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Transfer, Diffusion and Adoption of Next-Generation Digital Technologies

IFIP WG 8.6 International Working Conference on Transfer and Diffusion of IT, TDIT 2023
Nagpur, India, December 15–16, 2023
Proceedings, Part II

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Editors

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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

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[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
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Academia and Generative Artificial Intelligence (GenAI) SWOT Analysis - Higher Education Policy Implications

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Abstract. ChatGPT - it's the buzzword of the moment in Higher Education with both academics and students discussing this Generative AI tool. The reality, however, is that many do not truly understand it or, at this point, have not been equipped with the skills to use it as an effective tool in the workplace. HE is having to grapple with the widespread use and probable misuse of ChatGPT by students and re-think their business model moving forward to protect the quality and standards of university degrees. Exploration of the challenges and opportunities faced by GenAI within Academia is thus critical at this current point in time. This research paper aims to address this by capturing insight from HE stakeholders (academics, students and educational managers). Challenges as well as opportunities are explored whilst considering the implications this GenAI has on policy and assessment with future direction of potential research considered, in this rapidly evolving arena.

Keywords: Generative AI · Educational Management · Policy

1 Introduction

Higher education is facing an existential crisis due to the recent explosion of Generative Artificial Intelligence (GenAI) especially since the launch of ChatGPT. In fact, Reuters [1] has stated that ChatGPT is the "fastest-growing consumer application in history", with Duarte [2] stating records have been broken with over 100 million active users between April and June 2023. Its appeal lies in its ability to use natural language to give human-like responses that can be harnessed by educational stakeholders [3]. ChatGPT is a chatbot based on the Generative Pre-training Transformer (GPT) architecture and is OpenAI's large language model (LLM). Alongside ChatGPT there are other LLM chatbots such as Google's Bard that is based on LaMDA (Language Model for Dialogue Applications) and Microsoft's Bing that utilises GPT-4 technology [4].

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The impact of this new form of AI technology is significant. The research by Salvagno et al. [5] discusses, Generative AI "should not be used as a replacement for human judgment" as its output is not always factually correct, something known as hallucinatory output even when appearing to be highly believable. Awareness of this is critical, especially in the education sector as it has implications for pedagogy, research and management. Many in the education sector are interacting with this technology due to its low cost of entry and human-like conversational style. All of which is being optimized and refined using Reinforcement Learning with Human Feedback (RLHF). GenAI is starting to become embedded within the HE daily working routine for educational management and administrators, academics, and students. This can be seen with GenAI workspaces being created with the likes of Microsoft's Copilot that will integrate ChatGPT and DALL-E into Microsoft 365 suite of apps, something that has the potential to transform how users use these software packages, such as PowerPoint, Outlook, Microsoft Teams and OneNote in innovative and advanced ways [6]. All these evolving AI initiatives will require the education sector to keep up to speed with the most recent developments to mitigate risk and identify opportunities. It is thus the purpose of this paper to analyze and assess the complexities and intricacies of GenAI into a meaningful narrative for the Higher Education (HE) sector to inform HE AI policies. To achieve this, it is essential to explore and understand HE stakeholders' perspectives when it comes to GenAI and its adoption within the educational setting that they work or study in. Thus, the following research question (RQ) have been formulated:

RQ1: What do HE academics and students think are the strengths, weaknesses, opportunities and threats of generative AI for them?

RQ2: How can the AI policies of HE institutions be informed by the guidelines from HE quality assurance agencies as well as aligning with the needs of HE stakeholders?

The next section of this paper will address the disruptive impact of GenAI within HE (from three different perspectives, those of academics, students and, educational management and administrators). Educational managers, for the purpose of this paper, are those that give direction to and have oversight of systems within educational institutions [7] coupled with those that could be considered as leaders who influence those within a HE institution. A SWOT Analysis of GenAI on the HE Sector will then be explored to feed into HE AI policy frameworks before addressing future research direction and conclusions.

2 Disruptive Impact of Generative AI within Higher Education

During the initial panic phase [8] created by the adoption of GenAI (when it comes to fear of new technological innovations) for the education sector, a number of top universities in the UK decided to ban the use of GenAI [9]. The sector has now progressed from this initial reaction and has reflected more on how to integrate GenAI in more practical and realistic ways whilst mitigating any academic misconduct issues due to its misuse [3]. When considering impact, Dwivedi et al. [3] pointed out, "learning happens everywhere, it doesn't happen only in class" which is important when also thinking about inclusivity and the varying learning styles of HE students. Ethical issues must also be considered, particularly for researchers and the use of data when engaging with GenAI tools. This section will now consider the many varied issues of GenAI from the perspective of three key HE stakeholders: educational management and administrators, academics, and students.

