a. Cynicism adversely influences the attitude toward success. H2b. Cynicism favorably influences the attitude toward failure. H2c. Cynicism favorably influences the attitude toward learning the process.

Previous studies validated the impact of attitude on consumers’ intentions to use (Hwang et al. 2021). Based on their attitudes towards success and learning to use technology, customers are more likely to develop a general attitude towards adopting technology (Badrinarayanan et al. 2014). People who generate good achievement assessments likely form a favourable overall view of adopting technology. However, individuals are more likely to generate a negative opinion about the adoption when they take an optimistic attitude toward failure (Davis et al. 1989). Additionally, individuals are more likely to have a favourable opinion on adopting technology when they take a favourable attitude towards learning to use it.

Social factors significantly influence users in the NFT Metaverse (Albayati et al. 2023). The social impact highlights a person’s perspective of the people they trust or believe in, which influences how that person uses technology. The behaviours, motives, beliefs, and levels of trust that other individuals exhibit are directly influenced by social influence and the people we trust (Ramjan and Sangkaew 2022). Previous research demonstrates a strong correlation between social behaviour and behaviour in users’ NFT Metaverse decision-making. According to this, social influence is a crucial factor to consider while adopting blockchain-based technologies, the NFT, and the Metaverse (Albayati et al. 2023). Therefore, we hypothesize that.

H3. Attitude towards success favorably influences the NFT trying attitude.

H4. Attitude towards failure adversely influences NFT trying attitude.

H5. Attitude towards learning to use NFT investment favorably influences the NFT trying attitude.

H6. NFT’s trying attitude favorably influences the investment in NFTs.

H7: Social influence favorably influences the NFT trying attitude.

3 Research Methodology

NFTs are unique digital assets gaining importance in the Digital world. It is crucial to approach investments in NFTs cautiously and comprehend the pros and cons involved. The study aims to analyze how the NFT trying attitude can lead to NFT investments based on attitude towards success, failure, and the NFT learning process. Primary data was collected using purposive sampling to ensure respondents had experience exploring NFT marketplaces such as OpenSea, Rarible, SuperRare, and Foundation.

3.1 Measurement Scales

All constructs' measuring items were adapted from earlier studies. Five items each for general self-confidence (GSC) (Chaouali et al. 2017), Cynicism (CYN) (Chaouali et al. 2017), Three items each for Attitude toward success (ATS), Attitude toward process (ATP), Attitude toward failure (ATF) and Attitude of trying (TRI) (Lin and Bautista 2017; Taylor et al. 2001; Moore and Benbasat 1991), four items each for Social influence (SI) (Holt et al. 2010), and NFT investment (INVS) (Salim et al. 2022) were modified to measure constructs on seven-point Likert scale. Customer sentiment measures, such as adoption surveys measured on a 7-point scale are likely to give slightly higher mean scores hence 7-point scale was used (Dawes 2008). Table 1 contains the respondents' demographic data.

Table 1. Respondent profile

Profile		Frequency	Percentage (%)
Investor Gender	Male	164	58%
	Female	117	42%
Investor Age group	18–29 yrs	134	48%
	30–39 yrs	82	29%
	40–49 yrs	53	19%
	50–59 yrs	2	1%
NFT marketplace experience	Less than 1 year	182	65%
	1 to 3 years	91	32%
	More than 3 years	8	3%
Qualification	High School	6	2%
	Diploma	25	9%
	Graduate	167	59%
	Post Graduate	83	30%

3.2 Sampling and Data Collection

The minimum sample size calculation was done using the G*Power tool (Faul et al. 2009). Six hundred people from India were selected by purposive sampling. The structured questionnaire was conducted online. A response rate of 46.33% was obtained from 309 replies, of which 281 were completed for further data analysis. The Smart PLS data analysis tool was used to perform structural equation modeling.

4 Data analysis and Findings

Data analysis was undertaken to assess the extent and structural models (Hair et al. 2021). The inner variance inflation factor (VIF) values were below the cutoff value of 3 (Petter et al. 2007), which verified that common method bias was eliminated.

4.1 Measurement Model Evaluation

We begin by evaluating the essential construct reliability, convergent validity, and discriminant validity (Hair et al. 2021). The evaluation of AVE value greater than 0.5, Cronbach's alpha, and composite reliability greater than 0.7 are in Table 2. Discriminant validity was assessed using the Fornell and Larker's (1981) criteria. Table 2 shows construct reliability and validity.

Table 2. Construct Reliability and Validity

Constructs	ATF	ATP	ATS	CYN	GSC	INVS	SI	TRI	Cronbach's alpha	Composite reliability	AVE
ATF	**0.864**								0.881	0.885	0.746
ATP	0.610	**0.870**							0.868	0.869	0.756
ATS	0.614	0.473	**0.847**						0.867	0.870	0.718
CYN	0.573	0.546	0.675	**0.860**					0.936	0.938	0.740
GSC	0.453	0.462	0.459	0.462	**0.851**				0.909	0.911	0.724
INVS	0.419	0.524	0.543	0.524	0.439	**0.873**			0.902	0.904	0.763
SI	0.553	0.303	0.512	0.503	0.642	0.577	**0.796**		0.859	0.867	0.634
TRI	0.670	0.623	0.602	0.623	0.345	0.611	0.527	**0.852**	0.866	0.881	0.726

4.2 Structural Model and Hypothesis Testing

Standardized path coefficients (β), significance level (t statistic), and R2 estimates were used to assess the structural model (Hair et al. 2021). R-square adjusted values for endogenous constructs were evaluated, explaining the variance of 45.1% for attitude towards success, 56.8% for attitude towards failure, 37.8% for attitude towards process, 56.5% for attitude towards trying, and 61.5% for NFT investment. As shown in Table 3, all hypothesized relationships are evaluated. Using the blindfolding process, Q2 is a criterion of the model's predictive significance calculated to be significantly greater than zero. As a result, the research approach has predictive relevance, and the findings can be usefully interpreted.

Table 3. Hypothesis testing

Hypothesis	Relationship	Beta (β)	T statistics	P values	Decisions
H1a	GSC -> ATS	0.245	2.821	0.009	Accepted
H1b	GSC -> ATF	−0.171	4.102	0.000	Accepted
H1c	GSC -> ATP	0.036	0.558	0.577	Rejected
H2a	CYN -> ATS	−0.201	5.868	0.000	Accepted
H2b	CYN -> ATF	0.308	5.511	0.001	Accepted
H2c	CYN -> ATP	−0.147	0.865	0.062	Rejected
H3	ATS-> TRI	0.210	3.083	0.002	Accepted
H4	ATF -> TRI	−0.283	3.789	0.000	Accepted
H5	ATP -> TRI	0.173	1.598	0.090	Rejected
H6	SI -> TRI	0.292	3.564	0.000	Accepted
H7	TRI -> INVS	0.496	8.020	0.000	Accepted

General self-confidence has significant positive influences on attitude toward success and negative influences on attitude toward failure ($\beta = 0.245$, $p < 0.01$; $\beta = -0.171$, $p < 0.001$, respectively). However, general self-confidence was found insignificant toward attitude towards the NFT process ($\beta = 0.589$, $p > 0.05$). As opposed to general self-confidence, cynicism has a significant negative influence on attitude toward success and a positive influence on attitude toward failure ($\beta = -0.201$, $p < 0.001$, $\beta = 0.308$, $p < 0.01$). Additionally, cynicism was found insignificant in attitude toward the NFT process ($\beta = -0.147$, $p > 0.05$). Further, attitude toward success and attitude toward failure have significant positive and negative impacts on trying attitude to invest in NFTs ($\beta = 0.210$, $p < 0.01$; $\beta = -0.283$, $p < 0.001$, respectively). However, attitude towards the process was found insignificant in trying attitude to invest in NFTs ($\beta = 0.173$, $p > 0.01$). Also, social influence significantly impacts trying attitude to invest in NFTs ($\beta = 0.292$, $p < 0.001$). Lastly, trying attitude to invest in NFTs significantly impacts NFT investment behaviour ($\beta = 0.496$, $p < 0.001$). Therefore, it is more appropriate to consider the concepts of general self-confidence and cynicism as antecedents of attitudes toward success, failure, and the NFT process.

5 Discussion

Here, we discuss the results from a theoretical and practical standpoint. Due to internal user characteristics and external environmental barriers, investing in emerging digital assets like NFTs is regarded as risky behaviour in developing and emerging economies.

As a result, it is decided that applying the theory of trying is more appropriate in this situation. People in these nations frequently consider both the success and failure of their decisions when deciding whether or not to invest in new financial products. Additionally, many may need help learning about new investment products like NFTs due to their lack of familiarity with new technologies. Therefore, it was interesting to note that as per H1c, H2c, and H5, attitude toward the process was insignificant in our model test, as the maturity levels of governance are still primitive to enable investors to make informed investment decisions in NFTs.

According to Bagozzi et al. (1992), attitude can be broken down into the three sub-attitudes that were studied in order to be better understood. Together, these three aspects of attitude comprehensively explain why consumers adopt new technologies.

5.1 Theoretical Implication

First, applying the 'theory of trying' to an evolving domain of NFT investments is unique and one of the first of its kind. In order to explain the appraisal processes underpinning the conduct of risky behaviours like NFT investing, a multidimensional conceptualization of attitude was verified (Bagozzi and Warsaw, 1990). The study proposed an innovative theoretical model to examine if fundamental antecedents such as general self-confidence and cynicism are influential in investors' success, failure, and process attitudes to trial-run the creation, purchase, and sale of NFTs. In addition, the theory of trying provides a lens for examining the psychological and affective dimensions of NFT participation. Second, with the core concept of "trying," associated with pursuing a particular outcome, the study emerged with the underlying psychological factors that motivate involvement in NFTs. Theoretical contributions pertaining to psychological aspects within the framework of the Theory of Trying offer a holistic understanding of human motivation, intentionality, and effort in new experiences such as NFT trial investments. Third, by contemplating the psychological implications of NFT participation, researchers can investigate the potential positive and negative effects of trying to shape their actual investment decisions.

5.2 Practical Implication

First, general self-confidence is crucial in determining users' attitudes towards success. The current study finds that individuals' self-confidence is a catalyst for shaping their attitude toward success, which corroborates with the work by Chadwick et al. (2023). The study finds that general self-confidence can negatively impact an individual's attitude toward facing failure. While self-confidence can be beneficial in some instances, an excessive sense of self-confidence can hinder the learning and trying experience, corroborating with Sundermeier and Kummer (2022). It is imperative for practitioners who engage with individuals interested in the growing asset class of NFTs to acknowledge the adverse influence that self-confidence can have on investing intentions. Practitioners can mitigate the impact of overconfidence bias in the NFT market by implementing educational initiatives, providing support systems, and employing behavioural interventions.

Second, in the current study, respondents believe that cynicism significantly hinders a person's ability to achieve success. Practitioners, including mental health specialists, and financial consultants can facilitate individuals to cultivate a mindset that fosters motivation and perseverance, enhancing their success probability and substantiating the works of DeCoito and Briona (2023). From the current study, we understand that respondents believe that they often anticipate the likelihood of a failure, which can consciously prepare them to deal with it validating the works of Alicke and Strigel (2020).

Third, interestingly, respondents believe that need not negatively impact their attitude about learning a process. Skepticism can be gainful in the pursuit of new knowledge. Hence, as Asikainen et al. (2022) recommended, a healthy measure of cynicism can eventually improve the learning process. Given the unique and digital nature of NFTs, respondents in our study believe that a positive attitude towards success can contribute to the investment's potential growth and profitability, verifying the works of Chalmers et al. (2022) and Klein et al. (2023).

Fourth, according to the current study, NFT engagement can be negatively impacted by an individual's position on failure. The volatile nature of the NFT market can be threatening. Hence, respondents believe that a negative attitude may view potential losses as a personal failure instead of learning opportunities, corroborating the earlier works by Tunca et al. (2023). Therefore, without a robust regulatory and governance mechanism, individuals may make uninformed or rash investment decisions based on unrealistic expectations, verifying earlier works by Cappai (2023).

Fifth, the present study shows that social influence positively affected individuals' willingness to attempt NFTs. Corroborating with the works of Hadi et al. (2023) and Ramjan and Sangkaew (2022), social influence eventually plays a crucial role in motivating individuals to approve the NFT space as an exciting investment avenue. Proactiveness enables investors to gain valuable insights and make prudent investment decisions, validating the works of Safiullah and Paramati (2022).

6 Conclusion and Future Directions for Research

Goal-directed behaviour, not the intention to adopt, is the focus of the trying theory. The effect of general self-confidence and cynicism on attitudes towards process, failure, and success was tested in this research. The study's shortcoming may be the respondents' demographic makeup. The results could be partially impacted by the respondents' knowledge of the NFT market and their high level of education, particularly in light of their varied attitudes about investing in NFT. Future research can examine the role of cynicism and overall self-confidence as moderators. Markets can be divided based on customer cynicism and general self-confidence, which range from high to low.

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Metamorphosis of Recommender Systems: Progressive Inclusion of Consumers

Srishti Bokadia(✉) and Ruchi Jain

Amity School of Business, Amity University Uttar Pradesh, Noida, India
srishti.bokadia@s.amity.edu, rjain@amity.edu

Abstract. Recommender Systems (RS) are computer-based tools that use Artificial Intelligence (AI) algorithms to make product or service recommendations to users. A recommendation algorithm is usually applied to predict users' tastes and preferences based on their behavioral characteristics. RS has gained the attention of e-retailers and managers connected to e-business. This research aims to provide a holistic and deep understanding of RS concerning its current progress and future scope. Hence, the goal of the study is to review the various trends and developments that have taken place in the field of RS in the last decade. Also, it outlines the key future scope and its application in various domains. For this purpose, a comprehensive and systematic literature review has been conducted using recently developed *Scientific Procedures and Rationales for Systematic Literature Reviews* (*SPAR-4-SLR*). A total of 60 journal articles and conference proceedings published from 2010 to 2022 under top publishers have been selected. The extant literature has been scrutinized and research gaps have been identified. Furthermore, this paper also envisions the future of RS, which may broaden the horizon for new research directions in this field.

Keywords: recommender systems · e-commerce · consumer behaviour · systematic review

1 Introduction

The main aim of artificial intelligence (AI) is to advance and develop systems that have intelligence similar to that of a human being that could be applied to a vast number of fields (Dessì et al. 2019). AI has played a prominent role in the field of e-commerce and one such advancement is called Recommender Systems (RS). An RS is an intelligent computerized tool, which predicts and recommends items to the user as per their preference and taste from a vast pool of items available (Singh et al. 2021). AI algorithms, usually associated with machine learning and computational intelligence have been used in the development of these RS (Zhang et al. 2021). AI algorithms are used in RS to supply users with better recommendations (Oumaima et al. 2020).

There is a major problem of overburdening data since the internet is filled with a substantial amount of content related to products and services. One such AI algorithm

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called machine learning makes the work easier by making personalized suggestions of items of interest or additional products to the user. Thus, bringing down the efforts of reviewing each item recorded on the internet (Monti et al. 2021). These can be based on multiple criteria, like purchase history, search history, demographic profile, ratings or feedback and other factors (Adomavicius and Tuzhilin 2005; Adomavicius et al. 2013). RS suggests the users with messages like "you may like, people who purchased this item also purchased…etc." (Lee and Hosanagar 2021). It is extremely useful for sellers as well as targeted customers as it enhances the purchasing experience (Pu et al. 2011). The are two entities associated with RS-users and items. Items are the products and their variants available on the online marketplace. Users make the end-use of the product. RS provides the items of interest to users based on numerical values called ratings (Adomavicius and Tuzhilin 2005).

Recommender systems work based on algorithms and the popular ones are content-based RS, collaborative filtering and hybrid (Li et al. 2013; Yan et al. 2016). However, there are many new forms of RS emerged recently. Some of them are Knowledge-based (KB), Utility-based (UB), Demographic-based (DB) and many others. The significance of RS is to recommend important and useful items to consumers, hence eliminating the drawback of information overload. Out of all the existing types of RS, Collaborative Filtering (CF) is most commonly used in e-commerce and businesses and known to be a very strong technique (Hwangbo et al. 2018).

Though RS are embedded with so many functions yet there still exist some problems with it. Data sparsity is the most common problem. It is caused by the ratings received by users for a limited number of items or criteria. Another well-known problem is cold-start in collaborative filtering approaches. Here, reliable suggestions couldn't be provided due to a lack of data for a new user or new item. There are many other problems like personalization, noise, scalability etc. which are also associated with RS (Monti et al. 2021).

This paper provides a systematic review to scrutinize how the usage of RS influences consumers and what are the latest trends and developments in the field of RS. It is expected that with the help of this research, retailers and researchers will be able to procure more information in this domain, gain a better understanding and make better decisions. Since e-shopping and e-marketing are a vital part of e-commerce now, it becomes very important to study this field of research.

The goal of this study is –

a) to scrutinize the extant literature for theoretical underpinning of recommender systems.
b) to chronologically establish the metamorphosis of RS with advent of time.
c) to project varied domains of RS's application and investigate its key future scope.

2 The Systematic Review

In this work, we follow the newly proposed systematic literature review protocol by Justin Paul called *Scientific Procedures and Rationales for Systematic Literature Reviews* (*SPAR-4-SLR*) protocol—that researchers can rely upon to guide and justify decisions in systematic literature reviews (Paul et al. 2021). According to Paul et al. (2021), it provides several grounds based on which researchers could explain and give justification for their review decisions in comparison to preferred reporting items for systematic review and meta-analysis (PRISMA) coined by Moher et al. (2009). SPAR-4-SLR consists of the following three stages (Fig. 1):

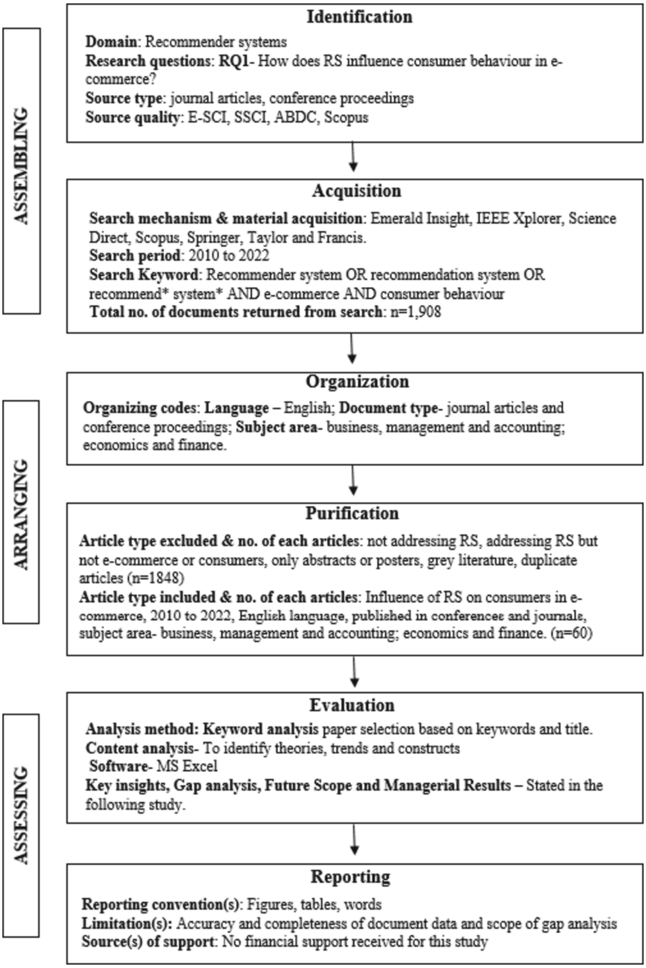

Fig. 1. Review procedure using the SPAR-4-SLR protocol.

2.1 Purification of Data

See Fig. 2.

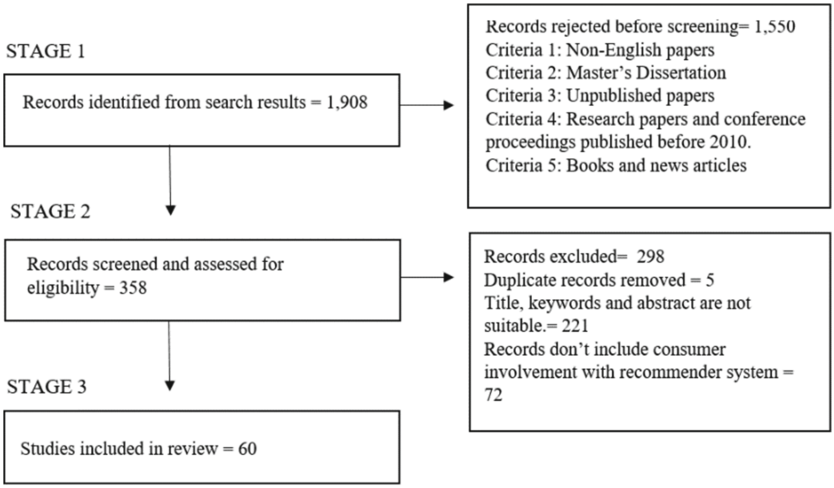

Fig. 2. Inclusion and exclusion process for arranging the records for final study.

2.2 Sources and Paper Selection

See Table 1.

Table 1. Number of papers selected in every stage from each source.

Source	Total Search Results in Stage 1	Short-Listed Papers in Stage 2	Selected Papers in Stage 3
Emerald Insight	116	75	15
IEEE Xplorer	186	54	14
Science Direct	1132	118	6
Scopus	49	32	14
Springer	86	22	5
Taylor & Francis	339	57	6
TOTAL	**1,908**	**358**	**60**

2.3 Year-Wise Distribution

See Fig. 3.

Fig. 3. Number of papers selected per year from 2010 to 2022

3 Chronological Trends in Recommender Systems

The term **'Recommender Systems'** was first coined by Elaine Rich in 1979, unknowingly in trying out different ways to recommend a book to a user which he/she may like. Her idea was to build a system that interrogated user-specific information and assigned stereotypes based on the information. Depending on those stereotypes, recommendations for a book might be made which might be liked by the user (Rich 1979; Beel et al. 2016). The first mention of the term recommender systems was made in a report named 'digital bookshelf' by Jussi Karlgren in 1990 (Karlgren 1990).

The research trends and developments have been evaluated from 2010 onwards since the major growth in internet users, e-commerce and personalized shopping apps like Myntra, Amazon etc. have taken place since then. As per the reports of the Internet and Mobile Association of India (IAMAI) and Credit Rating Information Services of India Limited (CRISIL), significant growth in e-commerce and e-tail has taken place since 2010 (Patel 2015). Hence, all the major research documents were retrieved from 2010 to 2022 and the periphery for the research has been drawn accordingly.

Development of New Concepts in RS

In 2010, Zhu et al. (2010) proposed an intelligent online recommendation system (IOLRS). It aimed at making the purchase decision easier for the consumer based on apparel knowledge and apparel matching. Abdullah et al. (2010) focused on the products purchased infrequently as it is difficult to collect their data such as ratings and purchase history etc. A recommendation approach was proposed based on user opinions and navigation data to generate product profiles and user profiles respectively. Martínez-López et al. (2010) examined the role of aspects of psychological ordering in the behavior of online consumers, concerning their use of WS-RS (website recommendation system).

Increasing Role of Trust and Social Presence

In 2011, Choi et al. (2011) established a shred of empirical evidence demonstrating relationships between social presence and reuse intention and trust. Trust played a mediating role between the two variables. Their study also compared their effect on two different products: hedonic and utilitarian.

Consumer's Intention

In 2013, As per Ku and Tai (2013) RS intended to raise consumer purchasing intentions and could improve consumers' experience value by providing personalized service. The insights of the study established a vital relationship between recommendation information with consumers' attitudes and purchase intentions. Wu et al. (2013) investigated the effects of famous recommenders such as collaborative filtering (CF) and content-based (CB) filtering to study if they have varied effects on user satisfaction and willingness to purchase for customers with multiple awareness of products. Lepkowska-White (2013) aimed at studying the use of online recommender systems on e-commerce sites. It helped marketers to advance their operations and consumers' shopping experience. Consumers' reactions to recommendations drafted for search, experience and credence goods were examined. It also explored the features of recommendations that helped in facilitating purchasing decisions. Adomavicius et al. (2013) aimed at upgrading recommendations technology to improve the preciseness of predictions and consequently focused on the behavioral aspects. It was inspected how RS impacted consumer preferences at the time of consumption. The study highlighted the noteworthy issues related to the design and implementation of RS. Jeong and Lee (2013) constructed a theoretical framework of consumers' perception of the marketers' motive, in which, consumers respond to a variety of recommendations generated by e-commerce websites. The study had practical implications for marketers interested in improving consumers' attitudes towards their websites using RS. Christidis and Mentzas (2013) considered the functions of electronic marketplaces. The user's browsing of items and the seller describing and pricing and items were addressed in the research work.

Inclusion of Consumer Review

In 2014, Christensen and Schiaffino (2014) proposed an approach to produce recommendations for groups using social factors obtained from social networks. In addition, to identify potential influence from members to predict the group's opinion on every item. Baum and Spann (2014) aimed that interpreting an interplay between online consumers' reviews and recommender systems and its impact on consumers' decision making. Online consumer reviews and provider-generated recommendations for high and low-involvement products and also for search and experience products were experimented with. He et al. (2014) stated that the main focus of RS was to accelerate sales by forecasting the additional items that the consumer might buy, but haven't noticed yet. Companies like Amazon.com have a competitive advantage of an efficient RS over others. The need arises to predict consumers' needs and wants due to the growing competition. Hence, an intent-based RS was constructed. Lin (2014) attempted to answer the relative impact of users and system-generated recommendations on sales of goods in e-commerce. Also, to investigate if the system recommended substitutes or complements affected product sales. The research was conducted on the digital camera product category on a Chinese platform called Tmall.com.

Consumer Journey

In 2015, Chadha and Kaur (2015) presented an overall explanation of RS and compared the different features of various types of RS (i.e. CB, CF and Hybrid). The study was conducted in the area of digital libraries and information systems. The research provided all the technical details and features comparison of types of RS. Martínez-López et al. (2015) expressed that consumers' adoption and use of RS include subjective factors which require a psychological approach. The aim was to validate a model focusing on an extensive approach for the consumers' acquisition of e-vendor RS. Priya et al. (2015) presented an explanation of how RS helps e-commerce sites boost sales and evaluate business patterns. It produced creative ideas for the new applicability of RS in B2C interactions. Heimbach et al. (2015) demonstrated an experiment to overcome the cold-start problem of the recommender system, where no transaction history is available for new users by retrieving external data from websites like Facebook based on the posts shared, content views and likes. Martínez-López et al. (2015) discussed the issues related to understanding the psychological perspective of consumers which in turn helps purchase processes in online stores by empirically testing them. Scholz et al. (2015) addressed the gaps in research on RS. Firstly, predicting consumers' willingness to pay. Secondly, it provides a better estimation of consumers' preferences using non-linear utility functions, which are considered better than linear functions. An approach was developed to estimate them simultaneously.

Recommendation Accuracy

In 2016, Congying (2016) investigated apparel recommendations in the commercial market for the authentication of its importance and research value. Köhler (2016) discussed how consumer preferences have an impact on the preciseness of RS. A microeconomic model was introduced that enables a systematic analysis of varied components of consumer preferences. A model-specific metric to measure recommendation accuracy was established. Panniello et al. (2016) focused primarily on enhancing the accuracy of recommendations generated on RS. The main attention was given to understanding the firm's incentive such as profit or margin via recommendation. It was suggested that RSs can better balance customer relevance with profitability. Beladev et al. (2016) highlighted the importance of recommendation bundling of products and how they satisfy the customer's needs as well as maximize the firm's profit. Since most of the recommendation methods did not include personalized price alteration, the paper focused on a model, combining collaborative filtering, demand functions and price adjustments. Jiao et al. (2016) mainly presented the fuzzy theory that dealt with customers' behavioral data. A personalized recommendation model was constructed and assessment and development functions were enforced to enhance recommendation accuracy.