Educational Management and Administrators – Mindful management of student learning is the focus of any effective management educator within HE who must do this in cooperative and transparent ways. This ensures institutional goals are met in efficient and effective ways. Strategic thinking, planning, implementation and oversight of quality educational programmes requires much collaboration and teamwork to ensure standards are met and maintained [10]. In the AI age these programmes require well thought out pedagogical approaches, learning outcomes and assessments that maintain the expected rigor and standards demanded by HE institutions in ways that limit the negative consequences of AI whilst harnessing the technological opportunities [11].

Ratten & Jones [12] discuss the following five key steps educational managers can take to incorporate and manage GenAI: "modify assessment" (potentially through the use of real world case scenarios), "incorporating AI" (into a learning and teaching environment), "anticipating ChatGPT dilemmas" (through contextualized learning activities), "integrating new educational technology" (to benefit students) and "reducing uncertainty about ChatGPT" (through open discussions). It is vital that academics are not left to their own devices to figure some of these things out. Thus, educational managers need to be responsible to work collaboratively with academics to drive any AI initiatives in a collegiate and supportive way. Educational managers may choose to harness technology to overcome many of the challenges that disruptive GenAI technology is creating for the education sector. However, some suggest shifting to in-person exams [13] or using creative writing assignments [14] to address the issues around AI misuse. Yet others point out the drawbacks to handwritten assignments which are considered to be less effective as an assessment tool [15]. Whatever is decided by educational managers, assessments that truly test a student's knowledge in "realistic situations" is important [16] as this motivates students who appreciate the meaningful application of authentic assessments [17]. These decisions should be shaped after understanding the perspectives of academics and students alike, something that is- explored in this paper.

Librarians should not be forgotten about here as they are important administrators and specialists when it comes to managing the information that is stored both physically and virtually whilst also supporting students in how to find and use this information whilst studying in their institution. It is thus critical that any AI strategy considers an AI library strategy in their discussions. Cox [18] explored this element with important library strategists (such as the Head of Digital Research at the British Library, the Head of Edtech at Jisc and librarians, chief knowledge operators and relevant CEOs) in an article titled "Library strategy and Artificial Intelligence". Cox found that these strategists have already been developing chatbot, text and data mining services and they stressed the importance of making sure that users are AI and data literate through training. Some concerns that emerged from this article was around ethics, inclusivity and accountability and ensuring that decisions and strategy in this area is based on evidence whilst taking a critical and reflective approach to this to minimize any bias in the process. These experts also pointed out that AI was not being included in library strategies in academic institutions and that it is critical to include all members of staff that work within an institution's library in any upskilling and ongoing CPD training in this area. One suggestion that came up by these library strategists was for a Community of Practice to facilitate collaboration within a HE institution.

Academics - Academics do their best to encourage and guide students to develop critical thinking. This equips students with problem solving skills that can be applied to solve real world scenarios, an essential employability skill. This could be jeopardized with recent AI developments with O'Connor [19] suggesting that this ability could be hindered due to the misuse of ChatGPT by students. However, Hapsari & Wu [20] point out that AI tools could actually help "foster critical thinking" in students whose English is not their first language as these tools help support these students who may feel anxious about speaking in class whilst also facilitating language learning and understanding for these particular students.

Research is also another important area for HE academics, be it their own personal research/project, supervision of PhD or master's students. Academics should thus be aware how LLMs can help them with their research and writing tasks but also how the students they are supervising could benefit too, especially to assist in problem solving and critical thinking [21] Nonetheless, the use of ChatGPT or other GenAI tools calls into question the scientific and academic rigor of research studies that lean on AI tools such as chatbots to write content, with ethical issues of this being discussed by the likes of Lucy & Dowling [22]. There are also concerns about the privacy of content shared with ChatGPT when writing prompts, this is particularly true if inputting sensitive participant or clinical trial data of any sort into this chatbot as we do not know how secure an AI platform is and researchers could easily breach GDPR, ethical and other data security rules and regulations [23]. It is therefore imperative that HE institutions mitigate such risks through policy and internal ethics regulations.