Personalization of RS

In 2017, Li et al. (2017) presented a blueprint to recommend desirable products to customers with a thought to not only satisfy their preferences but also, the product's quality performances and their online retailer's service performance. The framework consisted of three modules namely, the data collection and preference analysis module, the hybrid recommendation module and the recommendation generation module. Gao et al. (2017) Stated that low-quality recommendations posed a great challenge in traditional CF due to the sparsity of data. A deep learning model was proposed to forecast the value of null ratings. Personal recommendations based on consumer preferences were analyzed to solve the issue. Yang and Gao (2017) expressed how broadly RS had been adopted by retailers to boost their sales and had a considerable influence on the stakeholders involved in the supply chain. An online retailer could maximize its revenue and income by constructing a strategic RS between two competing manufacturers and selectively recommending them. The system helped in successfully managing the supply chain by diminishing the channel conflict associated with the recommendation market produced by RS. Ma et al. (2017) proposed a user-preference-based CF recommendation approach that assimilated the aspect-level information demonstrating user preferences. The proposed model helped in identifying user similarities using the aspect preferences, which were further integrated into collaborative filtering. Aspect importance and aspect need were the two measures for aspect preference appraisal established to aspect relationship to overall rating and the opinion's differences to aspects respectively. Badriyah et al. (2017) developed a hybrid recommendation system that incorporated content-based filtering and collaborative filtering methods that calculated similarities between product descriptions and user profiles. Cena et al. (2017) stated that personalized suggestions are produced by anticipating ratings for products consumers are not aware of, which is done based on the user ratings of other products. Explicit ratings accumulated by a graphical user interface called rating scales helped in making such predictions.

Imbibing Knowledge and Value in RS

In 2018, Zhao et al. (2018) highlighted the idea of personalized RS on consumers' purchasing decisions to influence people to use RS. It also reduces decision-making efforts and time of consumers boosts the input of user information and consequently enhances the overall quality of decision-making. Social media and social networks have encouraged research scholars to explore the impact of product recommendations and user recommendations on demand and supply. Roudposhti (2018) developed a new model by recognizing the influencing features of consumers' purchase intention in RS. The established model would help the e-commerce website developers improve the RS based on the provided factors. A model was also provided to understand consumers' motivation for recommendation acceptance. According to Li et al. (2018), Consumers could be characterized concerning preferences between two products (locational differentiation), on the other hand, with regard to awareness about the two products (informational differentiation). An RS shortlisted the recommendation based on the recommendation score. As per Yadav et al. (2018) content-based filtering and collaborative filtering methods have been utilized by hybrid recommendation. It integrated the coincidence of user files and product descriptions. Yin et al. (2018) stated that to know the consumers' online behavior in time and to maximize the satisfaction level of consumers was extremely crucial for a successful RS. Ying et al. (2018) Expressed that RS helped in aiding consumers by reducing information overload. A framework was offered that practices a user-centered approach to analyze the impact of RS on unplanned purchase behavior in e-commerce. Alyari and Jafari Navimipour (2018) Provided a comprehensive study of empirical pieces of evidence on RS and its techniques. As per Cheng et al. (2018), to maintain consumer attention and boost purchase rates, many e-commerce retailers adopted CB-RS however, it resulted in a limited content analysis problem. A value-based recommendation method was proposed for identifying favorable attributes, benefits and values based on means-end chain theory.

Integration of Information and User Opinion

In 2019, As per Cha et al. (2019), users became distant from the information that didn't agree with their opinions. Hence, they separate themselves in their ideological bubble. Hence, there exists a filter bubble in RS methods and it is important for AI (Artificial Intelligence)-RS to understand people's behavior.

User and Product Information

In 2020, Huang et al. (2020) focused on online lifestyles and their role in predicting consumers' purchasing preferences across different product categories considering the impact on personality traits. Virdi et al. (2020) consolidated CF-RS with consumers' social network information, e-commerce sites generate recommendations based on the social networks of the users. The primary focus was to qualitatively investigate consumers' psychological outlook on accepting SRS in e-commerce websites. Hence, the analysis leads to the emergence of three main themes - social gratification, self-gratification and information gratification. Srivastava et al. (2020) presented a psychographic model-based approach for the refined identification of grey sheep users. The presence of grey sheep users, with unconventional tastes, reduces the complete productivity of RS. Grey sheep behavior was also studied across varied domains and contexts. Yang (2020) examined the influence of informational factors on purchase intention in social recommender systems. It also verified the effect of trust in recommendation and perceived value between informational factors and consumers' purchase intention. Zhang and Bockstedt (2020) aimed at examining whether and how recommendations of types of other products influence consumers' economic behavior for a focal product. In many e-commerce websites, numerous co-purchase and co-view recommendations appear with a product, which usually contains complements and substitutes. Wakil et al. (2020) Proposed a model to analyze the performance of RS based on informational factors like customer history, product classification and prices in e-commerce. The factors like user profile, expert opinion neighbors, loyalty and clickstream positively influenced RS. Alamdari et al. (2020) compared the different types of filtering techniques i.e. content-based filtering (CBF); collaborative filtering (CF); demographic-based filtering (DBF); hybrid filtering (HF); and knowledge-based filtering (KBF). It was observed that CF techniques were used more than all other methods. The latest papers focused on new approaches such as data and web mining algorithms, neural network-based methods and generic algorithms. Deng (2020) Proposed a heterogeneous network-based approach to utilize consumer behavior for recommending products. Meta paths explained the behavioral relationship between consumers and products and were used to evaluate the similarities.

Overcoming Challenges and Exploring New Approaches

In 2021, Lee and Hosanagar (2021) investigated the moderating effect of product attributes and review ratings through different purchase stages i.e. awareness (views), salience (conversion conditional on views) and final conversion of a purchase-based CF-RS on an e-commerce website. Recommender's awareness lift is greater than its saliency impact. Shahriari-Mehr et al. (2021) proposed a personalized RS pertaining commercial domain. It considered internet searches as the latest and vital contextual information to enhance recommendation tasks. Voronoi diagram helped in similarity analysis in CB-RS to lower computation difficulties and time. Chinchanachokchai et al. (2021) bridged the gap between marketing and computer science by examining the moderating effects of consumer knowledge (expertise) on the performance and evaluation of CB-RS and CF-RS. It was found that expert consumers preferred user-based CF systems. There is no difference between the two systems in the case of inexperienced consumers. Khodabandehlou et al. (2021) provided constructive and exhaustive recommender system to minimize the issues of cold-start, sparsity, scalability and interest drift in actual performance. It used a combination of basic customer information and big data techniques. Abdul Hussien (2021) produced an overview of RS and analyzed CF techniques, which presented suggestions to the customers as per their interests, thus making it easier for the customer to search and choose products which fit their needs. Monti (2021) conducted a systematic literature review considering common research problems, recommendations approach, data mining and machine learning algorithms. Domains of applications were also investigated, suggesting promising future works.

Increasing Effectiveness of RS

In 2022, Yunhui et al. (2022) focused on how online recommendation systems might affect the evaluation of focal products. It mainly concentrated on the comparison of complement-based recommendations and substitute-based recommendations in terms of evaluation of focal products by studying complementation-warmth VS competition competence and processing fluency. Zhou et al. (2022) studied the effects of RS and pricing strategies on competition between store brands and national brands and consumers' search behaviors. Two market segments, namely brand-preference and price-preference consumers were explored by comparing the impact of the model with RS and without RS. Roy and Dutta (2022) reviewed a bunch of recent contributions in the field of RS systematically, primarily focusing on varied applications like books, movies, products etc. Algorithmic analysis was performed and a taxonomy was developed for components required for establishing an effective RS. Lina et al. (2022) focused on how recommendation systems influence online purchase intentions.. High-involvement consumers seek a feeling of certainty, whereas low-involvement consumers look for a sense of approval while opting for the recommended items. Kim et al. (2022) proposed sequence-aware recommender (SAR) system for fashion product recommendation to overcome the limitations of CF and CB regarding behavioral characteristics of clicking the product information sequentially.

4 Findings and Future Scope

See Table 2.

Table 2. Table reporting the findings and scope for the future research.

S. No.	Future Scope	Authors	Findings
1	Adoption of advanced technology	(Abdullah et al. 2010; Zhu et al. 2010; Beladev et al. 2016; Congying et al. 2016; Köhler 2016; Li et al. 2017; Alyari and Jafari Navimipour 2018; Huang et al. 2020; Chinchanachokchai et al. 2021; Kim et al. 2022)	• There is further scope for the adoption of new technology like 3D technology, advanced fusion techniques for product selection, and technology to adopt lifestyle scores of consumers and generate preference prediction • Adoption of newly devised algorithms like RNN (recurrent neural networks) algorithms etc • Exploring recently developed recommendation systems methods like hybrid RS and others
2	Varied demographics and domains	(Martínez-López et al. 2010; Choi et al. 2011, 2017; Lepkowska-White 2013; Wu et al. 2013; Jeong and Lee 2013; Lin 2014; Christensen and Schiaffino 2014; Priya et al. 2015; Martínez-López et al. 2015; Heimbach et al. 2015; Köhler 2016; Li et al. 2017; Ma et al. 2017; Cheng et al. 2018; Li et al. 2018; Yin et al. 2018; Alamdari et al. 2020; Virdi et al. 2020; Zhang and Bockstedt 2020; Deng 2020; Roy and Dutta 2022)	• Theoretical discussions could be universally validated by working on varied demographics of the population, data sets, and categories of the products (hedonic, utilitarian, heterogeneous) • Different domains of RS could be explored on several online platforms using various sampling methods

(*continued*)

Table 2. (*continued*)

S. No.	Future Scope	Authors	Findings
3	Consumer purchase intention and consumer behaviour	(Adomavicius et al. 2013; Ku and Tai 2013; Lin 2014; Scholz et al. 2015; Jiao et al. 2016; Cena et al. 2017; Ying et al. 2018; Zhao et al. 2018; Yin et al. 2018; Cha et al. 2019; Wakil et al. 2020; Lina et al. 2022)	There is a scope to study the impact of RS on consumer preferences and perception Consumer purchase intention and willingness to buy should be focused upon Dynamic behaviours could be further assessed by incorporating the issues related to trust and biasness Impact of consumer ratings and reviews on RS should be studied
4	Performance of RS for information accuracy	(Christidis and Mentzas 2013; Baum and Spann 2014; Heimbach et al. 2015; Congying et al. 2016; Badriyah et al. 2017; Gao et al. 2017; Ma et al. 2017; Yadav et al. 2018; Yang 2020; Zhou et al. 2022)	Performance of RS should be evaluated and consistency of RS should be improved for accurate results Information accuracy may increase recommendation strength
5	Consumer traits and cultural differences	(He et al. 2014; Chadha and Kaur 2015; Cheng et al. 2018; Ying et al. 2018; Zhao et al. 2018; Srivastava et al. 2020; Virdi et al. 2020; Chinchanachokchai et al. 2021; Khodabandehlou et al. 2021; Lee and Hosanagar 2021)	Consumer traits like personality, information learning effectiveness should be taken into consideration for future research Impact of subjective norms and cultural differences on consumer acceptance of RS Exploring consumer perception and satisfaction

(*continued*)

Table 2. (*continued*)

S. No.	Future Scope	Authors	Findings
6	New dimensions for research	Martínez-López et al. 2015; Priya et al. 2015; Congying 2016; Panniello et al. 2016; Roudposhti 2018)	New variables and constructs are to be explored. Some of the most discussed variables are attention, user profile, product profile, attitude, attention etc Implementing research in new industries like aviation industry, online gaming, meta-verse etc.
7	Economic impact of RS	(Li et al. 2018; Zhang and Bockstedt 2020)	It is essential to study the economic impact of RS Consumer's economic behaviour should be considered

5 Discussion and Conclusion

Deciding among a plethora of options available from a vast pool of data on the internet becomes a difficult and confusing task. Hence, RS helps users to overcome this problem by providing them with suitable suggestions as per their requirements. RS uses several AI algorithms to perform this task efficiently and accurately. Over the last decade, comprehensive research work had been done to propose new techniques and recommendation approaches. In this paper, a holistic and comprehensive understanding of RS concerning current progress and future scope has been provided with the help of a systematic review tool known as SPAR-4-SLR developed in 2021. Various trends and developments that have taken place in the field of RS with respect to consumers have been studied. It has also stated a few domains in which the research has been conducted. The trends in the field of RS have been studied from the year 2010 to 2022 and the major development of each year had been outlined. Some interesting statistics have surfaced. The maximum number of papers were retrieved from the year 2018. Emerald Insight has published the highest number of research papers on this subject. Adomavicius and Tuzhilin (2005), Adomavicius et al. (2013), Martínez-López et al. (2015) are some of the major contributors to the related study. Online apparel retail and gadgets are a few domains popularly worked upon. A number of systematic reviews have been conducted in this field, but there are hardly any using the SPAR-4-SLR protocol. This research will provide a guideline for future research in the domain of RS. However, it has some limitations which provide directions for further research. Technical reports, editorial notes, web pages and books were excluded from the research which may have important literature related to the study. Also, no related study was found from the year 2012 and very few from the year 2019. Hence, it cannot be claimed that all related items were found and reviewed.

Papers were selected on the basis of title, abstract and keywords. There may be papers which don't include the combination of keywords used in this study but could be completely relevant to the study. The items were ranked in chronological order, there could be other creative arrangements too. It is expected that the forthcoming research on RS will witness several new and innovative avenues.

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How Do Cryptocurrency Miners Perceive the Ecological Implications of Their Work?

Kayla Brown, Pitso Tsibolane(✉), and Adheesh Budree

Department of Information Systems, University of Cape Town, Cape Town, South Africa
brwkay004@myuct.ac.za, {pitso.tsibolane, adheesh.budree}@uct.ac.za

Abstract. The ecological consequences of cryptocurrency mining have been a topic of debate since the inception of blockchain technology. The widely used proof-of-work (PoW) mining technique, which requires a significant amount of energy, has raised concerns about the long-term environmental sustainability of cryptocurrencies. However, the perspectives of crypto miners have been largely underrepresented in these debates. This study used the Values-Belief-Norms (VBN) framework to explore how cryptocurrency miners perceive the potential environmental effects of PoW mining. In-depth qualitative interviews were conducted with twelve crypto miners from South Africa (5), Argentina (2), the United States (1), Australia (1), Taiwan (1), France (1), and Switzerland (1). The results indicate that crypto miners' values, environmental worldviews, and convictions about the value of cryptocurrency and PoW mining significantly influence their environmental attitudes. The findings of this study shed light on the attitudes and viewpoints of crypto-miners and the implications of their beliefs regarding the mining process. This not only contributes the perspectives of crypto miners to the discussion on the ecological effects of cryptocurrencies, but it also offers policy-makers insights into how people perceive the environmental consequences of their actions.

Keywords: Blockchain · Cryptocurrency · Crypto-mining · Sustainability · Ecology · Values · Beliefs · Norms

1 Introduction

The proof-of-work (PoW) process of verifying transactions and generating new cryptocurrency coins, known as mining, depends on high computational power and thus necessitates significant electricity consumption. While it is uncontested that this method of cryptocurrency mining consumes copious amounts of energy, the environmental impact of cryptocurrency is a complex and nuanced subject. In keeping with the blockchain ethos, cryptocurrency mining is mainly decentralized and unregulated. As a result, the technology's ecological footprint is difficult to measure accurately. This is worsened by the volatility of the prices and volumes at which cryptocurrency is traded.

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Prior research shows that the environmental impact of cryptocurrency has the potential to push global temperatures above the 2 °C threshold within less than three decades, threatening global leaders' efforts to alleviate global warming's effects [1–3]. In response to this, several countries have banned cryptocurrency mining within their borders, notably China, Egypt, and Qatar, among others [4, 5]. Others hold that although cryptocurrency consumes large amounts of electricity, this does not translate into environmental damage due to the widespread use of renewable energy sources in blockchain mining [6]. Extant literature has also highlighted that accounting for blockchain technology's environmental impact is unclear, and the lack of central authority makes it difficult to estimate energy consumption and carbon emission levels precisely [7, 8]. This has resulted in discrepancies between various estimates [9]. Given the variety of perspectives and responses to the issue, an opportunity is presented to engage crypto-currency miners (an underrepresented group) in discussing the implications of crypto-currency mining on the environment.

Despite the growing body of research on the environmental impact of cryptocurrency, little is known about the perspectives of the miners themselves regarding their attitudes towards the ecological impacts of crypto mining. This is a significant gap in the literature, as the attitudes of miners are likely to influence their mining practices and the environmental impact of the technology. The following research questions will be addressed in this paper: What are the attitudes, values, and beliefs of cryptocurrency miners on the ecological implications of their mining activity? Secondarily, how do attitudes, values and beliefs influence their actions in cryptocurrency mining?

The remainder of the paper is structured as follows: Sect. 2 will provide a literature review of the environmental impact of cryptocurrency and the attitudes of cryptocurrency miners. Section 3 will describe the research methodology used in this study. Section 4 will present the findings of the study. Section 5 will discuss the findings and their implications. Section 6 will conclude the paper.

2 Literature Review

The Value-Belief-Norm (VBN) theory was developed to provide insight and understanding into non-activist support for environmental movement goals [10]. The VBN model is depicted in Fig. 1.

The value-belief-norm (VBN) theory postulates that pro-environmental actions stem from an individual's moral norms about the environment. These norms, referred to as personal norms, develop when an individual is aware of the negative consequences that the conditions of the environment can have on themselves, other people, and the biosphere (termed awareness of consequences), and that their actions hold the capacity to prevent or reduce these negative consequences (termed ascription of responsibility) [10, 11].

The three values that are characteristic of environmentalism are biospheric, altruistic, and egoistic (or self-interested) values [10, 11, 43]. In their research, [10] found that personal values play a vital role in informing behavior and attitudes when considering the costs and benefits of acting. Value orientation influences a person's beliefs, which in turn impacts attitudes and behavior [13]. This is because a person's values serve as a filter to regulate the information that they are exposed to [13]. As a result, if the information they receive about a scenario, an object, or behavior is consistent with their values, they are more likely to hold positive beliefs about that scenario, thing, or behavior [13].

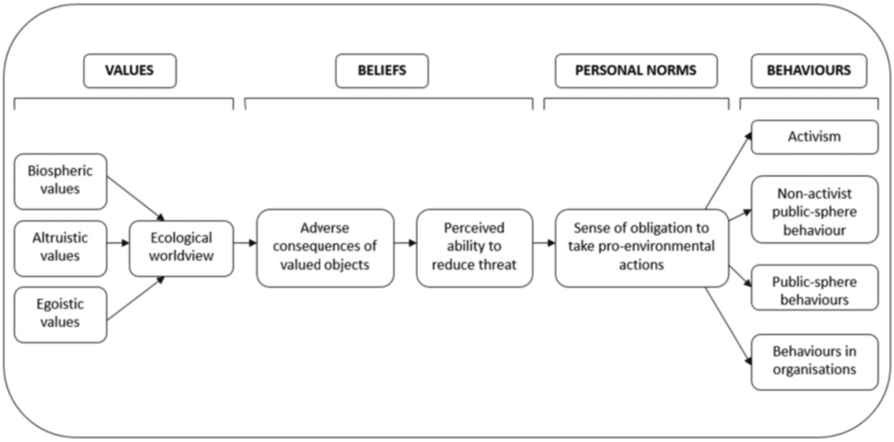

Fig. 1. Value-Belief-Norm theory of environmentalism [adapted from 41]

In a study investigating the connection between personal values and pro-environmental conduct, researchers found that biospheric values (those showing care for non-human species and the biosphere as a whole) and, to a lesser extent, altruistic values (those focused on caring for others), were reliable predictors of environmental activism [13, 14]. Conversely, environmental activism and self-centered values were found to have a substantial negative association [13, 14].

The individual's ecological worldview is connected to their biospheric, altruistic, and egoistic values [10]. In the VBN theory, these values form the foundation of an individual's ecological worldview and environmental beliefs [10, 11]. The sequence of values influencing ecological worldview has been described as shifting from the central aspects of personality and beliefs toward the more defined belief about an individual's ecological impact and responsibility, which then triggers actions that aim to support pro-environmental ideals [10]. Each construct within the theory impacts the next, with personal norms operating as a dominant influence (see Fig. 1).

In developing the VBN theory, [10] adopted the new ecological paradigm (NEP) [15]. During the time of the conceptualization of NEP, the pro-environmental move-ment was growing, and society was beginning to adopt the view that people's actions can negatively affect the ecology [10, 15, 43]. Based on this, [10] contended that an individual adopting this ecological worldview is predisposed to accept responsibility belief. Thus, the VBN model includes a causal link between the ecological worldview and AC of an individual (Fig. 1). This nexus between an individual's values, environmental beliefs, personal norms, and pro-environmental behavior is displayed in the VBN model in Fig. 1.

Figure 2 shows an adapted VBN model, adjusted to the context of this study, which focuses on crypto miners and their mining activity. Based on the VBN theory and adjusted

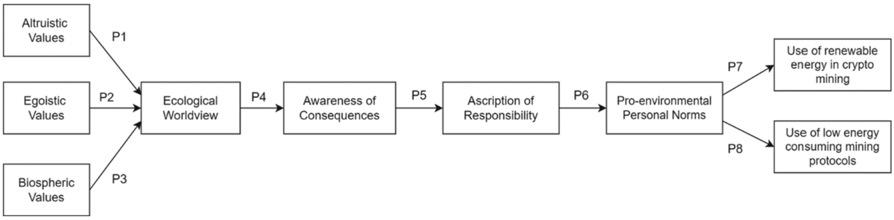

Fig. 2. Adjusted Value Belief Norm model (adapted from [10])

VBN model (Fig. 2), the propositions shown in Table 1 were developed and tested to answer the research questions of this study.

Table 1. Table captions should be placed above the tables.

Construct	Definition	Proposition	Reference
Biospheric values	Values driven by self-focused motivations, including wealth, power, social status, etc	**P1:** Biospheric values influence cryptocurrency miners' ecological worldview	[13, 16]
Altruistic values	Values related to showing concern for other people	**P2:** Altruistic values influence cryptocurrency miners' ecological worldview	[13, 16, 17]
Egoistic values	Values related to showing self-interest or concern for oneself	**P3:** Egoistic values influence cryptocurrency miners' ecological worldview	[10, 11, 18]
Ecological worldview	Related to the belief that ecosystems and hu-man civilizations are interconnected, and that humans should strive to coexist peacefully with nature rather than attempting to dominate it	**P4:** Cryptocurrency miners' ecological worldview influences their awareness of consequences	[10, 11, 18]
Awareness of consequences	The awareness of negative environmental consequences and the fact that environmental conditions have the potential to either improve or threaten oneself, others, or the biosphere	**P5:** Cryptocurrency miners' awareness of consequences influences their ascription of responsibility	[16, 19]

(*continued*)

Table 1. (*continued*)

Construct	Definition	Proposition	Reference
Ascription of responsibility	Perception of one's ability to reduce threat; an individual's belief or denial that their actions caused or could promote or reduce potentially negative environmental consequences (of crypto mining)	**P6**: Cryptocurrency miners' ascription of responsibility influences their sense of responsibility	[10, 16]
Personal norms	A belief in one's moral obligation or responsibility to reduce potentially negative environmental consequences	**P7:** Cryptocurrency miners' ascription of responsibility influences their pro-environmental personal norms	[10, 16, 19]
Pro-environmental actions	Actions that aim to mitigate and reduce potentially negative environmental consequences in response to personal norms	**P8:** Cryptocurrency miners' pro-environ-mental personal norms influence their pro-environmental actions	[10, 16]

3 Methodology

3.1 Research Approach

The study adopted an interpretivist stance as it aimed to provide an understanding of the factors influencing crypto miners' ecological attitudes and beliefs within their given context—their context being working within the cryptocurrency mining process and receiving some form of benefit from it [20].

The interpretivist philosophy is a foundation for the study's exploratory research purpose, as the research topic is a relatively new area of study into which the research aims to provide insight. As such, a qualitative case study strategy was adopted to understand crypto-currency miners' attitudes within their context [21, 22].

An inductive approach was used to discover potential themes in the data that are not informed by the theoretical framework. Using this approach, potential influences on the supporting evidence of the propositions (for example, geo-graphical location, climate, energy infrastructure) were discovered and analyzed [23].

3.2 Data Collection and Analysis

The data analysis process began by organizing the gathered data, followed by a process of familiarization and immersion by reading through and taking notes on the transcripts

[24, 25]. The analysis took place sequentially, first following the deductive analysis process followed by the inductive analysis process.

Deductive thematic analysis was first conducted, where a codebook was developed which labeled and defined each code based on the propositions developed from the VBN theory [26]. From this process, the existent themes in the dataset that align with the VBN theory were identified [23, 26].

A process of open coding then took place which entailed detailed, line-by-line readings of transcripts, and developed codes based on the emergent themes and categories in the data [25]. Overlapping categories from the deductive and inductive analysis were then identified, aggregated, and refined. This process was con-ducted iteratively, alternating between the theory-driven code, and the separate emerging themes in the interview data [23, 27, 28]. This was done until a second conceptual model that incorporated the emerging themes and concepts from both processes was developed [23].

Once themes were identified, a process of review and refinement took place, in which inconsequential and aggregated themes that were not sufficiently promi-nent to include as a main theme were removed. Included in this phase was also the process of identifying patterns and relationships between themes by making use of an interview tracker.

Semi-structured interviews were conducted with crypto miners via MS Teams, Zoom, and phone calls for a duration of 30–45 min on average. Criterion sampling, a non-random sampling technique, was used, where participants were chosen based on their knowledge of cryptocurrency and cryptocurrency mining and their willingness and ability to articulate this knowledge [29, 30]. The research involved a sample size of 12 interviews, including a pilot interview based on the recommendations of [30], who state that phenomenological studies require 10 or less interviews to reach saturation.

4 Findings

4.1 Demographics and Socioeconomic Contexts

Among the crypto miners (CM) who agreed to participate in the study, all the participants were male, with the majority being between the ages 18–39. Most participants also had received tertiary level education, with 5 out of 12 participants having obtained a master's degree. Additionally, most crypto miners interviewed were employed, and working or studying in IT-related fields. Of the 12 participants, 7 reside in developing economies with unstable or volatile energy infrastructure. Two interviewees sourced energy for mining from private solar panels, while the majority utilized the energy provided by their country's energy infrastructure. Of the 12 miners interviewed, 5 resided in countries with developed economies, while the remaining 7 were living in developing economies. Of those living in developing economies, the majority (5 out of 7) reside in South Africa.

4.2 Values

Altruistic Values. Analysis of the data revealed that most of the research participants held altruistic values. Participants with particularly strong altruistic values (CM5, CM6 and CM11) expressed that the welfare of society was a motivating force in their lives:

CM5 - *"I do describe myself as a social entrepreneur like I want my entrepreneurial endeavors to have social impact. So, and then of course, wealth like the more there's abundance and profit that would position me more to do more social impact."*

Biosphere Values. The biospheric values of participants were categorized as anthropocentric values and eco-centric values. Participants CM1, CM6 and CM7 voiced anthropocentric biospheric values, indicating that they valued the environment insomuch as the environment benefitted human beings. When asked if they felt that the well-being of human life was equally important as the well-being of animal and plant life, CM7 responded: *"Overall well-being, yes. But I do believe they are here to serve us a purpose"*, expressing biospheric values that are anthropocentric in nature. Other participants (CM3, CM5, CM9, CM12) attributed comparatively lower value to the biosphere, redirecting emphasis to their concern for humanity. For example, although CM9 viewed the natural biosphere as holding value, they expressed greater regard for society: CM9 - *"The value of the natural environment is to be maintained if not protected, but at the same time, um, there are so many people who are living in disadvantage because you know, certain countries have taken advantage of the environment. And I don't think we should protect the environment while letting those people lose chances for a better life, in a sense."*

Egoistic Values. Most participants did not voice strong egoistic values, stating that wealth, social influence, social power, etc. was not of important or a motivating factor to them. Participants CM2, CM7 and CM10 conveyed that financial security and comfort was important to them. However, egoistic values were not strongly expressed among these participants: CM10 - *"I have been driven by opportunities which brought me a better financial stability and status, uh, but not necessarily for the social, uh, recognition of it, just, uh, to have the, the luxury."*

Socio-political Views. Participants CM2, CM3, CM5, and CM12 were among those who expressed strong socio-political views. CM5 and CM12 voiced distrust of the government and media's agenda in the climate change discourse. When asked about their view on climate change and their individual carbon emissions, CM5 expressed the view that the popular narrative surrounding climate change and carbon footprint were *"gas-lighting middle class and lower-class people" (CM5). Participants CM5 and CM3 viewed the narrative surrounding climate change as being harmful particularly for developing economies, and expressed that the interventions of Western, developed governments in the environmental affairs of developing nations would ultimately be regressive for economic prosperity, rather than constructive: CM5 - "I do think politics make it difficult, like, even though it seems like a lot of the green new deals and policies come from good intention, but a lot of it hinder innovation and progress as well. And sometimes the Western countries enforce their environmental regulations on Africa and in South America."*

Ecological Worldview. Ecological worldviews were ordered as strong or weak ecological worldviews, and strong or weak anthropocentric worldviews. Participants with a strong ecological worldview (CM4, CM8, CM10, CM11) believed that the environment was easily damaged by human activity leading to the destabilization of the eco-systems, and that the interests of human beings should not be prioritized over the natural world.

CM10 voices their strong convictions as to the importance of upholding the protection of the environment over seeking the interests of human beings: CM10 - *"[Humanity] should be able to live in harmony with the nature as much as possible. And if it doesn't, then it's a failure on humanity and humanity should at some point pay the cost for it."*

Anthropocentric Worldview. Participants with an anthropocentric worldview (CM1, CM3, CM5, CM6, CM7 and CM9) viewed humans as dominating the natural environment and validated the interests and welfare of humanity as having priority over the interests and welfare of animal and plant life. CM6 - *"We are not here to take advantage… that's what we do so that we can prosper even more and that sort of thing, but it's at the expense of the environment… We're the dominating species. If there was another species, some super lion or whatever, they'd be doing the same thing. We, and we'd just be another speck of wildlife out there."*

Perception of Cryptocurrency's Value to Society. A significant number of crypto miners interviewed (7 out of 12) expressed a strong conviction as to the value of cryptocurrency to society (namely, CM2, CM3, CM5, CM6, CM7, CM8 and CM12). The perceived value of cryptocurrency was mainly centered on the financial inclusivity that cryptocurrency enables, decentralization and the ability of the technology to transcend geographic, language, political and economic constraints. CM12 - *"I mainly talk about financial inclusion which is, a very, it's a big problem in Argentina. I'm also very passionate in Monero because it addresses the problems… with systemic exclusions of the financial system, that Argentinians face on day to day."* Some crypto miners also believed that proof-of-work mining has the potential to promote the use of renewable energy (CM5, CM3, CM6, CM9 and CM12). These miners explained high energy consumption of mining could drive up the demand for low-cost renewable energy as miners are seeking to maximize profits and efficiency: CM5 - *"Bitcoin mining's impact is that it has caused a great adoption of renewable energy because it the incentive structure that Bitcoin mining makes renewable energy much more feasible and much more cost effective."* Others, namely CM10 and CM4, did not perceive proof-of-work cryptocurrencies as having significant value to society, and expressed that they viewed the technology as being overhyped. CM10 - *"I think some people are a bit indoctrinated… they believe the cryptocurrencies are the second coming or something like that, and for me, I don't see what they have improved in the life of humans where they even fail as currencies because they fluctuate so much that they're just used for speculation. You cannot just hold one of the cryptocurrencies except to speculate."*

4.3 Attitudes Toward the Ecological Consequences

While some cryptocurrency miners interviewed were relatively neutral toward crypto mining's environmental implications (CM2, CM8, CM9 and CM11), others felt that proof of work mining had a positive impact on the environment (CM3. CM5, CM6, CM7 and CM12). Still, others had strong negative attitudes toward proof of work mining's ecological implications (CM1, CM4, and CM10).

Miners with a neutral attitude (CM2, CM8, CM9 and CM11) viewed the severity environmental impact of crypto mining to be dependent on the type of energy sourced and type of hardware used in mining, as CM8 states: *"I think it depends a lot on where the electricity comes from. If electricity of course is just, is renewable, then there's not really much of an issue"*.

Miners with a negative attitude toward the ecological implications of proof-of-work (CM1, CM4 and CM10) tended to have particularly strong disapproval of proof-of-work mining's impacts. CM4 described the high energy consumption of proof of work as "appalling", later reiterating: *"It just looks increasingly bad. You know, everyone knows the energy consumption is very high."*

Miners with positive attitudes toward the ecological impact of crypto mining (namely CM3, CM5, and CM12) had a favorable opinion of mining's ecological effects. These miners typically believed that mining had a beneficial impact on the environment, primarily through driving demand for renewable energy and reducing the curtailment of renewable energy, e.g. CM12: *"I think that... Monero, uh, in this case, uh, provides something useful. Provides something that cannot be done another way."*

4.4 Awareness of Consequences

A number of participants (CM2, CM4, CM6, CM7, CM9, and CM11) believed that mining did have some consequences but did not view these consequences as being detrimental to the environment or having a serious impact.

CM8 expressed that although they believed in the negative consequences of crypto mining, they did not see these consequences as critical as the development of new mining technologies would likely reduce the harmful impacts of crypto mining: *"I'd say yes, because it's, I guess it, it really well, yes, right now it probably would be harmful environment. At some point, it won't be because of renewable energies and because of, um, cause of the fact that we will be we'll have more advanced technologies to store that electricity."*

On the other hand, CM10 a high awareness of the potentially negative consequences of crypto mining, particularly mining that consumes non-renewable energy. They state: *"Until we have 100% renewables, or decarbonated energy source everywhere, every time someone is mining with decarbonated energy, that energy might have been used to power something else, which would not have consumed, uh, coal or gas generated electricity." (CM10).*

Almost all participants expressed high general awareness of consequences, highlighting the current extreme weather conditions that are occurring globally and the potential for these conditions to worsen, as CM4 and CM6 expressed: *"So, we if we carry on the way we are, we're gonna see more and more extreme weather events whether that's droughts, heat and floods and so forth which ultimately will lead to loss of life, loss of productivity and the loss of our environment in some cases."* (CM4).

4.5 Ascription of Responsibility

The ascription of responsibility among miners was generally low, with miners such as CM1, CM5, CM4, and CM6 highlighting the high energy consumption of traditional banking systems and large mining companies, which they believed held greater responsibility than themselves and other individual, small-scale miners: CM1: *"I don't think I* *contribute that much to the negative impact of crypto mining on the environment… Even when I used to do it, it was uh just one PC, so it didn't consume that much power, it didn't have that much processing power, so it didn't consume that much energy."*

When asked about their beliefs relating to their ascription of responsibility in their daily actions, most participants expressed low ascription of responsibility. Five of the twelve miners interviewed (CM1, CM2, CM5, CM6, CM8, CM9) placed responsibility on large corporations and government institutions: CM1 said *"yeah, sure [people's activity] can [have a negative impact on the environment] but I feel personally that it's mainly corporations."*

Other miners (namely, CM12 and CM4) believed in the responsibility of the collective, rather than government and large corporations, to address the negative impacts of human activity and protect the environment: *"I think that every single person should work… for the solution. And, and we should have like, disagreements and different opinions and different approaches I think that's healthy, uh, to have those discussions. Uh, because, uh, I think that from that collaboration we will find [something] that works because, I mean, it's our planet, so we can't ignore it forever."* (CM12).

4.6 Personal Norms

Most miners did not express feeling a moral obligation or sense of guilt regarding the potential negative impacts of mining (CM1, CM2, CM3, CM6, CM7, CM8 CM9, and CM12). CM1 shared that although they were aware of their contribution to the potentially negative impact of crypto mining, they did not feel a sense of responsibility to for it: CM1 - *"I wouldn't say I feel responsible but I'm aware that I contribute to that also to that when I'm doing mining and using the proof of work mechanism. So I'm aware of my contribution but I don't feel responsible personally."*

Conversely, CM10 expressed a strong sense of personal responsibility, moral obligation and guilt when discussing their crypto mining activities: CM10 - *"Every kilowatt hour that I consume is not available for exporting to Germany, for example, which means that they have to, uh, compensate for, for it by consuming more coal and more gas."*

4.7 Pro-environmental Behavior

Most miners (CM8, CM2, CM3, CM4, CM5, CM6, CM12) participate in pro-environmental activities in their daily lives, including practices of recycling, environmentally friendly consumption practices, the use renewable energy and environmentally friendly transport: CM10 - *"I use the bicycle to limit my carbon footprint."*

5 Findings

The primary research objective of this study was to ascertain the attitudes of crypto miners toward the ecological implications of crypto mining. The findings of this study reveal that crypto miners hold a diversity of attitudes toward the ecological implications of mining, which cannot be generalized. This is consistent with the findings of previous research, which have presented several different, and oftentimes opposing findings [6, 31, 32]. Most miners held a neutral attitude toward the ecological implications of mining, seeing the ecological implications as dependent on several different factors [6]. Miners with negative attitudes toward crypto mining's ecological implications viewed mining as harmful and damaging to the climate [31, 33]. The findings regarding the positive attitudes toward the ecological implications among miners have also been affirmed in several studies [34–36].

The findings of this study provide evidence to support the following propositions from the Value-Belief-Norm (VBN) theory:

Biospheric Values. The findings with respect to biospheric values were consistent with literature, providing evidence to support P1. It was found that biospheric values had a strong positive association with participants' ecological worldview. Participants that voiced high value for the biosphere and viewed animal and plant life as holding intrinsic value (referred to as eco-centric values), typically held a strong ecological worldview. Conversely, participants with lower biospheric values, and higher anthropocentric values tended to hold an "anthropocentric worldview", which [44] defined as an anti-new environmental paradigm (NEP).

Altruistic Values. The association between the altruistic values and the beliefs of participants who held an ecological worldview was positive and not particularly strong, similar to the findings of [37] and [19]. Interestingly, participants with high altruistic values tended to hold strong anthropocentric worldviews. This finding provides suffi-cient evidence that altruistic values influence the ecological worldview of crypto min-ers, supporting P2 (Altruistic values influence cryptocurrency miners' ecological worldview).

Egoistic Values. Most participants expressed low egoistic values, and as a result, this research did not find sufficient evidence to support P3 (Egoistic values influence cryptocurrency miners' ecological worldview). This lack of evidence may be explained by participant's unwillingness to appear self-centered and egoistic, which potentially led to "systematic distortions" in the answers of participants, as described by [45].

Socio-political Views. The findings related to participant's socio-political views are supported by the findings of [38] and indicate that an individual's socio-political views are influenced by their altruistic values and influence their ecological worldview.

Ecological Worldview. The findings show two distinct worldviews that emerged from the data – namely, the ecological worldview as defined by [44], and the anthropocentric (or anti-ecological) worldview [38, 44]. Analysis of the data revealed that individuals with a strong anthropocentric worldview did in fact value the natural environment and were concerned about the climate crisis and the limits of natural resources [38]. Based on the Value-Belief-Norm theory, this research proposed that crypto miner's ecological worldview influences their awareness of consequences (P4) [10]. While these findings do suggest a positive association between ecological worldview and awareness of consequences, in alignment of the findings of [13, 39] and [10], the association is weak due to the lack of conviction as to the consequences of most crypto mining across ecological worldviews.

Value to Society. The findings related to participant's perception of cryptocurrency and crypto mining's value to society indicate that miners who believe in cryptocurrency's value to society a positive association with the ecological implications of crypto mining. These miners were also found to have a lower awareness of crypto mining's potential environmental consequences, indicating a negative association. These findings are supported [40].

Awareness of Consequences. The findings indicate that most crypto miners did not have a high awareness of the consequences regarding the potentially negative impact of crypto mining. This may be due to the lack of certainty surrounding the environmental impact of crypto mining due to the decentralized, volatile, and anonymous nature of crypto mining.

Ascription of Responsibility. The findings related to the ascription of responsibility of crypto miners indicate that the majority of miners (8 out of 12) do not ascribe a high amount of responsibility to themselves and instead place blame on governments and large corporations. This was evident both in the ascription of responsibility regarding the negative implications of crypto mining and in participants' belief in their capacity and responsibility to reduce the threat of climate change and protect the environment. The findings also reveal a weak association between awareness of consequences and ascription of responsibility. Miners who showed a relatively high awareness of consequences did not consistently show a high ascription of responsibility. Rather, the ascription of responsibility among miners varied, particularly among those who showed some level of awareness of consequences. Crypto miners who did not believe crypto mining had any negative impact on the environment, however, typically did not perceive those involved in crypto mining (including themselves) as responsible for reducing the threat of potentially harmful consequences. This is most likely because they did not believe mining has harmful consequences. Thus, insufficient evidence is provided to support P5 (cryptocurrency miners' awareness of consequences influences their ascription of responsibility).

Personal Norms. In accordance with the theoretical framework for this study, it was proposed that cryptocurrency miner's ascription of responsibility influences their pro-environmental personal norms (P8) [10]. The findings of this study support this proposition, showing that among miners who expressed a relatively high ascription of responsibility, the presence of personal norms was more evident. Findings also suggest a positive association between personal norms and attitudes toward the ecological implications of crypto mining, with participants with negative attitudes typically showing greater personal norms.

Pro-environmental Actions. Interestingly, findings reveal that crypto miners with a stronger anthropocentric worldview, which typically influenced a more positive attitude toward the ecological implications of crypto mining, tended to have greater adoption of pro-environmental behavior, compared to their counterparts who held a more negative attitude. The findings of [38] support this. Findings revealed that participants who held weaker personal norms concerning the ecological implications of crypto mining were not less likely to adopt pro-environmental behavior. Thus, insufficient evidence is provided to accept P9 (cryptocurrency miners' pro-environmental personal norms influence their pro-environmental actions).

6 Conclusion

This study sought to explore the perspectives and attitudes of crypto miners, a group that is largely underrepresented in blockchain research, around the ecological impact of proof-of-work mining using the Value-Belief-Norm theory as the theoretical framework. The findings of this study provide a multilayered answer to the primary research question of this study, establishing three main attitudes toward crypto mining's ecological implications.

- Positive attitudes, which relate to the view of crypto mining's environmental impact as positive.
- Negative attitudes, which relate to the view of crypto mining as being harmful toward the environment.
- Neutral attitudes, which relate to the view that crypto mining's impact is dependent upon a variety of factors and neither here nor there.

The findings of this study contribute to the growing body of research on the environmental impact of cryptocurrency mining. They also provide insights into the factors that influence crypto miners' attitudes towards the ecological implications of their activity. These insights can be used to inform the development of more sustainable cryptocurrency mining practices.

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Mobile Salesforce Automation: A Study of the Acceptance and Use by Grocery Retailers

Ewe Leong Khoo(✉), Blooma John, Rosetta Romano, and Jennifer Loh

University of Canberra, Bruce, ACT 2617, Australia
el.khoo@canberra.edu.au

Abstract. This study aims to understand grocery retailers' acceptance and use of mobile salesforce automation (SFA). SFA deployment in a sales organization is time-consuming, costly, and does not necessarily improve salespeople's performance. Recent disruptions caused by the pandemic and the fast escalation of sales costs have prompted organizations to extend SFA deployment to grocery retailers through mobile SFA. There are limited SFA studies on understanding SFA acceptance and use in grocery retailers, as the focus was on the salespeople. A model is developed by integrating the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) and the Innovation Resistant Theory (IRT) with modifications to study mobile SFA technology acceptance and use by grocery retailers. The model also captures the flow experience of grocery retailers when using the mobile SFA. A case study was used in this study by involving Coca-Cola and their mobile SFA deployment to grocery retailers in Malaysia. It is a quantitative cross-sectional survey targeting grocery retailers from urban and sub-urban/rural regions. Data collected will be analyzed using partial least square (PLS) structural equation modeling (SEM). Findings from this study allow organizations to validate and predict mobile SFA technology acceptance and use by grocery retailers and to re-think their mobile SFA technology investment and deployment strategies.

Keywords: Mobile Sales Force Automation · Grocery Retailers · Sales Technology Adoption and Usage

1 Introduction

1.1 Sales Force Automation (SFA)

Sales force automation (SFA) promises great benefits to sales organizations by improving salesforce productivity and efficiency [1], as the cost-per-call and the number of sales calls needed to register sales transactions successfully have risen [2]. SFA enables organizations to automate sales activities and administrative responsibilities for higher productivity [3]. SFA can also help to enhance communication and provide faster access to accurate and relevant information to improve the quality of the sales effort [4]. Salespeople can reallocate their time from routine administrative activities to more critical and complex tasks [5]. Extending the sales technology to mobile applications is possible through smart gadgets like smartphones and customized SFA solutions [6].

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The COVID-19 crisis has resulted in a "blackout" period for many sales organizations. They could not interact with retail customers or had to reduce their interactions due to mobility restrictions [7]. They had to turn to unfamiliar digital communication channels [7]. These prolonged business disruptions have made sales organizations rethink their resilience and competitive edge [2].

1.2 SFA Adoption Challenges

While SFA promises benefits to sales organizations, its deployment and use are time-consuming and costly, and its adoption among salespeople only sometimes translates into better sales performance [9]. Statistics also show that up to 75 percent of SFA projects fail to meet the expectations of organizations [10]. Managing organizational change and transformation is the biggest challenge, including poor project planning, a mismatch between technology and business needs, lack of support from senior management [11], the project's cost exceeding the planned budget, and dissatisfaction of users [12]. Between 55 percent to 80 percent of organizations reported performance after introducing SFA as being worse off or having no improvement [13].

Large-scale SFA implementations commonly receive resistance and subsequent opposition from employees [17]. Researchers' most common explanation for SFA failure is the lack of SFA adoption and acceptance by salespeople [14]. The low adoption rate is mainly caused by users' unfamiliarity with the technology [15]. The factors cited impacting SFA adoption are the sales peoples' organizational commitment, job satisfaction, person-organization fit, and person-job fit across organizations [16].

1.3 Research Gap

Literature review shows that most studies on SFA adoptions and implications are done through the framework and lens of the salespeople [5, 18–25]. Some studies are centered around management and sales leaders' commitment [26–28] but are limited from the viewpoint of customers and retailers (see Fig. 1).

By extending mobile sales technology to retailers, organizations can rethink their sales force objectives, structure, and capabilities required to sharpen their competitive edge and improve salesforce productivity [31]. The first study on the benefits of SFA from a customer's perspective was reported in 2009 [29]. In 2020, another study investigated the antecedents of customers' acceptance of a knowledge-based software application in the supply chain, focusing on how customers can use digital sales technologies for improved effectiveness and perceived value. Ease of use and system adaptability contribute strongly to customers' perceived effectiveness and usefulness [30].

FMCG organizations are expanding SFA deployment beyond internal salespeople to retailers through mobile SFA. Retailers are expected to voluntarily take over a wide range of the salespeople's daily tasks, including order management, reviewing sales history, retrieving product and promotion information, and making payments online. Unfortunately, there is a lack of knowledge regarding the customer or retailer's perspective on adopting sales technology.

The main research questions addressed in this study are as follows:

1. What is grocery retailers' acceptance of mobile SFA technology?
2. What is the level of use of mobile SFA technology by grocery retailers?
3. Is there any variance in the acceptance and use of mobile SFA technology between urban and rural grocery retailers?

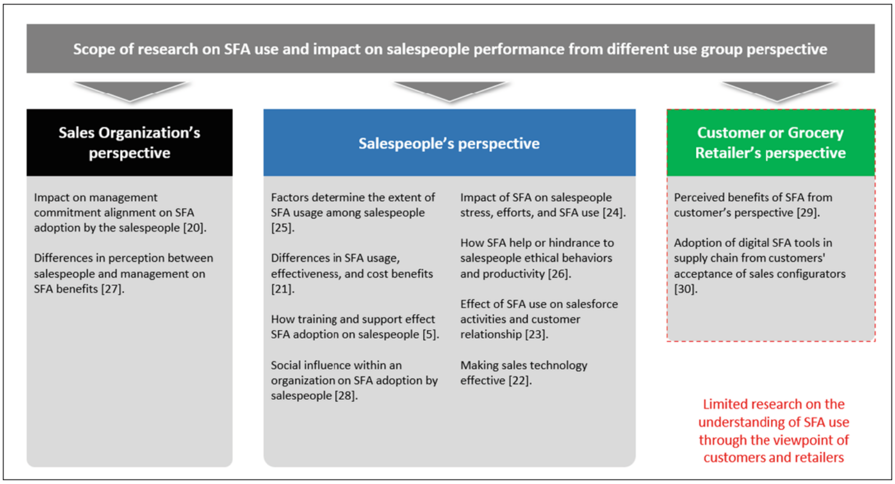

Fig. 1. Research on SFA use from different users' perspectives.

2 Theoretical Foundation

2.1 Background

Technology adoption and use by salespeople are strongly connected between technology investment and performance [33]. Low adoption of SFA among salespeople is always the leading cause of sales organizations not realizing the benefits of SFA investments [34], and resistance to using SFA is one of the major hurdles [8].

Generally, most salespeople consider themselves to have limited technology experience and create an inner fear of unfamiliar technology and low motivation to use SFA [36]. The varying research contexts based on technology, user type, location, adoption time, and task performed gave rise to many competing theories and models [37]. SFA implementation success was critically linked to use acceptance and motivation for SFA use [42]. The technology acceptance model (TAM) is a widely cited IT technology acceptance framework [39]. Venkatesh et al. integrated core elements from eight models and prominent theories to develop the UTAUT [40].

The UTAUT model emphasizes organizational users' utilitarian value after eliminating common constructs to predict or explain new technology adoption, acceptance, and usage [37]. With the deep penetration of consumer technologies supported by the advent of the internet and smartphones in the 21st century, the UTAUT model was extended to the UTAUT2 model to include the hedonic value of technology users. The voluntariness of use was dropped as a moderator since consumers' behavior is voluntary [41]. The model can explain 74 percent of the variance in consumers' behavioral intention and 52 percent in consumers' technology usage [42].

IRT studies the resistance toward user innovations and behavior toward adopting and using any innovation [43]. It offers a theoretical framework to help understand users' resistance-oriented behavior [44]. Innovation resistance results from rational thinking and decision-making to maintain the status quo and resist deviating from the current belief system [43]. Consumer resistance plays a prominent role in determining the success of innovation implementations caused by user behavior [45].

It is important to examine the effects of flow experience on users and incorporate these findings in designing engaging user experiences in smart device mobile applications [46]. Flow experience is a psychological state of an individual sensation in reaction to environmental stimuli and is created when individuals concentrate effortlessly and experience enjoyment while completing a certain task [47]. Control, attention focus, and cognitive enjoyment are three important dimensions of flow that help digital developers create sites and games that are more responsive to users [37].

2.2 Research Model

The proposed research model (see Fig. 2) integrates UTAUT2 and IRT models with modifications to validate and predict mobile SFA technology acceptance and use by grocery retailers. Grocery retailers' mobile SFA adoption and use are voluntary, and the mobile SFA application is free. Hence, two modifications are made to the UTAUT2

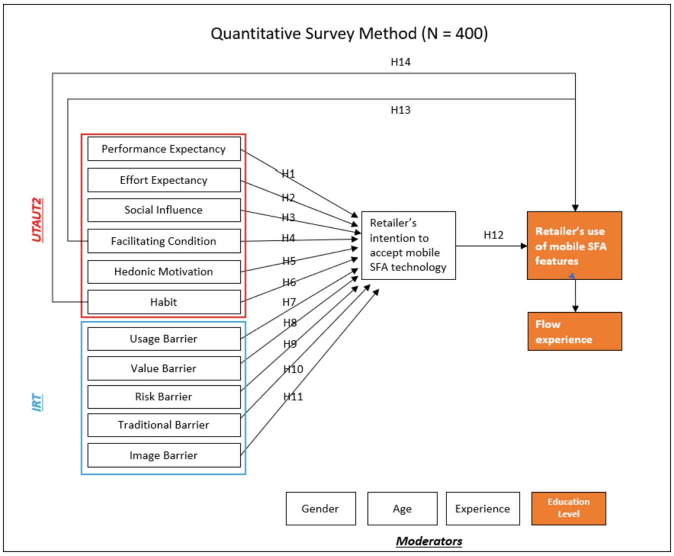

Fig. 2. Proposed research model.

model. Price-Value (PV) construct was removed, and retailers' education level was added as a moderate factor.

The education level of grocery retailers is added as a moderate factor in the study. Riddell and Song found a causal relationship between education level and the probability of using computers on the job [49]. An additional year of schooling increases the probability of using a computer in the workplace by six percentage points and increases computer use time by 1.4 h per week. In Malaysia, nearly 20 percent of the population above 25 received no or only up to six years of basic formal education [50].

The research framework also includes the flow experience of grocery retailers to help understand their level of control and engagement when using the mobile SFA.

3 Case Study

Coca-Cola is one of the market leaders in the non-alcoholic beverages industry in more than 200 countries, with 700,000 employees globally. In Malaysia, it commands nearly 20 percent of the total industry value [51], with 400 salespeople servicing all retail channels, including supermarkets, convenience stores, traditional grocery retailers, and food stores [52].

In 2015, Coca-Cola decided to digitalize its sales operation by introducing SFA technology to improve sales productivity and performance. It extended its SFA technology to grocery retailers through the mobile SFA application in 2021. Grocery retailers could self-administrate a wide range of traditional daily tasks of the salespeople, like re-viewing sales history, reviewing stock level status, and executing stock replenishment routines. The technology was deployed to 17,000 grocery retailers. Tracking shows that the usage rate was low at 30 percent despite multiple efforts to incentivize the retailers. Without a deep understanding of the level of acceptance and use of mobile SFA technology and why there is a lack of mobile SFA technology acceptance and use by these retailers, it is challenging for Coca-Cola to improve the results.

4 Research Methodology and Design

A quantitative research method involved 400 grocery retailers using the mobile SFA of Coca-Cola through an online survey. The survey questionnaire was designed and obtained Human Research Ethics Approval. Through the mobile SFA app push mail system, an e-survey form and survey questionnaire were sent randomly to grocery retailers who use the Coca-Cola mobile SFA and reside in the targeted cities and sub-urban/rural locations. Partial least squares (PLS) structural equation modeling (SEM) regression will be used to test and validate the proposed model and the results will be analyzed as part of future work.

5 Intended Contribution

This is the first application that combines UTAUT2 and IRT to validate and predict mobile SFA technology acceptance and use by grocery retailers. The inclusion of the flow experience will help understand the level of control and engagement when using the mobile SFA. The research will also explore the variance in grocery retailers' acceptance and use of mobile SFA technology in urban and sub-urban/rural areas. This allows customization deployment programs to improve mobile SFA deployment's adoption and usage rates. The findings could impact other major developing countries in Asia like India, Vietnam, Philippines, and Indonesia.