AI tools like ChatGPT could be harnessed by academics to decrease their workload, to be more innovative and creative within a learning and teaching (L&T) environment and, to gather student insights [24]. Mobilizing AI to support academics in their "report writing, project management, decision making" along with "lesson planning", "research and writing", "assessment and evaluation" along with automation of grading and standardizing student feedback could free academics up to add further individualized feedback to students [21]. Exploring an academics perspective on all this is essential and is what this research paper explores later.

Students – Digital equity is a good place to start when considering GenAI and student use. It is only fair that all students are given equal opportunities when it comes to learning and assessment regardless of their background and socioeconomic status [3]. According to Frąckiewicz [25], ChatGPT is bridging this digital divide whilst at the same time promoting inclusivity as it facilitates better access to resources and information, which is particularly true for those in developing countries that may not be able to afford and access formal education. Frąckiewicz [25] goes onto discuss the use of ChatGPT by people with disabilities, helping some of them to communicate more effectively and reducing miscommunication issues in the process. This is something that Hapsari & Wu [20] also discuss where AI tools have been shown to "alleviate speaking anxiety". Thus, students with learning difficulties in general could potentially harness these easy-to-use chatbots to support their learning and social difficulties in a very personalized way. For these students, this could potentially increase confidence through more independence and adequate and timely support that can be accessed 24–7.

Attewell [26] consulted with HE students on the role of GenAI for assessments and found that whilst students have a positive attitude towards GenAI integrated into assessments within he, they also felt strongly that any assessment should be based on "their own work". Attewell's study further found that the students they talked to felt AI tools like Grammarly should be allowed to assist students but that any GenAI type assessments should only account for 10% of their marks with transparent citations being attributed to the AI tools that have been used. Furthermore, students told Attewell that cheaters would always find ways around any AI detection tools and that there was no real clarity/guidance for students in the area of AI and academic integrity. When it came to these students' perspectives on academics using AI marking tools for assignments, some felt this should be limited to particular assessments (such as short assignments, quizzes of multi-choice questions) to decrease marker bias and increase marking transparency. That said there were also students in this study who doubted the reliability of AI marking tools which they felt lacked the ability to evaluate their work, especially with respect to creativity and/or nuances they had expressed in their work. These findings on AI tools for marking was also backed up by a study by Guy & Thomas [27] who found students really wanted and needed clarity on how they can use AI tools to help them with their assessments in a way that maintains academic rigor and fairness.

3 Methodology

In order to understand and ascertain the thoughts and feelings of participants a qualitative data gathering initiative was carried out for this research paper. Interviews were conducted to capture the varying perspectives of HE stakeholders. Academics (which included lecturers, researchers and those holding management positions) and students (from all levels – undergraduate, postgraduate taught and postgraduate researchers) were interviewed. A total of 29 interviews were carried out (with 15 academics and 14 students) and analyzed to assess what these participants of this study felt were the strengths, weaknesses, opportunities and threats of GenAI on the HE sector. The interview transcripts were further analyzed to capture academics' and students' thoughts on AI policy for HE institutions.

4 SWOT Analysis of GenAI on the HE Sector

Being aware of the opportunities and threats posed by GenAI on the education sector is critical, together with the utilization of the strengths of GenAI and mitigating any weaknesses is critical for those in HE. Thus, to address **RQ1**, this paper has thus captured some of the key areas around a GenAI SWOT analysis in Figs. 1 and 2 for policy makers and educators to draw upon in this fast-moving digital world. The SWOT analysis captures what HE stakeholders voiced when it comes to GenAI and HE. Figure 1 captures an academics perspective on what they consider to be the key strengths, weaknesses, opportunities, and threats from GenAI in HE (some of the academics interviewed also oversee educational management matters).