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Embracing Change from Shadow IT to Collaborative IT Models

Sumant Devasthali[1](✉) and Gaurav Gupta[2]

[1] SVKM's School of Business Management, NMIMS, Mumbai, India
Sumant.Devasthali@sbm.nmims.edu
[2] NEOMA Business School, Mont-Saint-Aignan, France
gaurav.gupta@neoma-bs.fr

Abstract. Every industrial business in the modern day strives to become technology-driven, for both survival and expansion. With the availability of new generational technology platforms and low-code tooling, technological manifestations are becoming increasingly decentralized. The two emerging forms of business led autonomous technology deployments are Shadow-IT and Business-managed IT. While Shadow-IT is constructed in secret without the knowledge of central IT team, Business-managed IT is a split-governance model built in collaboration with the IT organization. Common governance is required to ensure that IT investments are efficient, secure, and compliant. Despite being aware of Shadow-IT's limitations, businesses are unable to upgrade them to better models due to a lack of a simple toolkit that can act as a guidelight. This paper's goal is to present a framework that can fill this gap and illustrate precise steps for a business unit to make a transition to a business-managed IT model suitable to its technological capability. Based on extensive research and case study analysis, the paper captures insights about different forms of autonomous IT investments, proposes a framework to advocate an appropriate business-IT partnership model for a business unit, and finally solicits the opinions of eminent business executives from diverse industries to confirm its applicability. The framework will act as a guide not just for the initial transition, but also evolution of the partnership model as the business's technological capabilities grow over time.

Keywords: Shadow IT · Business Managed IT · Business-IT collaboration

1 Introduction

Most businesses use their central IT teams to create software solutions to support a variety of operations performed by different Business Units (BU). Business divisions' needs could not all be optimally satisfied, though. Organizations have found enough evidence of individual departments building their own smaller IT solutions tailored to their needs and created by their own staff. This can occasionally be a result of central IT teams' general delivery delays or a failure to fully address business requirements.

The aforementioned IT investment is referred to as "Shadow IT", and it manifests itself as modest, ad hoc solutions developed autonomously by business teams or people

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without coordination with the central IT department [1, 2]. These often take the form of spreadsheets, mobile applications, tiny workflows, and other similar applications built with basic low-code toolsets [3]. Shadow IT brings with it both threat and opportunity. Security threats, inefficiencies, and scalability issues are frequently mentioned as potential negative impacts [4]. Interestingly, research also highlights it's positive aspects, such as greater agility, productivity, or innovation [5, 6].

Shadow IT is not officially encouraged in organizations due to its significant negative side effects, and it may be hidden from central IT. Central IT units frequently use monitoring tools to find them, and then either decommission, seize control, leave alone with the BU's creators, or co-govern with the BU, thus legitimizing them [7]. The co-governance can take different forms depending on how the BU and IT divisions divide up the responsibility - a concept known as "Business IT partnership models" [8]. "Business-Managed IT" refers to a phenomenon in which BU manages all IT-related tasks for a given technology application, either entirely independently or in cooperation with central IT [9].

Business managed IT is considered a good mix of business autonomy and IT standards' compliance. However, there is no silver bullet for transitioning a business from a Shadow-IT situation to a business-managed IT mode. We believe that many firms continue to have poor IT investment portfolios due to a lack of clear guidelines on how to emerge out of the IT shadows. The current study closes this gap by providing a framework for selecting an appropriate transition path based on the capabilities maturity of the business units.

The study addresses the following research questions in order to achieve the aforementioned goal:

- RQ1: Can one establish a general recommended guideline to transition an IT system from Shadow-IT to Business managed-IT mode?
- RQ2: Which business-IT partnership model is most suitable for a BU, given the level of digital skills of its workforce, as it transitions out of its shadow investment?

In order to answer these questions, we first conduct a study of the literature to make sure we are up to speed on the most recent findings and to spot any gaps. Then, based on an examination of intricate industrial case studies including shadow IT transitions, we propose a suitable framework. Finally, we use semi-structured interviews with a number of business professionals to validate and verify the framework.

The next sections are structured as follows: Next, we will review existing literature on Shadow, business managed IT and related topics. We will outline our case analysis findings, illustrate conceptual framework, and summarize expert feedback in the Outcomes section. Finally, we will discuss the findings in relation to the conceptual framework and conclude with opportunities for future research.

2 Literature Review

2.1 Literature Search and Selection

We conducted a literature review to determine the present state of academic research on Shadow and Business-managed IT. SCOPUS, Business Source Complete (EBSCO), Emerald Insight, IEEE, Science Direct (Elsevier), and Springer Link were searched for peer-reviewed journal publications and proceedings from major IS conferences. We used the following search keywords:

[“shadow IT” OR “Shadow-IT” OR “Business-managed IT” OR “Business managed IT” OR “business-driven innovation” OR “IT consumerization”] AND [“Governance” OR “Architecture”].

Following that, we screened the identified articles to prioritize content dealing with both Shadow and Business-managed IT in tandem, along with their interaction in specific corporate scenarios. We used the final selected set of 55 papers for this study, as summarized in Table 1 below.

Table 1. Literature review summary of 55 selected papers

Data Source	Type of Study					
	Case Study	Experimental research	Exploratory study	Literature review	Research paper	Total
Scopus	4	1	1	3	3	12
SpringerLink	3	2	2	2	4	13
EBSCO	2	0	1	2	2	7
Emerald Insight	2	1	0	1	1	5
IEEE Xplore	3	2	2	2	2	11
ScienceDirect (Elsevier)	2	1	1	1	2	7

The most significant themes that emerged from the review are *IT-managed systems*, *Shadow-IT* (concealed IT work), *Shadow-IT impact* (positive, negative), *Business-managed-IT* (partnership amongst BU and central IT) and *IT-Integration.*

IT-Managed Systems: These refer to the conventional IT systems that are built and managed by the central IT unit. These are built using secure, modular architectures and follow formalized, software development best practices.

Shadow IT Systems: These refer to covert IT systems in which employees of a BU create IT applications for their own needs without consulting central IT unit [7]. When used in this context, the term “BU” refers to all business entities, including both individual users, employee groups and departments.

Shadow systems come into existence frequently to avoid red tape and gain faster access to resources [10]. Furthermore, [11] states that the advent of “shadow IT” shows a failure on the part of central IT unit to provide the services required to meet their users’ expectations. Businesses create shadows as a direct result of a number of issues, such as the central IT systems being unreliable, rigid, and challenging to use, as well as a lack of cooperation between the IT department and the business divisions. It frequently acts as a supplement to enterprise-wide IT systems like ERP as well as providing tailored adjustments for simplifying business operations. Due to the increased accessibility of new age IT tools and solutions, business units develop their own IT plans without the support of the IT department [8]. Shadow-IT systems undoubtedly give BUs more autonomy from the IT division, especially when IT department is deemed too expensive or too slow.

Literature revealed a wide range of Shadow IT applications. According to [10], shadow IT is frequently used in the context of multi-cloud settings, where public cloud services are contracted directly by departments within an organization. According to [12], it entails people or departments acquiring and utilizing software, services, or technology without engaging the central IT department.

Shadow IT must deal with several issues, including security, data discrepancies, organizational inefficiencies, conflicts, and loss of control [15]. Additionally, when shadow IT systems multiply, so does the need for support and maintenance personnel [16]. Decentralization of IT as a result reduces central IT unit's power and control over IT resources and presents a governance challenge for the company [17]. [18] found that Shadow-IT's covert IT management makes it difficult to execute risk assessment and preventative processes, generating compliance concerns. Typically, shadow IT systems are built in silos, and do not integrate with enterprise systems, which reduces standardization and reduces synergy at the overall organizational IT footprint.

Business Managed IT Systems: In "business-managed IT", the standardization focus and BU flexibility are balanced. The development of these overt IT platforms involves strong coordination between central IT and business units. According to [3], business-managed IT facilitates more effective and quick communication, which fosters creativity and innovation. Because of its adaptability, it also has the advantage of agility and better flexibility, especially when compared to large, rigid solutions like ERP systems [19]. In short, it provides BU with authentic means to build its IT apps and not break corporate rules.

IT-Integration: Organizations usually work to club the IT investments by migrating the Shadow investments to the business-managed form of IT, since its major negative side effects outweigh its advantages. Businesses frequently use central monitoring processes to keep an eye out for irregularities so that the necessary action may be taken. One choice when a Shadow instance is discovered; is whether to keep it operating, take over or terminate it [18]. Another choice is to set it up in a business-managed IT mode with governance split between business units and central IT [10]. A co-governance is frequently a reasonable compromise because simply prohibiting corporate investment may have a negative impact on employee creativity and morale [20].

The Fig. 1 below indicates various potential transition routes of Shadow-investments. Our research aims to provide an advice on how to avoid the red-dotted covert path and progress towards an open cooperation paradigm between business and IT indicated in green routes.

Our review of the literature revealed a dearth of research that could offer guidance on how to transition from shadow IT investments to collaborative governance and how to strike a balance between the crucial business flexibility and central IT's mandated formalization. This study seeks to fill this vacuum by creating a framework that proposes several business-IT partnership models and guiding factors to help determine which one is more suitable to a given skill level of the business unit.

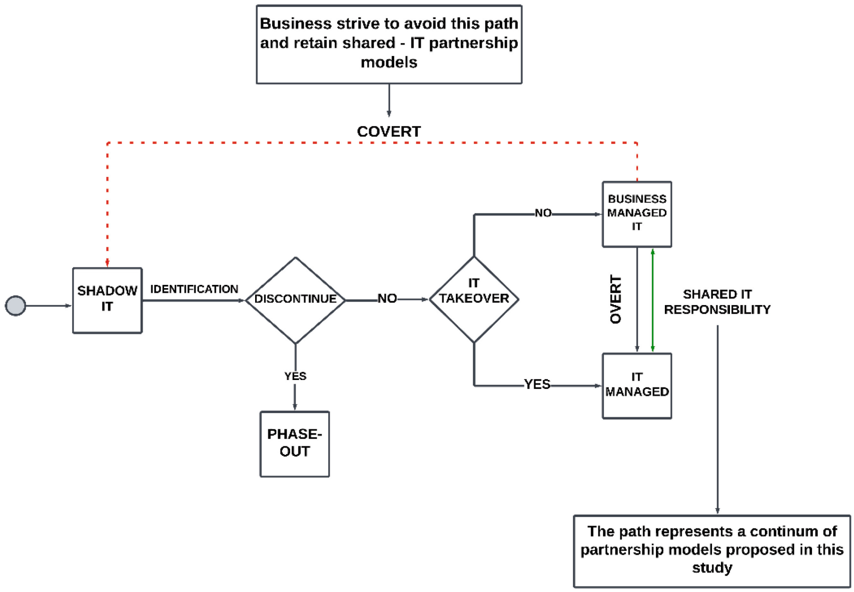

Fig. 1. Navigating IT transition in businesses (Author's own)

3 Methodology

This study has used a mixed set of steps for the research as outlined below.

- Literature review to determine research gaps in the areas of migrating off shadow investments.
- Case study analysis of diverse industry cases dealing with successful shadow migrations; to conceptualize a framework.
- Semi-structured interviews with industry experts to validate the framework.

The literature review section has outlined authors' rigorous effort of searching through academic content and examining organizations' present practices for handling shadow IT scenarios from prior studies. It assisted in identifying gaps in a lack of prescriptive guidance for practitioners to manage business IT portfolios with a fair balance of flexibility and IT norms.

Case study is the most appropriate research method to gain contextual, in-depth knowledge about a specific real-world subject and is often used in exploratory research to generate new ideas that might be tested by other methods [13]. Based on the primary authors' historical involvement with the company and ability to get the most accurate information, we chose a large technology-consulting firm as a source for these case situations. This study has employed case study analysis of carefully selected, three diverse shadow-IT situations as summarized in Table 2 below (and explained in detail under data analysis section further). Each instance depicts a different shadow situation and its progression towards BU-IT collaboration that best suits BU's digital skill quotient.

These cases were carefully chosen to represent all possible classes of BU-IT collaboration models. These form a foundation for the suggested framework, which provides the possible appropriate collaboration models (and related transition paths).

Table 2. Case Study scenarios

IT Solution	**Project Delivery dashboard**	**HR Analytics & predictions**	**Account management scorecard**
Department / Business Unit	Delivery excellence	Human Resources	Account management
Case evidence	Interviews with business executives and IT leads	Interviews with HR leadership, IT stakeholders, demo of the system by HR managers	Published Case study document by the firm, Interviews with Account leadership and IT executives
Prior IT Mgmt. mechanism	Covert	Covert	Overt
Business IT Partnership model	**IT Coached business** model	**Pioreering** business-IT partnership model	**Self-service Platform** model

Finally, to validate the suggested framework, the authors conducted interviews with five cross-industry experts holding influential strategic roles. We filed non-disclosure agreements; and anonymized all gathered inputs and outcomes. The selected individuals covered a diverse variety of industries, and IT investment sizes to guarantee that different aspects of the shadow IT problems were addressed. Semi-structured interview method was determined to be the most appropriate method, as described by [14, 15], to allow participants to speak freely about their perceptions and experiences. These inputs turned out to be essential in validating framework; especially based on the contextual industry experience. These experts also acknowledged the framework's applicability to other industries, demonstrating its external validity.

4 Data Analysis and Outcome

We gathered research information via case study analysis and structured interviews. To begin, three diverse Shadow IT scenarios are subjected to case study analysis. The insights gained from these cases helped in the formulation of a framework that defines business-IT partnership options to firms divesting from Shadow IT. Lastly, we discussed the framework with five industry experts and used their feedback to fine-tune the framework towards real-world industrial settings.

4.1 Investigating Business Scenarios: Using Case Study Analysis

The case's events occurred at a *large international consulting and IT services company* that provided consulting and information technology solutions to a variety of global businesses. A cybersecurity incident in 2018 compelled the company to launch a company-wide investigation of shadow IT instances, using network analysis and start talks on their use and future roadmap. The case studies represent three distinct tales of Shadow

IT systems developed within different departments at various points in time. Every story offers a different set of lessons, which we have combined as part of a larger analysis.

1) Project Delivery dashboard: (reflects as "IT Coached" model in the framework)
The *Delivery Excellence* Business Unit began working independently in 2015 to develop a smart web-based solution to monitor the overall status of its diamond customers' portfolio work, spanning multiple projects. It brought together all crucial project health indicators, hazards, issues, and watch areas at one single dashboard. Its vision was to automate all manual review activities into a workflow-based system, supported with an intuitive look and feel. The business unit possessed significant power within the organization, due to its direct reporting relationship to the firm's COO. This had helped the independent existence of this shadow-web application without much challenge.

The IT team discovered it during its network search and informed top management about future risks associated with maintaining it independently. Given the political clout and stakeholders' need for flexibility to meet their specific needs, the unit was advised to function in a partnership mode with the IT team's direction on important architectural principles. IT teams worked with the BU for six months to transition the system to a modular architectural platform, defined agile standards and taught important design principles to apply for any further work. IT teams also committed to undertake quarterly audits and be available to advice on special requests.

With this partnership, the application quickly expanded beyond diamond customers to become a comprehensive delivery excellence product, and adopted by more departments. The product also added AI-based capabilities of risk prediction, intelligent issue remediation and perform multi-dimensional delivery tracking. Later, it developed into a SAAS service that could be offered to independent businesses.

2) HR Analytics & predictions: (reflects as "Pioneer" of innovation model in the framework)
HR department secretly built an AI based analytics system, with involvement from many of its enthusiastic employees, who wished to replace the manual Excel-based operational reports with an automated reporting platform. When IT teams discovered this covert IT work, they contacted HR management. During the discussions, IT teams determined that the HR unit's need to stay strategically ahead of its challenges (for example, anticipating accurate attrition estimate to develop proactive response) was a legitimate need, and the built shadow system was simply an attempt to that end.

The IT and HR teams came to an understanding whereby the IT teams took over management of the analytics system and rebuilt its foundation architecture to established IT standards. On top, IT teams further built an "innovation studio sandbox" (innovation test area) for HR teams, where motivated, competent HR staff joined hands with IT members to experiment with cutting-edge technologies such as ML, generative AI, and NLP, to develop futuristic solutions. Among these were features, such as *identifying hidden reasons of employee-churn*; *real time performance appraisals*, and many more.

This platform allowed for the development of modern skills, which improved employee motivation and retained talent. Thanks to the collaboration, the HR department became the most forward-thinking AI-enabled workforce and considered as an HR practice leader among its peers.

3) Account management scorecard: (reflects as "Business self-service" model in the framework)

The company employed influential individuals in *account-lead* roles who created and maintained relationships with large corporate senior executives. These individuals contributed to the organization's major revenue sources, and hence, central IT frequently prioritized their IT needs. These account leads were looking for a system that allowed them to maintain a balanced scorecard of their accounts. The scorecard included critical measures of client satisfaction, new business prospects, and health of strategic partnerships with C-level executives.

This group desired a self-sufficient data Platform, where they could easily drag and drop information variables and use pivot tools for adhoc-analysis (like in Excel). They had made a few attempts to build solutions using off-the-shelf technologies but those but those fell short of many capabilities they needed. They were all non-technical salespeople, interested in an easy to use tool for real-time analysis of their customers, based on changing market conditions and business events.

The IT unit provided them access to a SAAS CRM platform, and setup all required data as its building blocks. They trained account leads on how to configure it and use it effectively to meet their needs. Except for any unusual action that required the IT team's support (such as new data integration), the business teams handled the platform fully independently. The business teams acquired the skills to use the toolset and gained the flexibility to manage everything from lead generation to strategic projections. As a result, they were more productive and happier, and the company's revenue increased significantly.

4.2 Outcome: The Framework

This section demonstrates the proposed framework, which can assist every organizational business unit, that decides to divest its Shadow-IT investments choose a suitable IT partnership model to align depending on its capability maturity.

The Business-IT Partnership Models

The framework (Fig. 2) displays four distinct models for BU and IT teams to collaborate. Each model differs in three essential dimensions: *environment control* (the adherence to IT norms), *business flexibility* (freedom enjoyed by the BU to construct solutions), and *innovation potential* (a mix of ideas, skills, and flexibility that BU can bring to the built systems). According to the framework, firms should constantly aspire to progress (vertically) up the flexibility scale, but they must begin with a model that is proportional to their existing capability maturity. As they invest more in their employees' talents, they will seek more possibilities for richer levels of collaboration and better innovation potential.

Each model is briefly described in the section below:

a) **IT managed:** This is a traditional approach of technology deployment in which the central IT team spearheads the creation of the most secure and scalable systems while adhering to the best software practices. This paradigm is required for mission-critical enterprise systems that serve the common needs across all departments in a firm. It is also an obvious choice for building IT applications for business functions that lack the technological capabilities required to work in other partnership models. The IT team creates systems in close collaboration with the business, with a continual loop back to verify it serves the objective of the business unit.
b) **IT coached**: Foreword looking skillful business units often begin by launching pilots that address smaller, pressing challenges in the business unit. They may begin by concentrating on certain functional opportunities like an advertising campaign, or manufacturing shop floor issue. Front line business personnel collaborate with high-energy IT savvy employees to create data hubs or smaller creative systems. To maintain compliance with corporate standards for secure, scalable systems, these units rely on IT teams for assistance due to lack of formalized technical knowledge. IT teams conduct audits and provide mentoring to guarantee compliance with overall company strategy.
c) **Business self-service**: Business units gradually develop capability in pursuit of more opportunity for innovation. Functional experts learn to develop data engineering, front-end, and data science capabilities in order to create more usable solutions. Smaller data hubs combine to form a robust data foundation that enables rapid application deployment. Business units begin to behave like software firms, allowing product management to design higher order business applications. Because the business does not require regular IT intervention, IT teams construct a secure platform and give them the flexibility to build useful apps on top. This foundation platform can range from SAAS CRM system to data-lakes or even a dot net-based coding platform, and business users utilize low-code and no-code tools to build on top of it.
d) **Pioneer:** BU identifies staff with know-how and ability to fuel digital innovation. Companies invest in coaching and training larger community of employees in order to develop digital athletes. Select business individuals with expertise team up with business-aware IT members, and they build innovative futuristic solutions. These can vary from predictive analytics models to intelligent automations in rounds of rapid experimentation. To enable maximum innovation flexibility for the teams, the central IT unit provides a secure sandbox architecture disconnected from the corporate network. The most inventive organizations provide this form of operational architecture to their front-runners for them to build newer solutions and stay ahead of the competition.

The Governance Layer

The governance mechanism is firm wide and keeps track of all IT systems across all business units, look for opportunity to scale them up to a higher level of partnership. The governance systems also seek options for sharing amongst BUs, include common foundational services like data-capture, and provide coaching to help produce more innovators within the workforce.

The Capability Maturity Assessment Model

This is the bottom half of the structure, which gathers information about BU's digital capabilities maturity and feeds it so that an appropriate collaboration model can be chosen. The maturity of a company's digital capability is defined as its capacity and ability to create desired digital functionality by combining people, process, and technology elements within its purview. Research in recent past have used varying digital capability models for performing digital capability assessments of companies, varying from generic models [16, 17] to those contextualized to specific technology or industry applicability [18–21]. We have deliberately avoided most of these models in favor of a relatively recent digital capability model from Jase Ann termed the 77-capability model [22]. While only a few renowned studies have used this model as a foundation, we believe it is ideal for our needs since it easily integrates contemporary digital trends such as social, mobile, and cloud with digital business. The model is based on global best practices for digital enterprises and is divided into 12 mega and 77 ingredient capabilities. It offers an easy means to score and aggregate the digital capability into four incremental maturity levels (basic, defined, optimized, and progressive) as shown below. We have selected this model as a foundation for the proposed framework; due to its relevance to the modern digital age, rich experience of its proposer, and its ease of use in measuring a firm's digital maturity.

4.3 Validating Framework Based on Business Interviews

We connected with five industry experts working for firms across broad range of growth stages, industries and sizes. These individuals held prominent executive/senior strategy positions with a strong exposure to technology. The interviews lasted an average of 45 min and conducted through video/audio conference. We recorded and transcribed the interviews before manually synthesizing them.

The interviews focused on the questions below.

Q1) how vital is it for business units to be able to meet their own sparse IT needs without relying on central IT? (Very High/High/Medium/Low/Very low)

Q2) would business unit staff be willing to learn new skills required by these BU-IT collaboration models? (Certainly yes/probably yes/not sure/probably no/certainly not)

Q3) does the proposed framework and associated four BU-IT partnership models cover all conceivable collaboration types?

Q4) how can we increase the applicability of this framework?

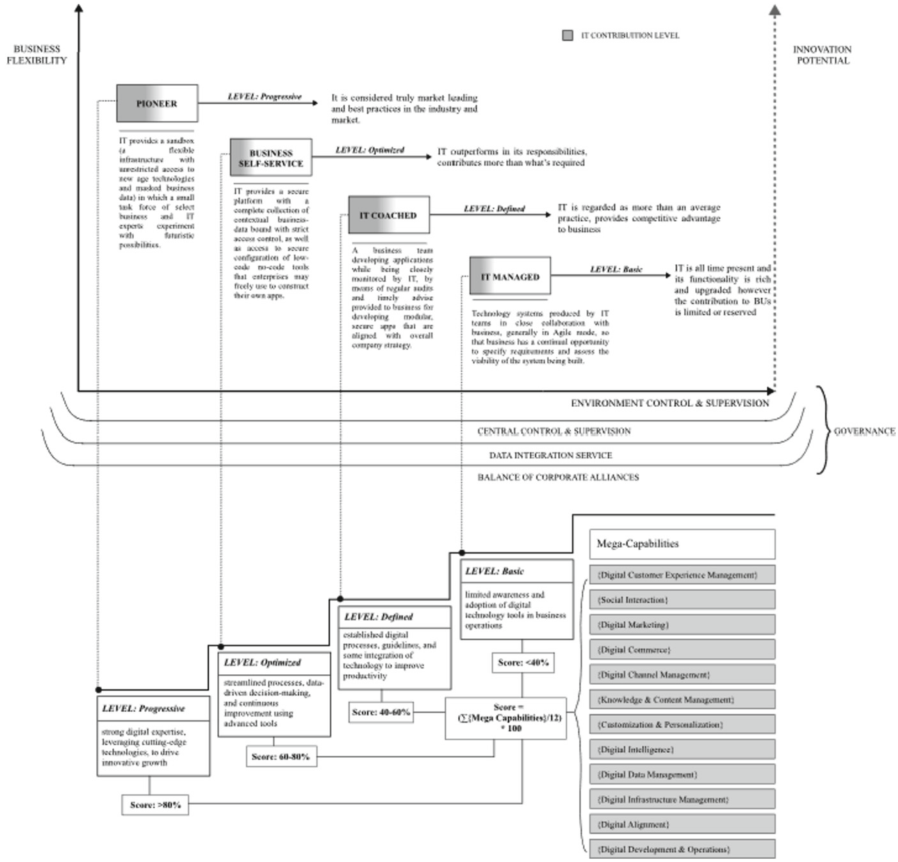

Fig. 2. Business-IT Partnership Framework (Author's own)

We employed an inductive approach to interpret the interview transcripts. In the first round, we used open coding to label the issues, framework gaps, and expert judgements [23]. We then modified, merged, and extended initially assigned codes into conceptual categories in an iterative process [23]. We did not feel a need to use a coding tool, however, the codes and categories were re-validated with research assistants (not connected to this research). The comments from industry professionals aided in fine-tuning the framework across all of its components. Table 3 summarizes the observations.

Table 3. Industry interview summary

Categories	feedback points	Observations and Gaps
Biz-IT Partnership models		
IT Managed	Business and IT work in Agile manner to iteratively build IT solutions. IT adhers to the software best practises of the IT system building.	1/5 expert asked to include a teaming possibility that splits up on front-end, back-end work distruibution. Here business envisions the user interface (UI) components of the desired solution, hands over to IT team to plug in the back end engine including data interfaces, middleware and infrastructure to make it a working reality. Interviewer agreed that this model is a specific variation of the IT Managed model.
IT Coached	Business resources build IT solutions with being coached by central IT teams. IT experts ensure compliance to standards.	
Business Self-Service	Business builds effective solutions using low-code, no-code tools on a secure platform, layered data entities and data with controlled access.	
Pioneer	Skilled business and IT member team up to build futuristi solutions using cutting-edge technologies on a sandbox environment with masked data.	
Central control and Supervision	This includes activities which are discovery (of Shadow instances), Assessment (look for potential of integrations or scaling partnership up) and Enablement (training and coach for further innovation)	4/5 experts discussed the topic in depth and provided numerous insights; both on its essential functions and what it should avoid to do. All are incorporated.
Data integration service	Based on the advice of the interviewers, in addition to governance, data integration service was introduced as an IT duty, keeping in mind the security and specialised capabilities required.	2/5 experts proposed that, central IT should provide data integration service (get new data sources either from enterprise lake/warehouse or from external sources using web service/API constructs)
Balance of corporate IT alliances	IT solutions within various business divisions utilize different business-IT partnership models. Central IT team manages overall balance.	As per 2/5 experts, Central IT will be best positioned to explore possibility of knowledge exchange among divisions, also teach high-performing divisions achieve higher levels of collaboration.
Capability Maturity Scorecard	The maturity of a business unit in terms of its digital capacity assists the framework in determining which partnership model is appropriate for its innovation journey	5/5 experts agreed that capability maturity should drive partnership decisions. They did, however, recommend more research to understand the corelationship between capabilities and type of technology solution.

5 Discussion

This section highlights key areas that need further work.

Future Framework Refinement Scope: The framework was highly praised as an organic toolbox, along with few advice to refine it further considered below:

- Apply to broader industrial use cases to find any missing BU-IT collaborative arrangement.
- Digital technologies are always improving, suggesting use of a more recent digital capability model as the foundation (the one used is this study is now four years old)
- Discovering any possible association between an organization's growth stage and its effect on BU-IT cooperation model
- Application of formal behavioral theory, such as Adaptive structuration due to the evolutionary nature of BU-IT partnerships.

Good and the Bad of Business-Managed IT: The framework should adapt to special situations such as:

- where shadow-IT should be retained (example: research hungry units, customer facing agile units).
- types of enterprise-wide systems (like data-lakes or ERP) where central IT is the mandatory choice

Limitations: The study used high quality but modest inputs, such as case studies within a single organization and insights from a limited pool of experts. This may limit the generalizability of the findings.

6 Conclusion

To summarize, the study began by introducing the ideas of Shadow-IT, its disadvantages, and the benefits of transforming it into business-managed IT. The primary goal was to present a simple framework that organizations may use as a toolkit to operationalize the migration of shadow IT into a suitable partnership model with IT unit, based on the competence level of the business unit.

The study initiated this effort by gathering the knowledge discovered through academic research. Next, using case study methodology, it formulated a suggestive framework, which was further validated with industry experts. The framework was fine-tuned based on their feedback.

This paper concludes by providing this framework as a toolkit to businesses looking to build technology applications, for determining a suitable IT partnership model. It also presents suggestions for additional research to widen the framework's coverage of contemporary technologies and emerging trends.

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- Raunak Rai (raunak.rai117@nmims.edu.in); and
- Swati (c.swati054@nmims.edu.in).

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Modelling Factors Influencing Charging Station Location Selection to Accelerate EV Adoption in India: An ISM-MICMAC Analysis

Sudhanshu Ranjan Singh[1(✉)], Abhijeet K. Digalwar[1,2], and Srikanta Routroy[1]

[1] Mechanical Engineering Department, BITS Pilani, Pilani, Rajasthan, India
p20220047@pilani.bits-pilani.ac.in

[2] Symbiosis Centre for Management Studies (SCMS) Nagpur, Symbiosis International (Deemed University) SIU Pune, Pune, Maharashtra, India

Abstract. Electric vehicles (EVs) are rising fast to prominence as a key component of the effort to meet sustainable energy goals. The research and mass manufacturing of new energy vehicles, especially electric vehicles, offer several benefits over conventional energy vehicles, such as zero exhaust emissions, zero pollution, cleanliness, and low cost. As a result, more and more nations are paying attention and placing importance over the development of EV-fleet, but EV sales are still a modest part of all vehicle sales. The protruding reason highlighted by the literature and researchers is underdeveloped charging infrastructure. To get the most out of an EV, an appropriate charging station with optimum configuration needs to be placed in a specific location with all the infrastructure to make it supportive and sustainable hotspot for EVs. This study aims to identify all the factors that needs to be considered while selecting a location for setting up a sustainable charging station for EVs in semi-urban areas. A deeper understanding of factors is explored, using interpretive structural modelling (ISM) and MICMAC analysis. A total of 17 factors are considered for the analysis which are crucial in developing the configurations for an EV charging station. The outcomes of the paper will support the policymakers to locate, determine and decide the suitable locations, and configuration for constructing EV charging stations and escalate the EV adoption.

Keywords: Electric Vehicles · EV charging stations · EV infrastructure configurations · ISM analysis · EVCS

1 Introduction

Carbon dioxide and its rising content in the environment has been a constant concern over the last decade among the developed and developing countries. Throughout history, the primary source of human needs has always been fossil fuels. One of the main sources of carbon dioxide emissions, which significantly contribute to global warming, is the transportation industry [1]. At the moment, the usage of fossil fuels in transportation

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contributes to environmental and noise pollution, which is threatening for environment [2]. The prime reason for transportation sector being the main highlight is because at present the 91% of Indian transportation sector is still relying on oil products [3]. Because doing so significantly reduces both the pollution brought on by fossil fuels, which is a critical issue, and the depletion of those resources.

Paying attention to environmental concerns and pollution from fossil fuel-powered vehicles has been a factor in government decision-making, particularly in the past two decades [4]. Due to these unfavorable circumstances and the depletion of fossil fuel supplies, interest in alternate energy sources has grown [5]. In response to the combined challenges of energy and the environment, electric vehicles (EVs) have attracted attention of governments, researchers, and investors. Because of this, experts and manufacturers of automobile vehicles have recently placed a high value on the development of electric vehicles as the least polluting vehicles [6]. Electric vehicles (EVs) are positioned as an alternative green and clean technology that may make it possible to preserve natural limited resources and transition quickly to a sustainable low-carbon emission transportation system [7].

The electric vehicle is still in its infancy in India. The Indian government is focusing to establish different EV-related laws and putting incentive schemes in place since it recognizes the significance of EVs [8]. Faster Adoption and Manufacturing of (Hybrid and Electric) Vehicles (FAME) India is a program developed by India that offers universal demand incentives to manufacturers as well as consumers [9]. The advancement of EVs and the infrastructure for charging them should coexist. Without the other, neither can develop. Consequently, it is equally vital to invest in the infrastructure for EV charging [10]. The creation of Electric Vehicle Charging Stations (EVCS) intends to simplify the process of getting individuals access to energy for their electric vehicles to overcome their range anxiety. Several significant Indian cities, including Delhi, Pune, Mumbai, Bangalore, Ahmedabad etc. have already established EVCS in accordance with the goal to accelerate the use of electric vehicles. Increased funding has been put towards the development of EVCS in India in recent years. Field findings show that the infrastructure for EVCS development has not been successful especially in the semi-urban areas [11]. Most of the investments by the government and leading start-ups have been made in few urban metropolitan cities only. This lack of framework development roots for slow development of charging stations because the investment made must benefit both investors and users which is another issue. This means the goal is not just to build charging stations, but to be built with the vision of business sustainability.

Understanding the factors and parameters based on technological, geographical, social, political, environmental, and economical grounds is need of an hour to increase the efficacy of EVCS deployment. The development of the EVCS infrastructure in India is hampered by several variables and restrictions. The purpose of the current study is to identify the responsible parameters and their hierarchy so that the priority is given in the same order to advance the framework according to their reliance and driving force. To develop an ordered hierarchy of parametric configurations Interpretive Structural Model (ISM) is used. ISM is one of the common methods for prioritizing the factors depending upon the defined issue [12]. It is important to understand the hierarchy of the parameters so that a deeper understanding can be formed about their nature and dependencies for which ISM-MICMAC tool is the most suitable one. This insight on hierarchy and critical analysis of parameters will support the growth of the Indian EVCS infrastructure for accelerating the adoption of electric vehicles [13]. The key parameters/factors are identified from the literature and discussions held with focused group for curating the configurations for EVCS. The subsequent sections of the paper are structured in the following manner: Sect. 2 of this study includes a literature review. Section 3 introduces to the methodology, calculations, and analysis. Results and conclusion are discussed in the Sect. 4.

2 Literature Review

To ascertain the determinants contributing to the sustainable growth of electric vehicle (EV) charging infrastructure and network in India, this study employed the utilization of web resources such as Scopus and Google Scholar. The search keywords "electric vehicle charging infrastructure," "electric vehicle charging stations," and "EV charging station development" were used to locate the pertinent literature for the current investigation. Through detailed investigation from literature various factors are defined upon which the different variables or parameters for the investigation are segregated. A list of factors with brief definition, variables in that category along with nomenclature is shown below in the Table 1.

Table 1. Dimensions with factor for EV charging-station location selection in India

Factors	Brief details	Variables	Nomenclature
Technological	Technological variables are those that are directly or indirectly connected to the technology of charging electric vehicles. These elements may be roughly divided into the areas of transaction mechanism, storage capacity, charging and battery technology	Battery maximum energy	TECH1
		Charging speed (slow/fast)	TECH2
		Mode of transaction	TECH3
Geographical	Geographical variables have major role in the decision making of location selection of charging station because they directly influence the accessibility and useability of the charging station	Road network	GEO1
		Site Accessibility	GEO2
		Electric vehicle density	GEO3

(*continued*)

Table 1. (*continued*)

Factors	Brief details	Variables	Nomenclature
Economic	Economic variables consider all related costs, including the original investment, land cost and electricity provision expenses	Electricity provision cost	ECO1
		Infrastructure investment	ECO2
		Land cost	ECO3
		Economic background of people	ECO4
Social	Social variables influence the society to access or adopt the developing EV infrastructure. Since EVs are a relatively new form of transportation, it is anticipated that social adoption would take some time. Identifying and addressing the societal capacities and limitations is crucial to hasten the adoption of electric vehicles	Public awareness	SOC1
		User satisfaction	SOC2
Environmental	Environmental variables are those elements which supports the noble cause of incorporating the new mode of transportation and supporting the environmental goals	Flexibility/Adaptability	ENVT1
		Clean energy potential	ENVT2
Government Support	Governmental regulations are significantly imperative in the advancement of electric transportation. Its policies on involvement and monitoring along with the subsidies in grid connections for charging can speed up the process of development	Government commitment	GOVT1
		Government involvement and monitoring	GOVT2
		Subsidy on EV charging	GOVT3

Different researchers have considered different set of variables in the analysis depending on their both internal constraints and external environment. Yagmahan and Yılmaz (2023) integrated a group of Multi Criteria Decision Making (MCDM) techniques for evaluation of sites for setting up charging stations by ranking several factors [14]. Wang et al. (2023) combined a clustering and planning model for evaluating the responsible factors and concluding an iterative solution [15]. Asna et al. (2023) proposed a queuing algorithm to reduce waiting time and optimize the station utilization in which location and capacity planning framework factors were considered [16]. The defining factors for charging infrastructure are briefed in Table 2 along with the reference from the literature.

Table 2. Factors related too different dimensions

S.No.	Factors	Brief details	References
1	Battery maxi-mum storage	The maximum amount of energy that can be stored in the battery. This variable also de-fines the range up to which an EV can go in a single charge.	[17–19]
2	Charging speed (slow/fast)	This variable defines the speed with which the EV supports charging.	[17–21]
3	Mode of transaction	The mode through which the charging inter-face interacts with the customer at the charging station.	[18, 20]
4	Road network	The network of roads needs to be accessed for understanding the traffic flow and junction points.	[5, 6, 17, 20, 22–34]

(*continued*)

Table 2. (*continued*)

S.No.	Factors	Brief details	References
5	Site Accessibility	This factor is important as the utilization of charging station depends majorly on its accessibility to the potential customers.	[1, 5, 6, 17, 19–36]
6	Electric vehicle density	The number of vehicles in the area decides in setting up the number of charging piles and size of charging station.	[5, 17, 18, 20, 23–25, 27, 29, 31–34]
7	Electricity provision cost	The cost associated in setting up the electricity connection from the grid to the charging station.	[17, 19, 20, 23, 24, 29, 34]
8	Infrastructure investment	The costs of the charging setup, AC-DC charging piles and other related services.	[20, 24, 29, 34]
9	Land cost	The cost of the land or place where the setup is to be placed. It can either be owned or rented or leased property.	[5, 23, 24, 29, 30, 31, 34, 36]

(*continued*)

Table 2. (*continued*)

S.No.	Factors	Brief details	References
10	Economic back-ground of people	This factor involves the assessment of over-all economic strength of the customers or potential customers in the region.	[1, 5, 17, 18, 20, 22, 25, 26, 28, 30–33]
11	Public awareness	Awareness among the people regarding the developed and developing charging infra-structure can reduce the range anxiety and uplift the EV adoption.	[1, 18, 20, 24, 31, 36]
12	User satisfaction	The feedback of customers from the experience with the charging infrastructure and satisfaction by the provided services because that will only enable the repeated use of the facility.	[33]
13	Flexibility/Adaptability	The provision to adapt according to the upcoming technological advancements and developments.	[1, 5, 18, 24, 34]
14	Clean energy potential	The calculation and approach to adopt a clean energy source for charging the EVs.	[1, 5, 6, 18, 20, 31]

(*continued*)

Table 2. (*continued*)

S.No.	Factors	Brief details	References
15	Government commitment	Policies and guidelines from the government for developing the EV infrastructure.	[20, 24, 36]
16	Government involvement and monitoring	Policies do not bring the implementation, but sheer involvement and regular monitoring brings. That is why this factor is critical from the government side.	[17, 20, 24]
17	Subsidy on EV charging	Subsidies on the EV infrastructure can boost the investments and can attract the investors to take interest in this sector.	[18, 20, 24]

It is evident from Table 1 and Table 2, that research on the charging infrastructure of EVs in the past have mostly focused on one or more of these issues. A comprehensive framework outlining the development of charging stations hasn't been created yet, though. Therefore, this study is intended to contribute to the facilitation and development of EVs charging infrastructure. India is still in the early stages in the deployment of EVs charging stations. Understanding the hierarchy through which the development of charging infrastructure can be escalated is the study's main goal.

3 Methodology

The methodology followed in this study is Interpretive Structural Modelling (ISM) technique. The ISM (Interpretive Structural Modeling) method was devised by Warfield in 1974 as a tool for multi-criteria decision-making, specifically aimed at addressing intricate situations [36]. The structural modeling technique discussed is a significant approach that prioritizes the establishment of a hierarchical structure model for complex systems based on the interrelationships among system elements. This method relies on the decision and judgement of experts about how the system's variables are depending on each other. It is structural because it is built on interrelations between linked variables and their dependency on each other, and its resulting structure is derived from a complicated system of variables. The application of ISM method is done by many scholars to demonstrate relationships and hierarchical links [36–39]. The consequent steps involved in ISM method are explained in the subsequent sections

3.1 Structural Self-Interaction Matrix (SSIM)

The relationships and dependencies between the different factors are defined in the form of matrix in which any of the 4 variables (V, A, X & O) are used. Each variable signifies a relation among the row and column factor which is listed in Table 3. The SSIM is a result of discussion and brainstorming sessions of experts and academicians collectively. The output from the expert's opinion and discussion is shown in Table 4.

Table 3. Denotation of variables in SSIM

Denotation	Representation
V	row variable influences corresponding column variable
A	row variable is influenced by corresponding column variable
X	row and corresponding column variable influence each other
O	row and corresponding column variable have no relationship

3.2 Reachability Matrix

In this step, the SSIM data is converted into binary numbers matrix form, which is known as Initial reachability matrix by swapping the denotations (V, A, X, and O) by 0 and 1 depending on the case. The approach for assigning 0's and 1's is given in the Table 5. For developing the final reachability matrix, the driving power and dependence is calculated using Eqs. 1 and 2. Table 6 shows the final reachability matrix along with the transitivity factors, which shows the factors that attain value '1' because of indirect dependency.

$$\text{Drivingpower} = \sum_{j=1}^{17} a_{1j} \tag{1}$$

$$\text{Dependence} = \sum_{i=1}^{17} a_{i1} \tag{2}$$

The driving force refers to the cumulative number of factors, including the factor itself, that it has the potential to influence. The dependence total refers to the overall quantity of factors that may contribute to its attainment.

Table 4. Structural self-interaction matrix

S.No.	Factors	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	GOVT1	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	
2	GOVT2	V	V	V	V	V	V	V	V	V	V	V	V	V	V	X		
3	GOVT3	V	V	V	V	V	V	V	V	V	V	V	V	V	V			
4	ENVT1	V	V	V	V	V	V	V	V	X	O	O	O	X				
5	ENVT2	V	V	V	V	V	V	V	V	X	O	O	O					
6	ECO1	V	V	V	V	V	V	V	V	A	X	X						
7	ECO2	V	V	V	V	V	V	V	V	A	X							
8	ECO3	V	V	V	V	V	V	V	V	A								
9	ECO4	V	V	V	V	V	V	V	O									
10	TECH1	V	V	V	V	V	V	V										
11	TECH2	V	V	V	V	V	X											
12	TECH3	V	V	V	V	V												
13	GEO1	V	V	X	X													
14	GEO2	V	V	X														
15	GEO3	V	V															
16	SOC1	V																
17	SOC2																	

Table 5. Criteria for assigning 0's and 1's

Entry	SSIM	Reachability Matrix value	
		i, j	j, i
i, j	**V**	1	0
i, j	**A**	0	1
i, j	**X**	1	1
i, j	**O**	0	0

3.3 Level Identification

By using the final reachability matrix, two different sets of factors are formed – reachability and antecedent set. Reachability set includes all the factors which are influenced by this factor including itself, whereas antecedent set comprises of those factors which influenced this factor including itself. The common elements in both sets are categorized into intersection set. The factor having maximum dependence will be on the top level because it will not have influence from any other factor. In our case the factor with

Table 6. Final reachability matrix

S.No.	Factors	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	Driving Power
1	**GOVT1**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**17**
2	**GOVT2**	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**16**
3	**GOVT3**	0	1	1	1	1	1*	1*	1*	1	1	1	1	1	1	1	1	1	**16**
4	**ENVT1**	0	0	0	1	1	1*	1*	1*	1	1*	1*	1*	1	1	1*	1	1	**14**
5	**ENVT2**	0	0	0	1	1	1*	1*	1*	1	1*	1*	1*	1	1	1*	1	1	**14**
6	**ECO1**	0	0	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	**11**
7	**ECO2**	0	0	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	**11**
8	**ECO3**	0	0	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	**11**
9	**ECO4**	0	0	0	1	1	1	1	1	1	1*	1	1	1	1	1	1	1	**14**
10	**TECH1**	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	**8**
11	**TECH2**	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	**7**
12	**TECH3**	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	**7**
13	**GEO1**	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	**5**
14	**GEO2**	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	**5**
15	**GEO3**	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	**5**
16	**SOC1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	**2**
17	**SOC2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Dependence		**1**	**3**	**3**	**6**	**6**	**9**	**9**	**9**	**6**	**10**	**12**	**12**	**15**	**15**	**15**	**16**	**17**	

Note - * indicate transitivity

maximum dependence is ‘1’ that is why it is placed at ‘Level 9’. Similarly, the level is identification for all the factors is performed and shown in Table 7.

Table 7. Level identification (Iterations 9)

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,	1,	1,	**9**
2	2, 3,	1, 2, 3,	2, 3,	**8**
3	2, 3,	1, 2, 3,	2, 3,	**8**
4	4, 5, 9,	1, 2, 3, 4, 5, 9,	4, 5, 9,	**7**

(*continued*)

Table 7. (*continued*)

Factors	Reachability Set	Antecedent Set	Intersection Set	Level
5	4, 5, 9,	1, 2, 3, 4, 5, 9,	4, 5, 9,	**7**
6	6, 7, 8,	1, 2, 3, 4, 5, 6, 7, 8, 9,	6, 7, 8,	**6**
7	6, 7, 8,	1, 2, 3, 4, 5, 6, 7, 8, 9,	6, 7, 8,	**6**
8	6, 7, 8,	1, 2, 3, 4, 5, 6, 7, 8, 9,	6, 7, 8,	**6**
9	4, 5, 9,	1, 2, 3, 4, 5, 9,	4, 5, 9,	**7**
10	10,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	10,	**5**
11	11, 12,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12,	11, 12,	**4**
12	11, 12,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12,	11, 12,	**4**
13	13, 14, 15,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,	13, 14, 15,	**3**
14	13, 14, 15,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,	13, 14, 15,	**3**
15	13, 14, 15,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15,	13, 14, 15,	**3**
16	16,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16,	16,	**2**
17	17,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17,	17,	**1**

3.4 MICMAC Analysis

The MICMAC analysis is employed to ascertain the dependence and driving force of each barrier. The driver-dependence diagram is separated into four quadrants, with the dependence on the x-axis and driving power on the y-axis. Based on their driving force and dependence, all the obstacles are plotted on this diagram; the result is depicted in Fig. 1.

- Autonomous variables are in quadrant 1, which are weak as they have no influence over the other factors because they lack dependency and driving power both. As in our case no factor is present in that region.
- Dependent variables are in quadrant 2, which have higher dependency but low driving power. Factors like technical, geographical, and social (10 to 17) are dimension are appearing in this region.
- Linkage variables are in quadrant 3, they hold high dependency and driving power altogether. In this region economic factors such as land, electricity, and infrastructural costs are present.
- Independent variables are in quadrant 4, they comprise of factors with extreme driving power and low dependency. Government and environment factors are found to be in this category.

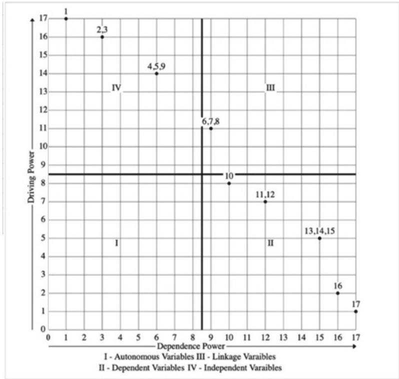

Fig. 1. MICMAC analysis – Driver dependence diagram ISM Modelling

With the help of final reachability matrix and level identification, the ISM model is developed. From the Fig. 2 it is observed that government commitment leads the development by drafting policies and subsidies for the cause. This will influence the economic and environmental aspect, as both needs to be hand in hand. Once the environmental and economic goals are set ten comes the technical level which is followed by the geographical factors. The final and top goal is user awareness and satisfaction which completely makes sense is because all this infrastructure development is framed for this goal only.

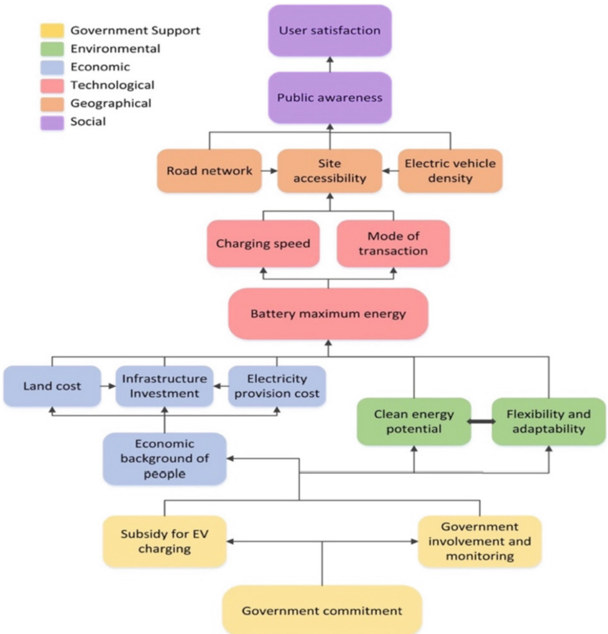

Fig. 2. ISM Model for EV charging-station location selection

4 Conclusion

The current study is able to identify and rank the critical factors of charging infrastructure development is based on their importance and interdependence using the ISM technique. The factors related to "Government Support" dimension such as Government commitment, Government involvement and monitoring and subsidy for EV charging are appearing in the bottom of the ISM model and driver quadrant of the MICMAC analysis – Driver dependence diagram. Hence, these factors play the significant role for the for EV charging-station location selection in India. Firstly, the government must commit, but effective subsidy and monitoring is also essential to escalate the EV development. To accelerate the EV adoption, the way development of charging stations is necessary same way, it is equally necessary to invest and innovate in adaptability of infrastructure along with technological upgradations. This study paves the path for the policymakers and stakeholder to understand the crucial factors in a hierarchical order for effective identification of opportunities and implementation of strategies.

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Role of Information Dissemination in Promoting Green Consumption Mediating a Media Richness Perspective

Anjali D. Manglani(✉)

MICA, Gujarat, Ahmedabad 380058, India
manglanianjali133@gmail.com

Abstract. Marketing among retailers involves various modes of information supply such as brochures, direct mail, newspapers, advertisements on radio, event marketing, social media marketing, e-commerce portals, etc. Retail marketing has its significance and contribution in effectively solving doubts of consumers and boosting sales. To make an effective consumption of green products among consumers, it is necessary to make their respective retailers aware of green marketing practices. The present study tried to analyse the significant modes of information supply and their contribution in generating awareness for green FMCG retailers of Gujarat; to identify the most contributing mode of information supply; and to build a communication model using MRT for generating awareness about green marketing practices with special ref-erence to FMCG retailers of Gujarat. A convenience sampling descriptive research design is adopted in Gujarat with a semi-structured schedule to collect data among 100 FMCG retailers of Gujarat. The data collected is analyzed using Frequency Distribution and Multiple Regression. After analysing the effectiveness of various modes of information supply, the results derived that majority of the retailers are unaware of green marketing practices. The results emphasized upon unreached communication. The MRT model for richer green communication proposed in the findings of the study can help in fulfilling the communication gap between stakeholders and can contribute in generating awareness regarding green marketing practices. MRT suggests that advertisement, social media and face-to-face communication via whole-salers /dealers are the richer medias' and have significant impact upon awareness for green marketing practices.

Keywords: Green Consumption · Green Communication · Media Richness Theory

1 Introduction

Information system (IS) has emerged as contemporary pathway for solving environmental problems by developing green IS. (Yaojie Li et al. 2023). Practitioners refers Green IS as the process of involving IT infrastructure for enhancing firm's environmental efficiency and reduce destructive impacts. However, Green IS also contributes in developing

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environment friendly products and services (Wang et al. 2015). Industries has developed green products and has adopted green communication strategies to deliver green products to society. This is necessary for significant green consumption by society. To make green products consumption stronger from society's part, companies need to communicate these practices in much better way than now. The present study emphasised the importance of green communication for stronger adoption of green products.

Green Marketing Practices (GMP) are those eco-friendly actions which have minimal or no negative impact on environment (Krishanveer Singh, 2023). Green marketing has emerged as a revolution to prevent climate change which is on urge to become irreversible as per IPCC (Intergovernmental Panel on Climate Change) reports (Fiona Harvey, 2023). Companies practicing green does not hold mere responsibility of ethically adopting green practices, but also to communicate those practices effectively to each stakeholder, inorder make best out of those practices. The result of these preventive climate actions not only depends upon initiating GMPs but also upon how these practices are implemented in cradle-to-cradle (C2C) life cycle model of a product (Starre Vartan, 2021). For successful implementation of C2C, awareness among each stakeholder is necessary. The companies adopting these practices have the crucial responsibility to inform every stakeholder about respective GMPs. Marketing of green practices will not only build-up a flow of green communication but will also help in building green brand positioning in emerging green trends. Consumers can only develop their purchase intention towards green products, once they know about its benefits and necessity in today's era (Emmanuel Mogaji et al. 2022).

Retailers are the most prominent source through which a consumer can get at least glimpse for GMP, primarily. To effectively make consumers aware about GMP, it is necessary to make retailers aware as well. Marketing among retailers involves various modes of information supply such as brochures, direct mail, newspapers, advertisements on radio, event marketing, social media marketing, e-commerce portals, etc. Retail marketing has its significance and contribution in effectively solving doubts of consumers and boosting sales (Michael Keenan, 2022).

Various mediums have their significance in reaching out for GMP effectively. Advertisements with a green message do have a strong appeal for understanding the green message involved and create purchase intention. Social media platforms are believed to be the most significant platform to establish green communication and generate awareness. Twitter was highlighted to be the most helpful platform (Emmanuel Mogaji et al. 2022). Websites of companies consisting of information about GMP are found least stakeholder friendly. These websites contained eco-labels and texts, but not every layman was able to understand those contents. Semiotics has the major role play which should be critically employed here. Newspapers and other associated secondary sources of information such as periodicals or magazines are considered as essential modes to communicate significant information (Emmanuel Mogaji et al. 2022). The effective use of each mode of information supply is important to get desired results. The present study tries to comprehend the position of each mode of information supply according to its content delivery and impact upon awareness with respect to GMP. To gain an insightful solution, MRT is applied to generate a model and comprehend the impactful implication of modes of information supply according to their content delivery.

2 Literature Review

2.1 Green Communication

Gocer and Oflac (2017) tried to identify the impact of associated factors that influence consumers towards purchase of eco-labeled products in Turkey. The study revealed that environmental concern had become the mediating factor having significant impact on eco-labeled product purchases (Bailey, 2016) and highlighting the propensity of consumer behaviour while making a green purchase. Environmental knowledge also had significant impact on eco-labeled product purchases (Gocer and Oflac 2017). Consumers have become the major driving force behind any trend and Consumer purchase intention was the main push factor behind any buying process. To influence purchase intention; viral marketing through internet strategies was found to have significant impact on consumers' entertainment and information delivery. Also, internet's viral marketing was identified as a credible source for content delivery of an eco-labelled product. Different industries have started working in terms of sustainability and the mere focus remained on green consumer behaviour. Among various industries, fashion industry also initiated sustainable practices as it is considered among most pollution generating industries (Dhir, 2020). Khare signified it and tried to evaluate the impact of peer influence and past eco-behaviour upon Indian consumers' gains through green apparel pertaining to its knowledge (Khare, 2020) and adoption among gen z and millennials as sustainable fashion (Mohr, et al. 2022). Social media holding a significant position among millenniums and gen z (Oberlo, 2023); Word of Mouth (WoM) through social media fore played for sustainable fashion industry. Green behaviour and green concern were the key factors, encouraged the WoM among social media. The study also adopted personality threat analysis highlighted the openness to experience, extraversion and agreeableness as the active personalities upon social media having optimistic impact on green apparel (Salem, et al. 2021). Green social media communication has the significant intention to cocreate green value among consumers (Li Zhao, 2023). The perceived service content quality on social media and the dominated information quality by the perceived marketer had significant impact on customer retention orientation of a green fashion retailer. It also found having favourable relationship with patronage intention (Kang and Kim, 2017).

2.2 Media Richness Theory

Saat and Selamat (2014) evaluated the impact of Media Richness Theory (MRT) applied to analyse the attitude with special reference to communicating with the help of websites displaying CSR practices. The study revealed that richer the media, contribution got more effective. A different dimension was added to MRT by extending its ends with Adaptive Structuration Theory (AST) to perform a group support system literature. The study revealed that rather than MRT, AST was found to have a vigorous impact on empirical analyses (Ugo Chukwu Etudo, 2015). Information disclosure & technologies, Privacy concern and Media richness were analyzed to examine their correlation among themselves for MRT in extension with Task Technology Fit (TTF) concept. (Jing-Ting Luo, 2020). Various media rich writing technologies were identified helping students enjoying and grooming their attitudes, motivation, removing anxiety (Yu-Feng LAN, 2011).

Evaluation of impact on task performance and satisfaction obtained by communicating through various MRT based mediums such as text, face-to-face, video and audio were analyzed with psychological factors (Kil Soo Suh, 1998). To make teaching effective, MRT contributed by playing a significant role with the help of multiple media that helped enriching communication and teaching experience on online platforms. (M S Balaji, 2010).

3 Research Methodology

A strong research methodology is the base for good research. The more comprehensive the methodology is, the more study will be able to contribute in terms of real-life adaptations. Parallelly, it will be able to explain the research problem in a way more realistic manner.

The literature review of study has aided in foregrounding the research gap which shall be a pedestal for further stages of respective research. The research gap here highlighted the lack of attention paid to, green marketing awareness generation with various modes of information altogether. Also, to make study more effective and useful; MRT is added as a new dimension to understand the contribution of different modes of information, communicating about initiatives taken by a FMCG company in the domain of green marketing and its effectiveness in generating awareness for green marketing practices. This study has tried to solve the problem statement i.e., "Companies have adopted all the necessary modes of information supply, to communicate effectively and to make the FMCG retailers of Gujarat aware about respective green marketing practices" (Table 2).

The study tried to achieve the following research objectives,

1. To analyze the significant modes of information supply and their contribution in generating awareness for green FMCG retailers of Gujarat.
2. To identify the most contributing mode of information supply.
3. To build a communication model using MRT for generating awareness about green marketing practices with special reference to FMCG retailers of Gujarat.

The research objectives are fulfilled by the respective research methodology. This study has adopted a convenience sampling descriptive research design in the geographical boundary of Gujarat. A semi-structured schedule is applied to collect data among 100 FMCG retailers of Gujarat. The data collected is analyzed using Frequency Distribution and Multiple Regression. To conduct a final data collection which can provide a valuable insight; a pilot testing was conducted among 20 FMCG retailers of Gujarat, prior to the final schedule survey (Fig. 1).

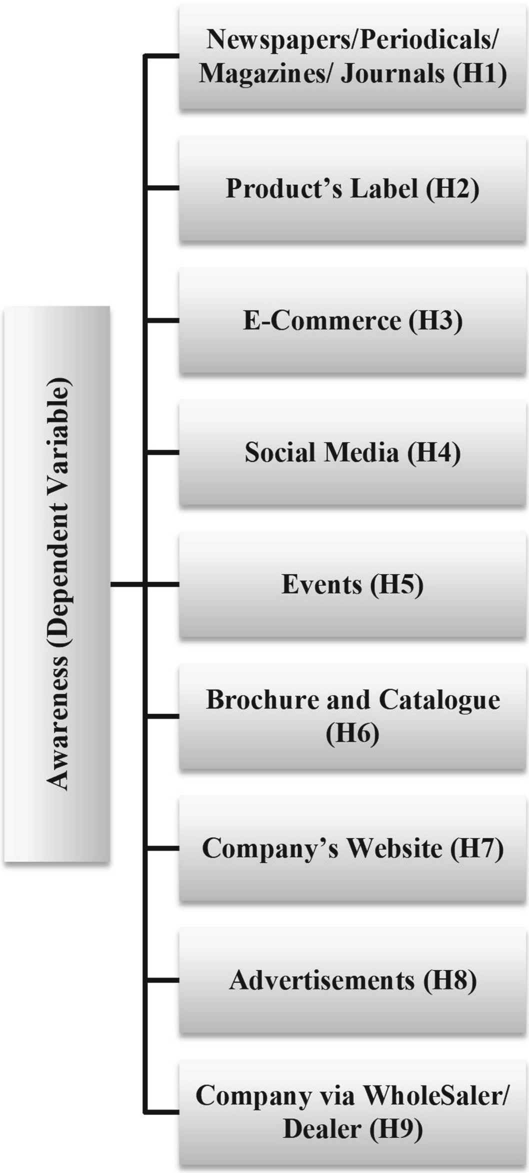

Fig. 1. Hypothetical Representation (Various modes of information supply are taken as Independent Variables)

Regression (R) represents the multiple correlation coefficients between the dependent variable 'Awareness' and all the independent variables (predictors) (Deepak Chawla and Neena Sondhi, 2016). It helps to identify the strength and direction of relationship (Kendra Cherry, 2022). Table 1 shows the value of R is 0.934 which represents the positive strong relationship between the awareness and all predictors. The R Square describes

Table 1. Model Summaryb

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	0.934[a]	0.872	0.862	0.168	0.872	89.155	7	92	0.000	1.637

a. Predictors: (Constant), Whole Seller Dealers through Company, Social-Media, E-Commerce, Products Label, Newspapers/ Periodicals, Advertisement, Brochure and Catalogue.

b. Dependent Variable: Aware.

Table 2. ANOVAa.

Model		Sum of Squares	Df	Mean Square	F	Sig
1	Regression	17.570	7	2.510	89.155	0.000[b]
	Residual	2.590	92	0.028		
	Total	20.160	99			

a. Dependent Variable: Aware.

b. Predictors: (Constant), Wholesaler Dealers through Company, Social-Media, E-Commerce, Products Label, Newspapers Periodicals, Advertisement, Brochure and Catalogue.

the variance or proportion of variance explained by all the independent variables for the dependent variable. The Adjusted R Square rectifies the overvaluation to derive the factual population value (Naval Bajpai, 2018). For the respective regression model, the value of R Square is 0.872 and the value of adjusted R Square is derived at 0.862. This adjusted R square describes the explained variance by independent variables for the dependent variable i.e., 86.2%. The proportion of unexplained variance is 13.8%. That value of unexplained variance signifies that the huge proportion of variance is explained, and the independent variables and dependent variable have a strong relationship. Durbin Watson analysis describes the existence of positive autocorrelation (Naval Bajpai, 2018) among the independent variables and dependent variable with the value of 1.637.

H1: The regression model is significant.

H0: The regression model is not significant.

As per the result obtained, the derived value of significance is 0.000, that represents the regression model is significant (Naval Bajpai, 2018).

Regression Model: 1.964 + (-0.389)*News Papers/Periodicals/ Magazines/ Journals + (-0.214)*Products Label + (-0.051)*E-Commerce + (-0.124)*Social-Media + 0.124*Brochure and Catalogue + (-0.597)*Advertisement + (-0.510)*Whole Seller Dealers through Company.

The regression model is constructed considering the beta coefficients with all the independent variables considered for the test. Constant (a) here is taken as derived from the Table 3 i.e., 1.964.

H1: News Papers/ Periodicals/ Magazines/ Journals is making significant unique contribution in generating awareness.

Table 3. Co-efficientsa (T-Test for the slope of regression line).

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig	95.0% Confidence Interval for B		Correlations			Co-llinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	1.964	0.019		101.159	0.000	1.925	2.003					
	News Papers/Periodicals/ Magazines/ Journals	−0.558	0.065	−0.389	−8.606	0.000	−0.686	−0.429	−0.564	−0.668	−0.322	0.685	1.459
	Products Label	−0.964	0.169	−0.214	−5.707	0.000	−1.299	−0.629	−0.161	−0.511	−0.213	0.997	1.003
	E-Commerce	−0.232	0.177	−0.051	-1.315	0.192	-0.583	0.119	−0.161	−0.136	−0.049	0.911	1.098
	Social Media	−0.558	0.215	−0.124	−2.587	0.011	−0.985	−0.130	−0.161	−0.260	−0.097	0.613	1.633
	Brochure and Catalogue	0.325	0.134	0.124	2.434	0.017	0.060	0.591	−0.282	0.246	0.091	0.542	1.845
	Advertisement	−0.732	0.057	−0.597	−12.796	0.000	−0.845	−0.618	−0.700	−0.800	−0.478	0.641	1.561
	Wholesaler Dealers Through Company	−0.964	0.071	−0.510	−13.540	0.000	−1.105	−0.823	−0.405	−0.816	−0.506	0.985	1.016

a. Dependent Variable: Aware.

H0: News Papers/ Periodicals/ Magazines/ Journals is not making significant unique contribution in generating awareness.

The result of analysis discloses the value of significance is below 0.05 i.e., 0.000. This derived value accepts the alternate hypothesis. Therefore, News Papers/Periodicals/ Magazines/ Journals do have a significant unique contribution in generating awareness. The standardized coefficient described the newspapers/periodicals/magazines/journals as the significant source of awareness after advertisements and wholeseller/Dealer. The beta value generated for same is 0.389 (negative sign is not considered). If the value of VIF is below 10 and value of tolerance is above 0.1, the independent variable has no multicollinearity (Jeremy Miles, 2014). Here, with this predator, the value of VIF is 1.459 and tolerance value is 0.685. As both the values are significant here, the multicollinearity does not exists here.

H2: Products Label is making significant unique contribution in generating awareness.

H0: Products Label is not making significant unique contribution in generating awareness.

The result of analysis discloses the value of significance is below 0.05 i.e., 0.000. This derived value accepts the alternate hypothesis. Therefore, Product Label does have a significant unique contribution in generating awareness. The standardized coefficient has displayed the products label as the significant source of awareness after advertisements, wholesaler/dealer and newspapers/periodicals/magazines/journals. The beta value generated for product label is 0.214 (negative sign is not considered). If the value of VIF is below 10 and value of tolerance is above 0.1, the independent variable does not have multicollinearity. Here, with this predator, the value of VIF is 1.003 and tolerance value is 0.997. As both the values are significant here, the multicollinearity does not exists.

H3: E-commerce is making significant unique contribution in generating awareness.

H0: E-commerce is not making significant unique contribution in generating awareness.

The result of analysis discloses the value of significance is above 0.05 i.e., 0.192. This derived value accepts the null hypothesis. Therefore, E-commerce does not have a significant unique contribution in generating awareness. The standardized coefficient has displayed the e-commerce as the insignificant source of awareness as it has the least value of coefficient among all other variables. The beta value generated for e-commerce is 0.051 (negative sign is not considered). If the value of VIF is below 10 and value of tolerance is above 0.1 the independent variable does not have multicollinearity. Here, with this predator, the value of VIF is 1.098 and tolerance value is 0.911. As both the values are significant here, the multicollinearity does not exists.

H4: Social-Media is making significant unique contribution in generating awareness.

H0: Social-Media is not making significant unique contribution in generating awareness.

The result of analysis discloses the value of significance is below 0.05 i.e., 0.011. This derived value accepts the alternate hypothesis. Therefore, Social-Media does have a significant unique contribution in generating awareness. The standardized coefficient has displayed the social media as the least significant source of awareness among all the sources. The beta value generated for social media is 0.124 (negative sign is not considered). If the value of VIF is below 10 and value of tolerance is above 0.1 the independent variable does not have multicollinearity. Here, with this predator, the value of VIF is 1.633 and tolerance value is 0.613. As both the values are significant here, the multicollinearity does not exists.

H5: Brochure and Catalogue is making significant unique contribution in generating awareness.

H0: Brochure and Catalogue is not making significant unique contribution in generating awareness.

The result of analysis discloses the value of significance is below 0.05 i.e., 0.017. This derived value accepts the alternate hypothesis. Therefore, Brochure and Catalogue does have a significant unique contribution in generating awareness. The standardized coefficient has displayed the brochure and catalogue as the least significant source of awareness among all the sources. The beta value generated for brochure and catalogue is 0.124. If the value of VIF is below 10 and value of tolerance is above 0.1 the independent variable has multicollinearity. Here, with this predator, the value of VIF is 1.845 and tolerance value is 0.542. As both the values are significant here, there exists the multicollinearity.

H6: Advertisement is making significant unique contribution in generating awareness.

H0: Advertisement is not making significant unique contribution in generating awareness.

The result of analysis discloses the value of significance is below 0.05 i.e., 0.000. This derived value accepts the alternate hypothesis. Therefore, Advertisement does have a significant unique contribution in generating awareness. The standardized coefficient has displayed the advertisement as the most significant source of awareness among all the sources. The beta value generated for advertisement is 0.597 (negative sign is not considered). If the value of VIF is below 10 and value of tolerance is above 0.1 the independent variable does not have multicollinearity. Here, with this predator, the value of VIF is 1.561 and tolerance value is 0.641. As both the values are significant here, the multicollinearity does not exists.

H7: Wholesaler /Dealers Through Company is making significant unique contribution in generating awareness.

H0: Wholesaler /Dealers Through Company is not making significant unique contribution in generating awareness.

The result of analysis discloses the value of significance is below 0.05 i.e., 0.000. This derived value accepts the alternate hypothesis. Therefore, Wholesaler Dealers Through Company does have a significant unique contribution in generating awareness. The standardized coefficient has displayed the wholesaler dealers through company as the second most significant source of awareness among all the sources. The beta value generated for whole seller dealers through company is 0.510 (negative sign is not considered). If the value of VIF is below 10 and value of tolerance is above 0.1 the independent variable does not have multicollinearity. Here, with this predator, the value of VIF is 1.016 and tolerance value is 0.985. As both the values are significant here, the multicollinearity does not exists (Fig. 2).

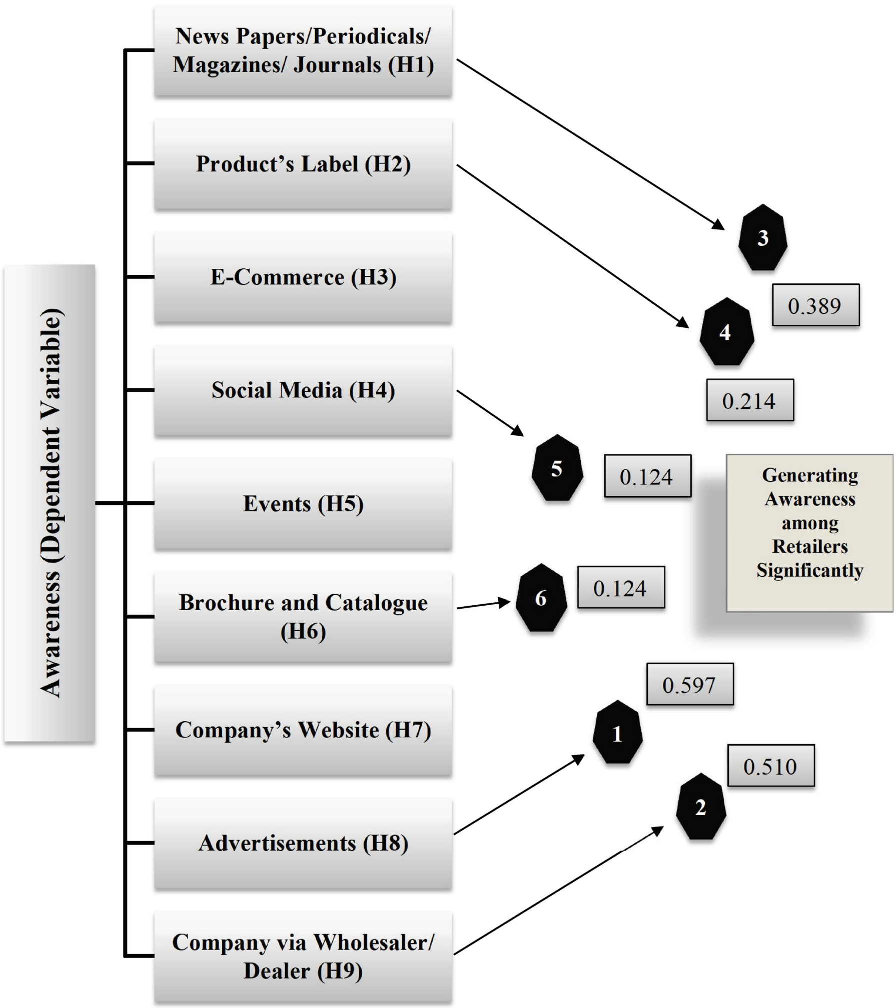

Fig. 2. Analytical Representation (Describing significant Modes of Information contributing in generating Awareness)

The above diagrammatic representation has described the most impactful modes of information that contributed up to a significant extent in generating awareness about green marketing practices prevailing in Indian FMCG sector among retailers of Gujarat. Newspapers/Periodicals/ Magazines/ Journals; Products Label, Social Media, Brochure & Catalogue, Advertisement, and Company via Wholesaler/ Dealer are the significant modes of supplying information to retailers which have huge impact in generating awareness among retailers. The diagram has explained the contribution of each of the mode of information along with the ranks allotted to each of them to make the interpretation comprehensive (Fig. 3).

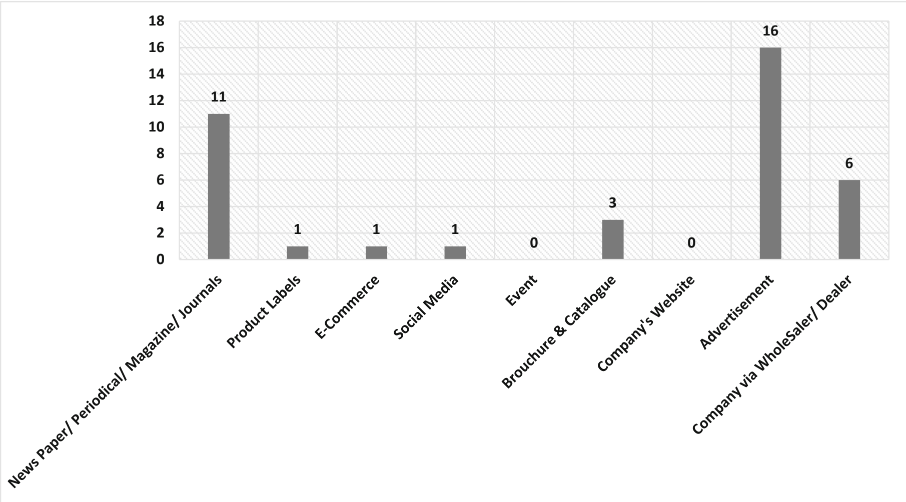

Fig. 3. Graph No. 1

Graph 1 representing a huge scope left where all the modes of information supply can play a significant role, if used appropriately. Advertisement is found to have a significant contribution among retailers in generating awareness. After advertisements, the major contributors are Newspapers/Periodicals/ Magazines/ Journals, and company via wholesaler & dealer. Events, company's websites, and e-commerce portals are least useful in making retailers aware about green marketing practices as per the results. These respective modes of information should be used for specific groups of people such as marketers, researchers, etc. The results described that these modes are the significant sources but at present they are contributing at its least as only 28% (Table 4) of retailers are found aware about green marketing practices.

Table 4. Frequency Distribution of Aware Retailers

	Frequency	Percent	Valid Percent	Cumulative Percent
Aware	28	28%	28%	28.0
Unaware	72	72%	72%	100.0
Total	100	100.0	100.0	

These various modes have their significant impact on FMCG retailers who are aware about green marketing practices and the major aspects that FMCG companies should take care about i.e., what, how and how much the retailers are availing in form of information associated to green marketing practices from these modes. The immediate scope for further study that arrived after this statement is “if the retailers are able to comprehend this information?”.

The major reason of unawareness among FMCG retailers of Gujarat is unfulfilled communication. Unfulfilled communication means either the information is not reachable, or the receiver is unable to decode the information. The modes that companies have adopted for now are unable to reach retailers as well as incomprehensive from retailer’s end. Hence, the present communication mode is inefficient. As per the Media richness theory, the present practices fall under Learner Media which are needed to be extended towards Richer Media (Barkhi, 2005; Mammadov, 2022). The detailed adoption of theory for respective study can be understood as follows.

4 Media Richness Theory

To use different media for passing the ambiguous information to mass audience, media richness theory is applied. This theory is influential as well as can contribute in improving the performance. The major task is to make an appropriate match of media characteristics with the task characteristics. It has potential to transform understanding. The main factors influencing the theory are:

1. The medium has the ability to transmit multiple cues, appropriately.
2. Feedback immediacy.
3. Varieties of language.
4. Everyone is focused personally through the right medium (Littlejohn and Foss, 2009).

Rich media theory focuses upon the mode which are rich in transforming the information and has great impact on receiver especially for equivocal tasks. Mode (media) choice is significant component of effective information transfer, added by Daft Lengal and Linda Trevino in 1987 (Mammadov, 2022). If the right mode of information used significantly to communicate i.e., richer mode, it can be most impactful in spreading awareness for green marketing practices as well as it can help in comprehending the information made availed to retailers effectively and efficiently (Fig. 4).

The above diagram can comprehend the use of appropriate mode of information for companies and make it adoptable for their target market. The suggestion is to adopt richer mode (media) to make the information effectively available and understandable through the right mode of information.

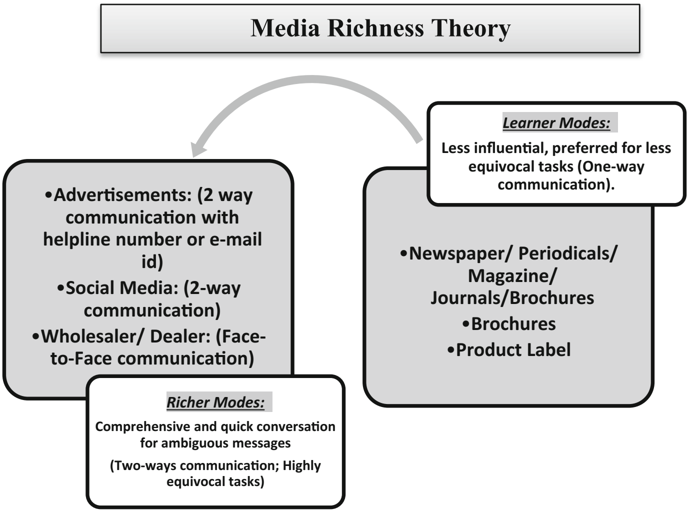

Fig. 4. MRT Model for Richer Green Communication

5 Conclusion

Green products are very helpful in making a remarkable contribution to environment conservation, but the major role play depends upon the information supply regarding these practices to all the respective stakeholders. After analysing the effectiveness of various modes of information supply, the results derived that majority of the retailers are unaware of green marketing practices. The results emphasized upon unreached communication. The MRT model for richer green communication can help in fulfilling the communication gap between stakeholders and can contribute to generating awareness regarding green marketing practices. MRT suggests that advertisement, social media, and face-to-face communication via wholesalers /dealers are the richer modes and have significant impact than learner mode. The maximum outcome can only be gained, if these modes are used appropriately to educate the stake holders effectively about the green marketing practices, green products as well as the green washing practices to maintain the rim of ethics involved in green marketing practices.

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Navigating the Stream: Unveiling the Factors Shaping Consumer Purchase Intention in Live Streaming Shopping on Social Media Platforms

Prianka Sarker[1(✉)] and Yogesh K. Dwivedi[2,3]

[1] Department of Marketing International Business and Tourism, Manchester Metropolitan University, Manchester M15 6BY, UK
p.sarker@mmu.ac.uk
[2] Digital Futures for Sustainable Business and Society Research Group, School of Management, Swansea University, Bay Campus, Fabian Bay, Swansea, Wales SA1 8EN, UK
y.k.dwivedi@swansea.ac.uk
[3] Department of Management, Symbiosis Institute of Business Management, Pune and Symbiosis International (Deemed University), Pune, Maharashtra, India

Abstract. The advancement in internet technology has firmly entrenched social media as an indispensable aspect of daily life. Social networking communities have evolved into a profoundly relevant space for marketers. Nowadays, social media offers a diverse array of features that actively engage users in buying and selling products and services. Live streaming, particularly, has gained remarkable popularity among social media influencers and businesses alike. Companies are increasingly investing time and resources into captivating consumers through social media live streaming rather than traditional offline methods. In recent years, many researchers have delved into this domain, identifying various theories/models and factors that influence consumers' adoption of this technology. This study synthesizes these models and factors, conducts weight analysis and sheds light on various limitations to guide future investigations. The study's findings reported that SOR model is the most adopted model in this domain therefore trust, enjoyment, and uncertainty are some key predictors of purchase intention. Moreover, it is important to acknowledge limitations such as geographical constraints, methodological challenges, and the use of purchase intention as a proxy for actual behaviour that shapes this research.

Keywords: Live-streaming · SOR model · Weight analysis · Literature review · purchase intention

1 Introduction

A real-time recording and broadcasting medium is referred to as live streaming [1]. Utilizing diverse forms of communication technology, live streaming offers an immediate and authentic experience to the audience, simulating their physical presence at the event.

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In 2023, social media platforms like Instagram, TikTok, Facebook, and YouTube successfully provide live streaming services. Live streaming now encompasses a wider array of services than in the past. Consumers enjoy fun and entertaining streaming on social media and are involved in the discussion and deal-grabbing process [2]. There are many advantages that come with using live streaming for social shopping, including direct and instantaneous interaction between sellers and potential buyers, and showcasing product transparency and authenticity.

The prior discussion highlights the effectiveness of live streaming for both businesses and customers. In recent years, many scholars have undertaken diverse research efforts to illuminate this technology's impact. Consequently, this study aims to review previous literature, synthesize models and theories employed in live streaming studies, and further narrow down the factors influencing consumer purchase intentions through a weighted analysis. This study, furthermore, synthesises the limitations of this domain to mitigate them in future research. This study would be beneficial for future comprehensive studies to create a holistic model considering important factors and mitigating the limitations.

2 Literature Search

The Scopus database was utilized for a comprehensive literature search, employing keywords such as "live streaming" OR "streaming" OR "social media live streaming," AND "behavioural intention," OR "adoption," OR "acceptance," OR "usage behaviour," OR "use intention," OR "purchase intention". The search, applied to titles, abstracts, and keywords, yielded an initial pool of 175 articles. This study subsequently excluded conference papers, reviews, and newspaper blogs, resulting in the removal of 43 studies due to duplication. This left 132 articles for further investigation. Upon reviewing these papers, this study identified that 47 studies had adopted and validated conceptual models and theories. Therefore, this study proceeds to synthesize these models, theories, and constructs from these 47 studies to conduct a weight analysis.

2.1 Theories and Model of Live Streaming Shopping Studies

Table 1 presents various models and theories adopted in live-streaming shopping studies. It is noted that the Stimulus-Organism-Response (SOR) model has been employed in ten studies, examining a range of factors [3, 4]. The SOR model simplifies the process of consumer decision-making into three stages. However, critics have argued that these simplifications may not fully capture the complexity of live-streaming shopping behaviour [73, 74]. Elaboration Likelihood Model (ELM) is the second most used model that has been utilized in three studies. Individuals tend to enhance their executive cognitive processing during decision-making [13–15]. Nonetheless, within the fast-paced and dynamic context of live-streaming shopping, not all users may engage in deep cognitive processing [15]. Furthermore, multiple studies have delved into the exploration using Affordance Theory, Signalling Theory, and the Theory of Planned Behaviour. Review of this study has unveiled that a limited number of studies used holistic models considering live-streaming technology adoption. Moreover, the majority of studies have not focused on the measurement of consumers' real shopping experiences but rather on intention.

Therefore, further investigations are imperative, considering more holistic models to enhance the experience and adoption of this technology.

Table 1. Theories and Model of Live streaming shopping studies

Models/theories	Frequency	Citations
S-O-R model	10	Dong et al. [3]; Gao et al.[4]; He et al. [5]; Li et al.[6]; Shang et al. [7]; Shiu et al. [8]; Tong et al. [9]; Wu and Huang [10]; Zhao and Bacao [11]; Zheng et al. [12]
Elaboration likelihood model	3	Gao et al. [13]; Sang et al. [14]; Zeng et al. [15];
affordance theory	2	Lu et al. [16]; Wang et al. [17]
Signalling theory	2	Chen et al. [18]; Lu and Chen [19]
Theory of Planned Behaviour	2	Apasrawirote and Yawised [20]; Wang et al. [17]
uses and gratification theory	2	Wongkitrungrueng et al. [21]; Wang and Oh [22]
Models/theories occur in single study		
Arousal and consumer memory theory, Zhang et al. [23]; Cognitive Transactional theory, Zhou et al. [24]; Complementarity theory Qin et al. [25]; Flow theory Zheng et al.[26]; Game theory Ji et al.[27]; Live Streaming Transaction model, Paraman et al. [28]; Influencer marketing theory, Chen and Yang [29]; Information foraging theory, Liu et al. [30]; IT affordance, Sun et al. [31]; Observational learning theory Zhang et al.[32]; Parasocial interaction theory Shen et al. [33]; Perceived value theory, Singh et al. [34]; Push-Pull mooring, Ye et al.[35]; Social identity theory, Qian and Seifried [36]; Social presence theory, Hou et al. [37]; Socio-technical system theory, Zhang et al. [38]; Speech act theory, Chen et al.[39]; Theory of reasoned action, Yu and Zhang [40]; Theory of telepresence, Ma et al. [41]; Uncertainty reduction theory, Hwang and Youn [42]; Utilization theory, Chen et al.[43]; Yale model and benefit-risk framework, Chen and Zhang [44]; Cognitive emotion theory, Alam et al. [45]; Media richness and media ritual theory, Zelenkauskaite and Loring-Albright, [46]		

2.2 Synthesis and Weight Analysis of Live Streaming in Social Media

After reviewing various models and theories, this study determined to synthesize the factors that influence consumer purchase intention using live-streaming technology. This section narrows down the factors and performed weight analysis to determine relative importance of different factors. Weight analysis determine the inductive and predictive power of independent variables over the dependent variable [47]. This technique is useful for ranking variables to understand their relative importance and the strength of their relationships within the model [47]. According to Jeyaraj et al. [76], this analysis helps to evaluate the effectiveness of individual independent variables in predicting technology adoption by considering three crucial components:

"(a) the number of times an independent variable was examined in individual IT adoption; (b) the number of times an independent variable was found to be significant in individual IT adoption; (c) the weight, calculated by (b)/(c) for individual IT adoption (predictive power)" [77, p. 6].

This study summarized the most influential predictors of purchase intention, segregating them based on their significant and non-significant relationships. The weight analysis reported that perceived enjoyment, social presence, flow, social interaction, customer engagement, perceived value, usefulness, Swift Guanxi, personal innovativeness and Dynamic brand experience are the strongest predictor of purchase intention with analysis score "1". While trust found to be second strongest predictor with an analysis score of 0.80, supported by findings in ten studies. Conversely, uncertainty acted as a negative predictor, inhibiting consumer purchases through live streaming. Table 2 presents a comprehensive overview of the most used relationships in live streaming studies. And those factors are placed into the following three categories: Psychological factors, emotional and social factors, and product and experience factors. These factors can assist researchers in selecting appropriate variables to develop more suitable research models for future investigations.

2.2.1 Psychological Factors

Factors that influence individual behaviour including their adoption and engagement with technology such as social media or live streaming uses are consider as psychological factors [75]. Many studies have examined psychological determinants such as Enjoyment and innovativeness in live streaming platforms. As demonstrated by previous research [30, 34, 53, 64], Enjoyment significantly impacts consumers' likelihood to shop, when providing positive experiences during live streaming. Similarly, when consumers find innovativeness in live streaming, they are more likely to purchase products [34, 35]. Positive attitudes and perceptions towards products boost purchasing tendencies [1, 40, 61]. On the contrary, Park and Lin [50] explained that attitude has no significant influence on purchase decisions. Chao et al. [60] found that perceived value positively determined consumers buying decisions during live streaming. Trust is another psychological key construct that strongly influences consumers to adopt this technology. Trust in streamers, platforms, and products/brands, as validated by Chong et al. [48], Chen et al. [49], Chen and Yang [29], and Dong et al. [3], has been demonstrated to have a significant influence on consumer purchase decisions while using this technology. On the other hand, Ma [51] and Rungruangjit [52] found no significant influence on purchase intention. Usefulness, strongly linked to perceived practical benefits, is important in consumer decision-making, as highlighted by [25, 62, 63].

2.2.2 Emotional and Social Factors

The emotional spectrum intertwines with social dynamics. Emotional engagement, emotional trust, and perceived emotional value, evidenced by Gao et al. [4]; and Addo et al. [58]; Chao et al. [60]; significantly affects usage intentions. Emotional contentment and trust, arising from perceived emotional value, strongly influence purchase intentions. Social presence, as observed by Ma [64]; and Gao et al. [4] exerts a positive impact on purchase decisions. The sense of social connection during live-streaming sessions effectively steers consumers' purchasing choices.

Table 2. Weight analysis Summary for Behavioural/Purchase intention

IV	Sig	Citations	Non-Sig	Citations	Total	Weight
Trust	8	Chong et al. [48]; Chen et al. [49]; Chen and Yang [29]; Dong et al. [3]; Hou et al. [37]; Lu and Chen [19]; Park and Lin [50]; Zhang et al. [32]	2	Ma [51]; Rungruangjit [52]	10	0.80
Perceived Enjoyment	6	Gu et al. [53]; Liu et al. [30]; Ma [64]; Singh et al. [34]; Yin et al. [54]; Zhu et al. [55]	0		6	1
Uncertainty	6	Chen and Zhang [44]; Chou et al. [56]; Gao et al. [4]; Hwang and Youn [42]; Lu and Chen [19]; Ma [64]	0		6	1
Social presence	5	Chen et al. [2]; Gao et al. [4]; Hwang and Youn [42]; Hou et al. [37]; Wang and Oh [22]	0		5	1
Flow	4	Li and Peng [57]; Paraman et al. [28]; Zhao and Bacao [11]; Zheng et al. [12]	0		4	1
Social interaction	4	Gao et al. [13]; Hou et al. [37]; Shiu et al. [8]; Wang and Oh [22]	0		4	1
Customer engagement	4	Addo et al. [58]; Qin et al. [25]; Yu and Zheng [40]; Zheng et al. [59]	0		4	1
Perceived value	4	Chao et al. [60]; Li et al. [6]; Singh et al. [34]; Wang et al. [22]	0		4	1
Attitude	4	Chen and Lin [1]; Evans et al. [61]; Yu and Zheng [40]	1	Park and Lin [50]	5	0.8
Usefulness	3	Doanh et al. [62]; Qin et al. [25]; Zhu et al. [63]	0		3	1
Swift Guanxi	2	Lu et al. [16]; Zhang et al. [32]	0		2	1
Personal innovativeness	2	Singh et al. [34] Ye et al. [35]	0		2	1
Dynamic brand experience	2	Shiu et al. [8]; Wang et al. [17]	0		2	1
Perceived risk	1	He et al. [5]	1	Singh et al. [34]	2	0.5

2.2.3 Product and Experience Factors

Uncertainty within the product domain also plays a pivotal role [4, 19, 42, 44, 64]. Hwang and Youn [42] illuminate that product uncertainty, encompassing aspects like product quality and fit, negatively affects the likelihood of consumer purchase through live streaming. Additional dimensions, such as background music and consumer memory, as elucidated by Zhang et al. [44], significantly influence purchase intention in the live-streaming context. This intricate web of factors underscores the complex interplay between psychological, emotional, social, and product-related dimensions, shaping consumer decisions during live streaming sessions.

3 Limitations and Future Research of Live Streaming Studies

The literature review of live streaming studies also unfolded various limitations that required to be identified within the domain. These highly mentioned limitations are geographical constraints, factors analysis, overemphasis on purchase intention and methodological drawbacks. Shedding light on these limitations and providing future direction are necessary within the context of live streaming in social media studies so that, the future scholar can mitigate them.

3.1 Geographical Constraints

An evident constraint in the landscape of live-streaming studies emerges from their pronounced concentration within the boundaries of China [77]. This geographical bias limits the transferability of findings across regions due to the divergent social and technological milieu [77]. The inherent global nature of live streaming contrasts with this singular focus, thus inadequately capturing a balance of consumer behaviour. Cultural disparities among countries further compound this limitation, necessitating future cross-cultural analyses to provide a more balanced understanding [49, 53]. To advance the field, expanding research efforts to emerging nations becomes paramount for refining the generalizability of research models and hypotheses [4]. This expansion holds promise for unravelling the intricate interaction between cultural nuances and impulse buying behaviour within the live-streaming context [37].

3.2 Variant in Factors

The limitation of factor analysis manifests in the sparse exploration of a comprehensive model that integrates multiple variables in live-streaming studies. Scholars recommend the inclusion of mediating variables such as flow and consumer experience to construct a more encompassing analytical framework [4]. Notably absent from some studies is the exploration of pivotal factors like social influence, which has the potential to significantly influence consumer behaviour [65]. Moreover, the role of "Experience" in live streaming contexts merits further investigation, as its impact on consumer behaviour remains understudied [4]. By delving into unique live streaming shopping factors, such as streamer influence and expertise, feature enhancement and innovativeness, researchers can glean richer insights into consumer motivations [4]. Addressing the socio-cultural dimensions in live streaming becomes imperative, as these differences play a substantial role in shaping consumer buying behaviour [37].

3.3 Overemphasis on Purchase Intention

A prevailing trend in live streaming studies revolves around an inordinate focus on examining consumer purchase intentions and behavioural intentions, thereby side-lining the exploration of actual behaviour. This imbalance overlooks the potential incongruity between intentions and actions [70], highlighting the need for research to shift its spotlight towards actual purchase behaviour [2]. The suggestion to investigate a broader spectrum of dimensions and perspectives that influence consumer behaviour is paramount, ensuring a more comprehensive understanding of engagement and behaviour within the live streaming landscape [12]. Scrutinizing the real-world behaviour of consumers, rather than their intentions, adds depth to the comprehension of their engagement [4].

3.4 Methodological Drawbacks

Methodological choices also constitute a limitation within the live-streaming studies domain. Predominantly quantitative methods and validated questionnaires have been employed, potentially introducing biases rooted in memory recall [2]. In pursuit of richer insights, embracing qualitative and mixed method approaches and incorporating laboratory or field experiments emerges as an avenue to unravel the complexities of live-streaming technology [12]. Strengthening the study's external validity calls for the adoption of research models that can traverse diverse cultural landscapes [4].

4 Recommendation and Conclusion

Many technology adoption studies have previously explored consumer adoption, taking into account various dimensions of social media. Their objective is to develop a comprehensive model that enhances the consumer experience and establishes a sustainable system that can be easily implemented [66–72]. Similarly, this study conducted an extensive literature review to uncover various models and theories, as well as the factors that significantly influence live streaming on social media platforms. The SOR model emerged as the most widely adopted model in this research, while trust was the most frequently used construct in conjunction with purchase intention. However, a more holistic consumer adoption model needs to be investigated in this domain. Additionally, diffusion of innovation, perceived compatibility, perceived complexity, trialability, and risk perception are some factors might be adopted within live streaming future studies. The evaluation of past user experiences, including satisfaction, usability, and aesthetics, should also be considered in future research. The research also synthesized several limitations and outlined potential future directions in this domain. Notably, addressing geographical and methodological drawbacks, as well as highlighting the overemphasis on purchase intention, emerges as vital steps for future research to undertake. A critical limitation to note is that the majority of studies did not employ specific models to investigate consumer actual purchasing behaviour, rather they focused solely on purchase intention. Thus, forthcoming research should direct its efforts towards constructing more comprehensive models encompassing pertinent and influential factors that impact actual purchase behaviour within the live streaming context.

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Selection of Cloud Service Providers: A Fuzzy-set Qualitative Comparative Analysis Approach

Mohammad Alamgir Hossain[1](✉), Alvedi Sabani[1], Sachithra Lokuge[2], Yee Ling Boo[1], and Shahriar Kaisar[1]

[1] RMIT University, Melbourne VIC 3000, Australia
{mohammad.hossain,alvedi.sabani,yeeling.boo, shahriar.kaisar}@rmit.edu.au
[2] University of Southern Queensland, Springfield Lakes, QLD 4300, Australia
sachithra.lokuge@unisq.edu.au

Abstract. Selection of a cloud service provider (CSP) is an important decision for businesses that make long-term investments. Notably, this process is a complex decision that involves assessing multiple criteria where more than one condition jointly may dictate the decision. In addition, the selection decision can be explained with more than one equally effective configuration of conditions. Moreover, the causal configurations for predicting the rejection of a CSP are unique and may not mirror opposites of the causal configurations of the selection of a CSP. Prior studies commonly apply traditional regression-based linear modeling techniques and thus far, these techniques do not fully capture the complexity of CSP selection but rather identify the individual and isolated effects of the conditions. This study fills the gap by proposing a new configuration framework, which posits that CSP selection does not depend on individual conditions, but on their specific configurations. The configurational model has been validated using fuzzy-set qualitative comparative analysis method. The results suggest three configurations to select and reject a CSP in conjunction with the implications to research and practice.

Keywords: Cloud Computing · Cloud Service Provider · Configuration · fsQCA

1 Introduction

In recent times, Cloud Computing has become increasingly popular and vital for businesses, as it enables them to efficiently consume and utilize computing resources over the web [1]. In order to perform Cloud Computing, users[1] take support from cloud service providers (CSPs) to handle their computing utilities (e.g., infrastructure, storage, computing power, and software applications) [2, 3]. A CSP vendor leases different types of cloud-based services (e.g., IaaS, PaaS, and SaaS) that are dynamically provisioned

[1] Both individuals and businesses can be the users; however, our focus is the latter.

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based on customer's demand. A wide variety of customized and reliable computational services are hosted on servers maintained by the CSPs, allowing users to access them from anywhere, replacing the on-premises information technology (IT) commitments [4].

With the rapid growth of cloud services in recent years and the continuously evolving market, businesses must evaluate their specific needs to select the most suitable CSP. "Given the vast diversity of these offers, the choice of the most appropriate CSP became a dilemma that confuses most cloud customers" [4, p. 71851]. For many users, "it is very difficult to choose the suitable cloud services" [5, p. 7015] as there are several competing CSPs, it is quite a complex task.

When selecting a CSP, users value the technical attributes including security, accessibility, and more [6]. Similarly, the non-technical or non-functional i.e., operational criteria e.g., performance, quality of support, and reputation must also be assessed to meet the service levels as set in the service specifications [5]. When selecting a CSP, users look at a wide range of service attributes that, in response, support multiple functional objectives [7]. Even though the selection of a CSP is a multi-criteria decision making (MCDM) process [4, 8], "most of the existing work assumes that the service attributes are independent of one another, while in reality, there are interdependencies between attributes" [7], p. 148]. In other words, while selecting a CSP, users do not look at one attribute but a combination of them. For instance, users do not decide on a CSP solely based on the cost [9] but take security into consideration as well [10]. Thus, "consideration of the interdependent relationship between selection criteria is critical for rational decision-making" [7], p. 148]. Nonetheless, several studies applied MCDM methods e.g., analytical hierarchical process (AHP) [e.g., 4, 5, 8], yet the joint effects of the attributed could not be explained. "Thus, more advanced techniques need to be explored to model the relationships between multiple attributes and enable service selection based on mutually interdependent criteria" [7], p. 148].

Against this backdrop, this study investigates: "Which configurations of technical and operational attributes explain the selection of CSP?" This study does not provide a process to select the most appropriate CSP [4]. Rather, it focuses on identifying the features a CSP should possess for users to select that CSP. We collected data from individuals who make CSP selection decisions in various industry sectors. To answer our research question, we have applied a fuzzy-set qualitative analysis (fsQCA) technique. The fsQCA excels in identifying complex, non-linear configurations of criteria that influence an outcome. MCDM methods typically assume linear relationships between criteria, whereas fsQCA allows for the exploration of interactions and dependencies among criteria that may not be apparent in traditional MCDM approaches. Furthermore, fsQCA provides a unique capability to identify necessary and sufficient conditions for an outcome. It can determine which combinations of criteria are necessary (must be present) and sufficient (alone or in combination) for a particular outcome, providing a more nuanced understanding of the decision-making process.

This study has several theoretical and practical implications. We respond to the research call of Sun, Dong [7]. From the practical perspective, this study provides an explainable guide to users on how to best bundle their products in combination of different service attributes. Thus, this will lead to enhance the efficiency of the CSP selection process of an organization.

2 Identifying the Attributes of CSP Selection

2.1 Identifying the Attributes of CSP Selection

Extant literature has identified several attributes important for CSP selection. For example, Godse and Mulik [8] suggest the following criteria for SaaS selection: functionality, architecture, usability, vendor reputation, and cost. Other studies group them under functional and non-functional service attributes [e.g., 5]. From a literature review, Sun, Dong [7] identified five *functional* attributes including functionality, accessibility, usability, scalability, and resource distribution. In addition, prior research highlighted functional attributes such as performance, reliability, portability, and customizability as important attributes for CSP selection [11, 12]. On the contrary, the *non-functional* quality of services "is considered the most significant attribute for appropriate service selection" in cloud computing [5, p. 7015]. Sun, Dong [7] identified payment, performance, security, and reputation as the non-functional aspects of CSP estimation. Among them, payment is considered by most of the service selection studies, which is typically represented by the price or pricing models. In addition, reputation, level of support, service variety, rapport, and geolocation are also considered as important for CSP selection [2, 13].

From extant studies, the attributes important for CSP selection can be grouped into two major categories: technical and operational attributes. The technical attributes refer to the technical aspects of cloud services. The *technical* attributes include performance, security, accessibility, scalability, reliability, usability, portability, and customizability of the CSP. The *operational* attributes refer to the attributes and considerations related to the operational aspects of the provider's services such as reputation, pricing, level of support, service variety, resource distribution, and subscription flexibility. Considering these attributes enables organizations to make informed decisions when selecting a CSP that aligns with their specific needs and requirements.

2.2 Identifying the Conditions for Configurational Model

Theoretically, all these 14 attributes identified from literature in Sect. 2.1 can be included in a configurational model. However, in the fsQCA method, the truth table (discussed in Sect. 4.4) computes 2^k possible configurations (or combinations) to predict an outcome variable, where k represents the number of conditions (i.e., attributes or attributes). Hence, for 14 attributes, it will be impractical to evaluate 16,384 possible configurations. Therefore, using a convenient sampling technique, we conducted a survey involving 29 small to medium-sized enterprises (SMEs) to assess, identify, and prioritize the relative importance of the technical and operational attributes in CSP selection. Subsequently, these identified attributes formed the variables for formulating the configurational model. In particular, the survey was designed with a questionnaire consisting of the technical and operational attributes, along with their definitions. The respondents were asked to rate each attribute using a three-point scale of "not important" (=3), "somewhat important"

(=2) and "very important" (=1) in selecting a CSP. The results of the survey are summarized in Fig. 1 where the attributes are ranked in descending order of their mean values. The mean of the mean values is 2.1 and the average of the highest (2.7) and the lowest (1.6) of mean rating values of all attributes included in the survey is 2.2. Therefore, 2.2 is identified and used as the cut-off value. In other words, those attributes that have mean values greater than 2.2 are considered as relevant conditions[2] for our configurational model to explain the selection of CSP. Thus, we identified four technical conditions (i.e., reliability, performance, security, and usability) and three operational conditions (i.e., reputation, pricing, and service capability), which are used as the variables to formulate the configurational model for selecting a CSP.

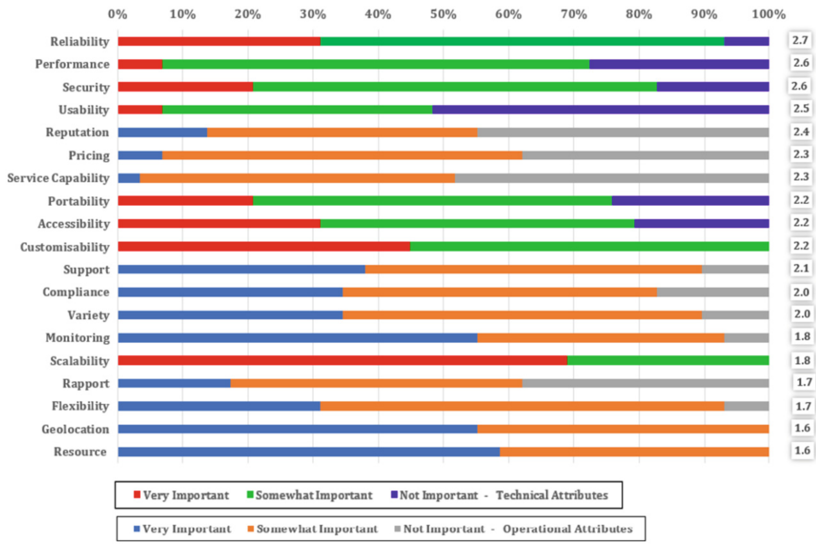

Fig. 1. Prioritizing the attributes affecting the selection of CSP

3 The fsQCA Model

3.1 Structuring the CSP Selection Problem

Based on the literature, we postulate that the selection of a CSP is a complex decision where asymmetrical relationships between technical and operational attributes may exist [14]. Our configurational research model is presented in Fig. 2 as a Venn Diagram [15]. In summary, our theoretical foundation is based on the argument that configurations between the technical and operational attributes affect the selection of a CSP: [scsp =

[2] In configurational models, the antecedent factors (i.e., independent variables) explaining a dependent variable are called "conditions" and the dependent variable is called as "outcome variable."

f(rel,per,sec,usb,rep,prc,srv)]. Alternatively, the rejection of a CSP becomes: [~scsp = f(rel,per,sec,usb,rep,prc,srv)], where " ~" denotes negation. Simply, selection of a CSP is a 'bundle' of technical and operational attributes.

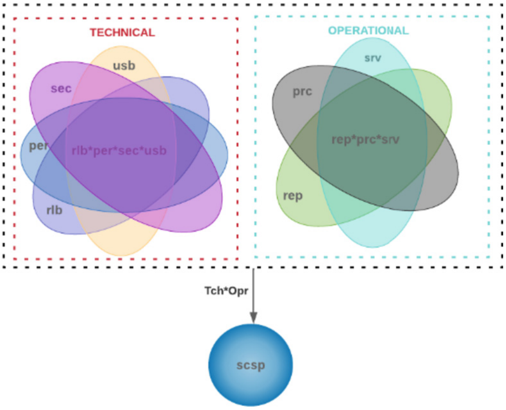

Fig. 2. The configurational model of cloud service provider selection.

3.2 Measures and Data Collection

All the measures of the variables have been adopted from established studies. *Reliability* is the ability of a cloud service to perform its intended function continuously and consistently over a period, without failure or interruption [11]. We measure *reliability* using items from [16, 17]. *Performance* is a measure of how efficiently a CSP can deliver computing resources, such as processing power, storage, and network connectivity [7]. We measure *reliability* and *performance* using items from [16, 17]. *Security* defines the practices, technologies, and policies that a CSP employs to restrict the access of resources and protect data, applications, and infrastructure from intruders [5, 8, 11]. The *security* feature allows to restrict the access of resources and helps in protecting the data from intruders. *Security* has been measured with scales from [16]. *Usability* is the ease with which users can interact with and use cloud-based services, applications, and resources [18]. The items of *usability* are adapted from [8]. *Reputation* – the perceived trustworthiness, reliability, and quality of a CSP [19] – is measured from [8, 16]. *Pricing* denotes the cost structure of cloud services, which typically include usage-based fees, subscription fees, or a combination of both [9]. Its items are adapted from several scales [8, 11, 17, 20]. *Service capability* is the vendor's ability to manage and deploy various tangible (e.g., physical IT infrastructure components, human IT resources) and intangible (e.g., knowledge assets, customer orientation) IT resources to provide the service [21, 22]. The items of *service capability* are taken from [19, 23]. Finally, *CSP selection* is measured with the items adapted from [24, 25]. All items, presented in appendix A [26].

The data for this study was gathered utilizing a convenient through an electronic survey, specifically targeting SMEs. Among the participants, the majority (68%) fell within the age bracket of 31 to 45 years, indicating a prominent presence of mid-career professionals. Following this, 25% of respondents were aged between 46 and 60, highlighting a seasoned demographic. A smaller portion of the participants (3.5%) were in the age range of 21 to 30, while an equivalent percentage represented individuals over 60 years old, representing a diverse age range. Around 66% of participants were affiliated with organizations with over 100 employees, signifying a preference for cloud adoption among more established enterprises. Within this spectrum, 12.5% were associated with organizations having 50 to 100 employees, indicating a moderate-sized segment. Additionally, 21.5% of respondents were connected to organizations with fewer than 50 employees, representing the small businesses. Various industry sectors were encompassed in the survey, including agriculture, consulting, education, healthcare, retail, food and beverages, manufacturing, construction, and property.

4 Application of fsQCA for CSP Selection

Before we proceed to the fsQCA procedure, we check the measurement properties of the variables. All items' loadings are higher than 0.6, and the internal consistency of all constructs (composite reliability and Cronbach's alpha) are higher than the acceptable level of 0.7 [27] (see Appendix A). In addition, the average variance extracted (AVE) for every variable is greater than 0.5. For discriminant validity, the Heterotrait–Monotrait ratio of correlations (HTMT) values of all constructs are significantly ($p < 0.05$) lower than the threshold of 0.85 [27].

4.1 Data Calibration

The fsQCA analysis was carried out using the software fsQCA 3.0 [28] from www.fsqca.com. We followed the guidelines from [e.g., 29, 30, 31]. During data calibration, to determine the degree of membership for each variable, three anchors are defined, denoting 'full membership' (fuzzy score = 0.95), 'full non-membership' (fuzzy score = 0.05), and the 'crossover point' (fuzzy score = 0.50) [32]. We rescaled the latent variable scores into fuzzy values (values between 0 and 1) [30]. It requires calibrating the standardized latent variable scores between -3 (i.e., full-set non-membership) and 3 (full-set membership), whereby 0 (zero) is the crossover point (intermediate-set membership) [30].

4.2 Assessment of the Necessary Conditions

"[A] necessary condition implies that the outcome of interest does not occur in the absence of the respective condition" [33, p. 4]. A condition is considered as "always almost necessary" if the consistency score exceeds the threshold level of 0.80 [14]. Based on this, statistically, three conditions namely *reliability, usability*, and *reputation* individually are found to be the necessary condition for selecting a CSP (see Table 1). It can be interpreted that a CSP is not selected without the presence of these factors. However, except *reputation*, the other two conditions are not present in every configuration for selecting a CSP and therefore are not considered as necessary conditions (see Table 2). Alternatively, no single variable comes out as a necessary condition for rejecting a CSP.

Table 1. The necessary conditions for selecting a CSP.

Condition	Selection of a CSP		Rejection of a CSP	
	Consistency	Coverage	Consistency	Coverage
Reliability	0.816	0.741	0.697	0.697
Performance	0.755	0.779	0.758	0.739
Security	0.773	0.791	0.730	0.706
Usability	0.833	0.844	0.708	0.678
Reputation	0.840	0.846	0.698	0.664
Pricing	0.784	0.802	0.735	0.710
Service Capability	0.786	0.809	0.743	0.723

4.3 Assessment of the Sufficient Conditions

We need to develop a truth table to identify the sufficient conditions. Analyzing the truth table, following Mattke, Maier [29, p. 560], we use "a raw consistency threshold of at least 0.75" and a proportional reduction in inconsistency (PRI) threshold higher than 0.50. Given the small sample size, we set the frequency threshold to 1. "[A] sufficient condition means that the outcome occurs whenever the respective condition is present" [33, p. 4]. All our consistency values are greater than 0.8 and the raw coverage values are above 0.2 [30], indicating significantly valid configurations for the outcome variables (i.e., SCSP). We present the diagrammatic representation of the sufficient solutions for modelling selecting and rejecting a CSP, as outlined in Table 2.

4.4 Findings and Discussion

Most of the studies dealing with CSP adoption mainly focus on the individual and main effects of various antecedents [7]; they have commonly applied symmetric and regression-based analysis methods (e.g., structural equation modeling). Regression-based models suggest that a predictor variable needs to be both necessary and sufficient to achieve the desired outcome. This is not plausible. Let us first discuss that an antecedent may be necessary but is rarely sufficient for predicting an outcome. Our study finds that *the reputation* of a CSP is a necessary condition for the selection of a CSP. However, *reputation* is not sufficient for selecting a CSP as it needs to be combined with either attribute e.g., reliability. Then, a sufficient condition may not necessarily be a necessary condition. For instance, according to C2, the presence of *performance*, *security*, and *reputation* are sufficient in explaining selection of a CSP; however, while *security* is absent, the selection of that CSP may still be high if *support capability* is high (C3). It suggests that *security* is not a necessary but a sufficient condition, which conventional regression-based models cannot explain.

Not only the technical attributes but also the operational attributes of CSP are considered while selecting or rejecting a CSP. In other words, selection, or rejection of a CSP is not dependent merely on technical or operational attributes of CSP but on their

Table 2. The sufficient conditions for selecting a CSP.

Conditions	Selecting a CSP			Rejecting a CSP		
	C1	C2	C3	~ C1	~ C2	~ C3
Reliability	●					⊗
Performance		●	●		⊗	⊗
Security			●			
Usability				⊗	⊗	
Reputation	●	●	●		⊗	
Pricing	⊗			●		●
Support Capability	●	●				
Raw Coverage	0.591	0.579	0.590	0.711	0.658	0.658
Unique Coverage	0.074	0.007	0.006	0.010	0.004	0.002
Consistency	0.931	0.921	0.911	0.918	0.956	0.919
Solution Coverage	0.722			0.879		
Solution Consistency	0.894			0.857		

Key: ● indicate the presence of a condition, ⊗ indicates its absence, and blank space refers to a "do not care" condition (i.e., either present or absent).

specific configurations. As such, this study contributes to providing specific guidelines for CSP selection process.

Our analysis finds three different combinations of attributes that are individually sufficient to select a CSP. By looking at these different configurations, a CSP can bundle the attributes differently for different users. Among these configurations (i.e., C1 – C3), C1 has the largest raw coverage and unique coverage as well as high consistency, meaning that it is empirically the most relevant and important configuration for selecting a CSP. C1 suggests combination of high *reliability* with high *reputation* and *support capability* with low *pricing*, where *performance*, *security*, and *usability* are 'do not care' conditions. C2 is the next statistically significant configuration that prescribes that if *performance*, *security*, and *reputation* of a CSP are high, users do not care if the other four attributes are present or not. This can be because reputation and security create a perception that overshadows the rest of the attributes. Finally, C3 suggests that CSPs should combine high *performance* and *security* with high *reputation*, where the other attributes do not matter. This is especially applicable for businesses that possess sensitive data.

We find three configurations (~C1 – ~ C3) that consistently can be responsible for rejecting a CSP. Configuration ~ C1 has the highest coverage, and hence is the most significant configuration explaining the rejection of a CSP. ~ C1 suggests that high *pricing* and low *usability* is sufficient for a user to reject a CSP, where the other attributes are not considered at all. Additionally, according to ~ C2, low *performance* and low *usability* along with low *reputation* of a CSP are sufficient for a user to reject a CSP where the presence or absence of the other attributes do not matter. This is a reminder for the CSP to improve the quality of their services. Complementary to ~ C1, our last configuration i.e., ~ C3 suggests that low *reliability* and low *performance* along with high *pricing* may lead to rejecting a CSP, where the presence or absence of the other technical or operation attributes do not make any difference. Similar to ~ C1, if the price is high, the likeliness of rejecting a CSP will be invariably high.

5 Implications and Limitation of the Study

There are several theoretical implications. *First*, the utilization of the configurational model in this study contributes to the evolving theory of decision-making in information systems (IS). It highlights the relevance of a configurational perspective in understanding complex decision processes, emphasizing the need to move beyond linear, single-factor models. *Second*, by showcasing the utility of the configurational model in the context of CSP selection, this study opens doors for the cross-domain application of configurational models in IS research. Researchers can explore the adaptability of these models in various decision-making scenarios beyond CSP selection, enriching the theoretical foundations of IS. These theoretical implications not only underscore the significance of our study within the IS literature but also encourage scholars to further investigate the complexities of decision-making processes and the configurational dynamics that underlie them. In doing so, we contribute to broader theoretical advancements in the field of IS.

Furthermore, there are also several practical contributions to this study. *First*, our study shows that the use of the configurational model can help facilitating the decision making to select as well as reject a CSP. This enables users to examine strengths and weaknesses of candidate CSP services and compare them with respect to appropriate conditions. *Second*, the findings of the study will immensely increase the quality of the CSP selection decision, especially the method we have suggested in this study will invariably add value to organizations, especially the CSP providers. Business users too can make informed decisions that will enable successful and suitable CSP selection for their respective organizations. The study informs managers that while reputation is important when selecting a CSP, there are other attributes that will influence the decision. In addition, researchers can use our methodical approach in other decision problems including selection of security service and data analytics providers.

Despite the implications, our study has several limitations. *First*, even though the sample size is suitable for fsQCA method, a larger sample may increase the validity of the findings. Also, longitudinal studies can be undertaken to assess the longevity and efficacy of CSP selections over time. *Second*, it is important to note that the choice between fsQCA and traditional MCDM methods should be based on the nature of the problem, the type of data available, and the specific research or decision-making context. In cases where problems are more quantifiable, traditional MCDM methods may remain more appropriate. Yet, researchers can extend the methodical approach developed in this study to address analogous decision challenges within the IS domain (e.g., selection of security service providers). *Third*, the data collection will be extended to include multiple industries that will improve the generalizability of the study findings. *Finally*, we agree the selection decision is a process; future studies may focus on the process of CSP selection decision.

Appendix A

The measures of the variables.

Attributes	Measures
Reliability CR: 0.70 AVE: 0.52	Most of the times, … 1…. [your provider] operates without failure 2…. [your provider] provides services at the promised time 3…. [your provider] fulfils the obligations to the contract 4…. The services of [your provider] are accurate/error-free
Performance CR: 0.93 AVE: 0.81	Most of the times, … 1…. The service response time of [your provider] is quick 2…. The performance of [your provider] is stable 3…. [your provider] meets most of the end-user requirements 4…. The services of [your provider] are available (e.g., no system crash)
Security CR: 0.89 AVE: 0.67	1. As far I know, [your provider] has anti-virus protection 2. As far I know, all data are encrypted in [your provider] 3. As far I know, [your provider] ensures data confidentiality 4. As far I know, [your provider] has secure data centers
Usability CR: 0.81 AVE: 0.53	1. [Your provider] has a simple user-interface for its contents 2. [Your provider] has a simple layout for its contents 3. The services of [your provider] are well organized 4. Overall, using the services of [your provider] is easy
Reputation CR: 0.89 AVE: 0.73	1. I believe that [your provider] has high brand value 2. When it comes to user problems, [your provider] shows a sincere interest in solving them 3. [Your provider] provides support that is tailored to individual needs 4. Overall, I believe that [your provider] has a good reputation
Pricing CR: 0.81 AVE: 0.51	1. The annual subscription cost of [your provider] is high 2. The acquisition cost (i.e., subscription cost) of [your provider] is high 3. The on-going cost of [your provider] is high 4. The financial charges [your provider] are high 5. The cost of using the service of [your provider] is significantly higher than buying and deploying relevant hardware and software by us 6. Overall, [your provider] is expensive
Service Capability CR: 0.89 AVE: 0.63	1. [Your provider] possesses a wealth of technical proficiency in delivering efficient cloud solutions 2. [Your provider] employs industry best practices, leveraging the latest advancements in cloud technology 3. [Your provider] consistently upgrades their capabilities to ensure they are well-equipped to address customers' dynamic demands of cloud computing 4. [Your provider] exhibits a strong command of cloud processes, enabling them to streamline deployment, management, and monitoring procedures 5. [Your provider] demonstrates a deep understanding of cloud architecture

(*continued*)

(*continued*)

Attributes	Measures
CSP Selection CR: 0.91 AVE: 0.77	1. We use cloud services from [your provider] in our business operations 2. Our business plans to continue to use cloud services from [your provider] 3. I will recommend [your provider] to others

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Lifestyle Applications Dimensions Priorities and Features – The Social, Mental and Dynamic Requirements

Ton Spil[1](✉), David Sundaram[2], and Jochem Groen[1]

[1] University of Twente, Enschede, The Netherlands
a.a.m.spil@utwente.nl
[2] University of Auckland, Auckland, New Zealand

Abstract. Obesity and diabetes are more common than ever. In particular, young adults aged 18–25 are becoming more susceptible to obesity through the abundance of fast food, the popularity of online gaming and other factors. This combination often leads to unhealthy lifestyles. For treatment or prevention of these unhealthy behaviors, lifestyle apps have shown to have big potential. Current lifestyle apps mainly focus on monitoring activity and eating patterns but keep a rather passive stance when it comes to changing users' behavior. Gamification could help greatly to actively change users' behavior and thus, encouraging healthy lifestyles. Some current lifestyle apps use gamification methods such as goals or sometimes even achievements to some extent. This motivates the user to change certain behaviors such as walking 5000 steps a day. Gamification has proven to be advantageous for changing user behavior, but gamification is broad and there is little to no research done on what sort of gamification works best. This research aims to fill that gap by researching the suitability of different gamification methods in lifestyle applications for users between 18–25. The research is done alongside plans for a lifestyle application against obesity and diabetes so the gamification methods will be evaluated according to these plans. Main requirements are fivefold: lifestyle apps have to be fun and personalized; the social and mental health side of lifestyle apps are not well represented; lifestyle apps are too static; and last but not least all interviewees state that that they have to be easy to use.

Keywords: Lifestyle · Gamification · Requirements

1 Introduction

The prevalence of obesity has continued to increase over the decades. Particularly, young adulthood between the ages of 18 and 35 is a vulnerable period for weight gain. As they entered adulthood, the average body mass index of the youngest generation was higher than that of the previous generation due to unhealthy eating habits. In this life stage, obesity can have a big impact on health [1].

Simple measures like a healthy diet or being physically active [2] are not enough to decrease the disease. To help people to deal with the obesity epidemic there are special

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lifestyle games (apps) developed, which has become possible thanks to the progress in the mobile technology industry [3, 4].

The importance and relevance of this study is supported by recent studies [2, 5, 6 , 7] that show that the problem of obesity, is well-known, but current measures of dealing with it [2, 8] are not very effective. Moreover, this problem has a direct impact on the current generation as they "are likely to have shorter life expectancies than their parents because of obesity" [6].

Gamification has become a popular mechanism to change users behavior. It uses game elements to stimulate and engage people to do something. Gamification can be used in many contexts and sectors, a well-known example being education. Using games or game elements to motivate students to learn is becoming a popular method in schools and universities.

The use of gamification in lifestyle apps to change behaviors can be of great value. Although many lifestyle apps already use minimal forms of gamification [9], the effectiveness of gamification in lifestyle apps has been shown undeniably [10].

This leads to the following research questions:

1. *What motivates people to play digital games and use lifestyle apps? In particular what general features and gamification features of lifestyle apps are important? – Literature Review (*Sect. 2*)*
2. *What are the dimensions and priorities in the design of lifestyle apps? – Interviews (*Sect. 3*)*
3. *How do we design lifestyle apps that supports these dimensions and priorities? – Proof of Concept Prototype (*Sect. 3*)*

To answer these question three systematic literature studies are performed and are presented in Sect. 2. Empirically we explored features in 93 interviews and created a prototype which is reported in Sect. 3. After that we analysed and validated the requirements of the prototype in 62 validation interviews in Sect. 4. Conclusions are drawn in Sect. 5.

2 Background from Three Perspectives

The method used for this research is systematic literature review, based on the guidelines discussed by Wolfwinkel et al. (2011) [11]. The database used for searching relevant literature is Scopus. This section discusses the steps that have been taken to answer the research question with regards to answering the first and third sub-questions. First, mobile game features that make people want to play them have been found. Then, all the necessary information from the medical requirements for the app has been gathered. Afterwards, the research made in the field of gamification in lifestyle apps has been reviewed. Finally, knowing the results of first three steps, the research question has been answered.

2.1 Features that Motivate Digital Gamers – Literature Review 1

A review of literature on what motivates digital gamers was conducted. Based on the search results, the most popular motivation to start playing a game, a mobile game in particular, is *entertainment/enjoyment* [12, 13, 14, 15, 16, 17]. All selected papers mention this concept. Then, five out of six papers mention *social* motivation [13, 14, 15, 16, 17]. Social is a broad term, it includes everything that is correlated with society, excluding the recommendations from friends or from media as there is a separate concept for this. Also, the nature of the game is important [12, 13, 14, 15, 17], five out of six articles mention it. Four out of six papers mention that *competition* and *reward/achievement* are also serious motivations. Finally, five out six papers have done their research on adults, which makes the results of this review even more applicable for the current study.

Table 1. Features that Motivate Digital Gamers – Literature Review 1 Concept Matrix.

	Çırak, N. S., & Erol, O. (2020, February 6). *What are the factors that affect the motivation of digital gamers?*	Nordby, K., Lokken, R. A., & Pfuhl, G. (2019, June 13). *Playing a video game is more than mere procrastination .*	Alha, K., Koskinen, E., Paavilainen, J., & Hamari, J. (2019, April 1). *Why do people play location-based augmented reality games: A study on Pokemon GO.*	Berkling, K., Faller, H., & Piertzik, M. (2017). *[PDF] Avoiding Failure in Modern Game Design with Academic Content - A Recipe, an Anti-Pattern and Applications Thereof*	Malik, A., Hiekkanen, K., Hussain, Z., Hamari, J., & Johri, A. (2020, November). *How players across gender and age experience Pokémon Go?*	Greenwood, J., Achterbosch, L., Meredith, G., & Vamplew, P. (2020). *Motivational Factors of Australian Mobile Gamers .*
skills development	x					
entertainment / enjoyment	x	x	x	x	x	x
challenging environment	x			x		x
competition	x	x		x		x
reward / achievement		x		x	x	x
social		x	x	x	x	x
break from stress		x				
escape reality		x				
break from everyday life		x				
curiousity			x			
reports (media/friends)			x		x	
physical activity			x		x	
previous experience	x		x		x	
popularity of a game			x		x	
technology			x		x	
nature of the game (shooter, puzzles, etc.)	x	x	x	x		x
immersion					x	x
nostalgia			x		x	
something to do			x			

2.2 Key Features of Lifestyle Apps – Literature Review 2

For the second literature study the query "lifestyle AND app* AND obes*(title)" was searched, and the search results Web of Science provides 23 articles results. After selecting literature related to the current research based on the abstract from the selected papers, 5 papers [18–22] were selected based on the full text, and a concept matrix was added for literature review. In summary, a total of five articles were selected in the definition-search-selection phase. A conceptual matrix for the literature review is presented in Table 2. According to the result of the generated matrix, the most useful functions used in lifestyle apps for people with weight problems, especially obesity, are 'physical activity tracker' and 'nutrition', in 5 out of 5 articles. The next most important features in the lifestyle app are "self-monitoring", "motivation", "stress management", "educational content (health advise)", "tracking dietary intake" and "health (interactive) communication" which mentioned in 3 out of 5 articles. Also, the third useful features is "diet recommendation" mentioned in 2 out of 5 articles. Especially, the features of "physical activity tracker" and "tracking dietary intake" means that your app cannot automatically fill in everything for you, and your app needs immediate input, such as the user's food eaten and their activity, in order to function properly.

Table 2. Key Features of Lifestyle Apps – Literature Review 2 Concept Matrix

Article/Concept	Chew, C. S. E. et al. (2021) [18]	Dehjan, Z et al. (2020) [19]	Dias, S. S et al. (2019) [20]	Antxon Apiñaniz, et al. (2019) [21]	Karduck, J., & Chapman-Novakofski, K. (2018) [22]
Self-monitoring	X		X		X
Motivation			X	X	X
Physical activity tracking	X	X	X	X	X
Recommended nutritional guidelines (nutrition)	X	X	X	X	X
Stress management		X	X		X
Educational contents (health adivse)		X		X	X
Reminder					X
Easy to use			X		
Tracking dietary intake	X			X	X
calorie counter					X
Health (interactive) communication	X	X	X		
Diet recommendation	X			X	
Weight tracker	X				
Sleep			X		

2.3 Gamification Features of Lifestyle Apps - Literature Review 3

Using the relevant articles, a review was conducted on gamification features present in lifestyle apps. A concept matrix was made as shown in Table 3. The occurrence of the gamification method "Penalties" was more than expected, however, multiple articles had a negative stance towards this method which does correspond with the initial expectations. Because the concept matrix only shows occurrence and not negative or positive attitude towards the gamification elements, this largely explains the deviation in the concept matrix. Daniel Johnson [10] found that rewards in the form of points and achievements lead to improvements in the desire to exercise. The trial of Pate [25] also used Points and levels to achieve step goals or weight targets but also feedback in the form of a leaderboard was used to encourage the participants. This showed that the use of competition and social interaction had a significant effect on the physical activity but only when used on a group of friends or family. This theory suggests that using gamification alone may not have significant effect but when combined with social interaction or other means of stimulation, it can be of great additional value. The prototype suggested by Heejin Chae [26] also contained gamification elements like competition And points that are used as virtual currency. This prototype also showed that without social interaction like a leaderboard or collaboration, motivation through gamification is hard to achieve.

Table 3. Gamification Features of Lifestyle Apps – Literature Review 3 Concept Matrix.

	Points and Levels	Badges /Achievements	Leaderboards	Goals/Quests	Penalties	Virtual Currency	Feedback
Johnson, D et al. (2016)	x				x		
Timpel, P. et al. (2018)	x		x	x			x
Patel, M. S. et al. (2021)		x		x	x		x
Chae, H. (2022)	x		x		x		x
Schulz, L. et al. (2020)	x		x		x		
Edwards, E. A. et al. (2016)	x		x	x	x	x	x
Checetti, P. et al. (2019	x	x	x		x		

3 Interviews and Proof of Concept Prototype

In order to answer the second empirical sub-question 94 interviews have been conducted. Each of the interviewee used a lifestyle app. In total 35 different apps were used. We first report on the 94 in total and then focus on 17 interviews that have been conducted regarding the Health app made by Apple. This app was selected because, first of all, this is one of the most used lifestyle apps, and, secondly, because it has a lot of features, which allows us to get more insights about their usefulness.

Table 4. Lifestyle apps use

Lifestyle app	Used by
Health Apple	17/94
Insurance app	10/94
Garmin	9/94
My fitness pal	8/94
Strava	8/94
Other	42/94

There were no special requirements for participants: they could be of any age (16–75), gender or nationality. The idea behind it is to get the broadest possible range of different people and opinions in order to select the most important features among the users as this particular app is intended for any iPhone user (Table 4).

Table 5. The most positively rated features of Apple users

Feature	Mentioned (positively)
Ease of use	17/17
Insights in goals, activities	15/17
Privacy	16/17
Social	13/17
Info could be used for diagnoses	12/17
Personal info may be shared with the app	12/17
Support	12/17

Table 5 shows the features of the app that at least 75% of the interviewees mentioned positively, making these concepts extremely important to consider when creating a future game. It is clear from this table that all interviewees rated high the ease of use, meaning the user-friendly interface as an example, and privacy, meaning that the level of trust to this particular app is high. 15 out of 17 interviewees rated positively the possibility of getting the insights in goals and activities, meaning among other the possibility to set these goals. 12 out of 17 interviewees said that they can share the personal info with the app, meaning, as how it was mentioned before, that the level of trust to this app is high. Finally, 12 out of 17 interviewees mentioned that they would not mind if their information from this app would be used for diagnoses, and that they are satisfied with the level of support provided by the app, both social and technical.

Based on the results we develop a model regarding the dimensions and priorities for lifestyle applications (Table 6). As can be seen physical activity and nutrition are reasonably well supported in terms of self monitoring and support by lifestyle applications. However social health and mental well-being are not well supported in terms of self-monitoring, support, and serious gamification.

Table 6. Priorities and dimensions for lifestyle applications

Priorities & Dimensions	Physical activity	Nutrition	Social health	Mental well-being
Self-monitoring	Well developed	Well developed	Need is high. But lack of features	Need is high. But lack of features
Support	Well developed	Reasonable	Need is high. But lack of features	Need is high. But lack of features
Serious gamification	Reasonable	Reasonable	Need is high. But lack of features	Need is high. But lack of features

To address the limitations and to also understand the dimensions a prototype was developed. Some of the screens from the prototype are illustrated in Figs. 1 and 2 highlighting the implementation of the priorities and dimensions of Table 6.

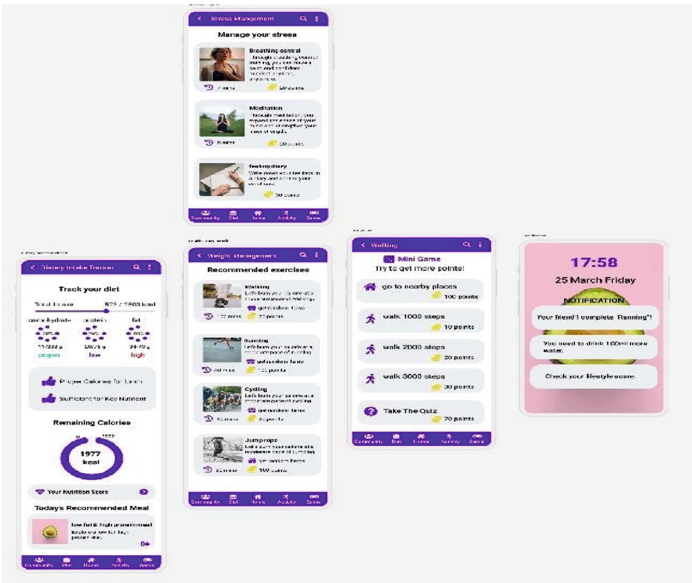

Fig. 1. Managing Stress, Diet, and Exercise

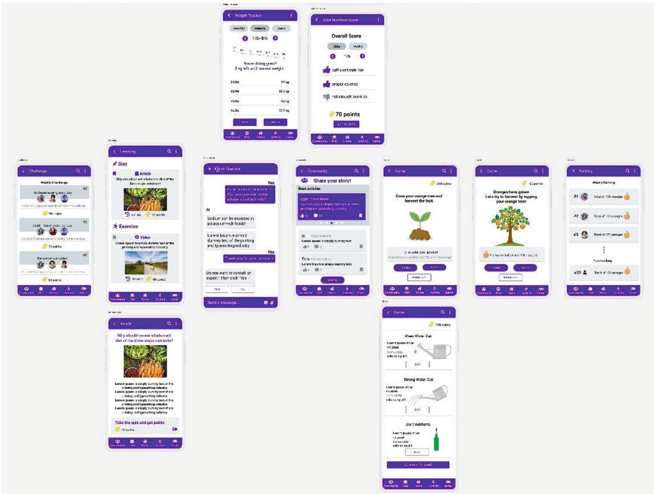

Fig. 2. Social Health and Mental Well Being Dimensions

4 Validation and Analysis

We performed three validation cycles, first a small survey (32 participants) on gamification to strengthen the third row in our model. Then we performed a usability survey (34 respondents) on the prototype and finally we performed 62 interviews on the requirement model with Table 6 as a basis. Results are given below.

This section will discuss the validation results in contrast to each other as well as providing an insight to the answers given to the open question at the end of the survey. While the main questions show that the methods: Goals & Quests and Positive feedback are likely to be most effective in a lifestyle app, the open question returns very diverse results that highly depend on personal preferences. While Goals & Quests are mentioned multiple times, Positive feedback is not mentioned. Many responses from the open question also suggest social interaction and leaderboards as most effective. While not showing a decisive result in the main question, Virtual currency is mentioned several times as their preferred method to stimulate them. Furthermore, most methods were widely known except for penalties which was a less known method but this is explainable because it is also a less popular method in the literature. To the question of which lifestyle apps the respondents used, Samsung health stood out particularly and Apple health was less used than expected. A possible explanation for this could be the financial situation because young adults might not be able to afford apple devices to use Apple Health. Strava, which is a tracking app for walking or running was also popular among the respondents, this app already uses a form of social interaction and comparison by the ability to show routes and other statistics. All in all, social interaction stands out as an answer to the open question. Social interaction is included in the method leaderboard. Also, different methods including social interaction are proposed. From the open question it becomes clear that a lifestyle app can be a great tool to stimulate user behavior, it is not the most effective way if it is not combined with social interaction.

This validation leads to the urge for more gamification within lifestyle apps as indicated by Edwards et al. [28] as well as other authors in Table 3.

We performed 34 prototype validations with a usability test of the prototype and came up with seven possible improvements: Home screen customization; AI chat bot; Challenges; Learning; Community; Notification and Activity. What stands out from the prototype validation is that personalization is needed and we have a lot of possibilities for gamification as mentioned in the first validation. Finally, it is clear from literature [19, 20] that physical activity is much better represented in the current lifestyle apps than social and mental health and that nutrition still needs a far better monitoring and gamification component which we can mainly see in the prototype validation.

Finally, 62 interviews were conducted on basis of Table 6. Next, we checked the interviewees on ease of use, user interface, privacy, money and time, fun, frequency and feedback and flow and habit. In all interviews ease of use was mentioned often in combination with ease of user interface and in combination with connection to hardware (smart watches and mobiles). This confirms work from Dias et al. [20] and is confirmed in practice in Table 5. Fun is considered very important, both in theory (see Table 1) as in practice where nearly all respondents see that as necessary. This is confirmed by literature study 1 in Table 1 where all papers state entertainment and/or enjoyment as most important features. From the 62 validation interviews we can see that the left upper corner of Table 6 is filled in best and the right under corner of Table 6 is filled in the worst. From this we draw our fourth conclusion in the next section.

5 Conclusions

Ease of Use is by far the most important condition for the success of a lifestyle application. Especially on the monitoring dimension there is need for automatic input. For physical activity this is already partly implemented but for nutrition, social and mental health this is still difficult.

The lifestyle application has to be personalized for each user. They should be able to choose on what subjects to monitor and in which pace. Different people need different kinds of support and need different kinds of gamification.

The current lifestyle applications are too static. The future lifestyle apps should be dynamic and constantly changing over time. A big effort is needed from the industry to create the mechanics and dynamics to accommodate that.

There is too much focus on physical activity and nutrition in the current lifestyle apps. There is need for more social and mental support because there lay the causes of obesity, diabetes, heart disease and other chronic diseases.

Finally, we conclude that fun is very important to be included in the lifestyle app. Be sure to notice that fun can mean enjoyment and interest so it does not necessarily has to be funny. Future work has to be done on frequency in combination with the formation of good habits. Only with repetition and fun, habits seem to be able to change.

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Author Index

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