STRENGHTS
Saves users time when earching for information or putting together content – "*Because one of the things that I found which at ChatGPT in particular is the fact that it's pretty good at giving you generalized answers.*
No training required - *"it is pretty intuitive" and "an easily accessible tool"*
Large data sets used that can be searched quickly and easily by researchers - "*it would make me more efficient as a researcher"*
It can be useful to create content, analyse data and bounce ideas off - *"And you can use ChatGPT to analyse this conversation"*
WEAKNESSES
Hallucination of ChatGPT output giving false information - "*ChatGPT fabricates content"*
Can give general output that lacks the academic depth and scientific rigour required by academia - *"It is not reliable".*
Limited by its training data (this can be particularly problematic if some training data was AI created) - *"I question the integrity and value of its output."*
Limited and restricted accessibility - *"In my experience it's also quite difficult to access."*
Security and privacy of data is a concern, particularly when dealing with sensitive, personal, clinical or other research data – "*So I would never want to put anything specific into it say like patient data or company data"*
Uncertainty in terms of originality - *"Can you consider Chat GPT as an author? Or can you attribute it to that when it's coming from different data sources?"*
Limited independence - *"it's being controlled by profit-making organisations."*
In-built bias within the system - *"ChatGPT is mainly based on literature written in English"*
OPPORTUNITIES
Could assess work with alignment of marking rubrics (saving time and creating consistent feedback*)* - *"we can possibly use this like to mark students' assignments"*
Upskilling in terms of AI literacy – "*It's something that I need to understand better"*
Creating internal AI tools – "*because you could make a live FAQ tool that direct students to exactly what they need"*
Drives technology in HE - *"it just means that we may be becoming more sort of technology based, which is a good thing. Higher education needs to evolve"*
Opportunity for education to develop - *"It has a really positive impact, because it forces to take a more critical look at technology generally and take a more kind of serious review of what we could set out education to be"*
Widening access to information and education - *"I mean those people from like rural areas. And just not helps the money to pay for the higher education."*
Simplifying tasks - "Make workflows a bit more streamlined for tasks that just might be simple*"*
THREATS
HE institutions cannot keep up with AI development – "*And I also think that education, on the whole is a sector that doesn't develop that quickly"*
Jobs could get lost - *"it could be some job of could be taken away by ChatGPT"*
Misuse of GenAI could create false information/data and skew academic research - *"we are no longer the sole proprietors of human originality"*
Student academic misconduct could go undetected - *"plagiarism is difficult to deal with and proving it was ChatGPT is going to be even harder"*
Students lack academic skills upon graduation – "*the issue with that is that students don't necessarily know that they're using it"*
Students are more AI literate than academics – "*I haven't really had the time to explore it."*
Digital divide consequences within the student cohort exacerbated with unequal use of GenAI tools *"widening the divide because you've got Chat GPT for where you have to pay for it"*
Security risk in terms of data protection - *"So I would never want to put anything specific into it say like patient data or company data"*
Devalues the role of academics - "*what is the value of a knowledge worker if you can just get a generative AI to do it."*
Disrupting learning - *"If a student is just putting the content into Chat GPT, they're not really learning anything because they're not writing it."*
Uncertainty of the future of education and the value of a degree – *"what is a degree for?"*, *"It just makes more and more of a mockery of higher education"*

Fig. 1. SWOT Analysis for GenAI and Academia – Academics' Perspectives

Figure 2 is a SWOT analysis from a student's perspective when it comes to GenAI and the HE sector. With the digital world potentially on the cusp of revolutionizing the education sector as we know it, interviewees identified many potential opportunities to illustrate what HE stakeholders think GenAI can bring to the academic sector at this time. However, one needs to be mindful of the output of GenAI content along with any potential bias it may have [3], as one academic put it, "academics generally, we have better evaluation skills" to verify GenAI output. Also, students voiced the use of ChatGPT where English is not their first language, with one student stating "*as a third language Speaker of English it's not very easy sometimes to articulate stuff and ChatGPT helps me.*" Another benefit students are finding is that around learning disabilities, this was expressed by a student who said, "I*t helps me as I have ADHD,*" "*it helps me (with ADHD) as it brings a lot of structure.*" When it comes to the use of LLMs like ChatGPT, the education sector needs to be ever mindful that the training data of this GenAI is not fully understood by its users. As one academic said, "*I am also concerned that at the moment ChatGPT is mainly based on literature written in English*". Ultimately, this will lead to potential bias in its output. Educators thus need to mitigate any ethical issues and consider how the use of the likes of ChatGPT can be done so in a responsible way whilst fact and sense checking any GenAI output (something that can only really be done by trained humans in the field in question).

The interview data captured in the two SWOT analysis above, confirms the findings by Guy & Thomson [27] that students are embracing AI without "*waiting to be told what to do*". They found that students are eager to use AI tools that they feel will be a part of the workplace when they graduate, with some students setting up their own AI powered start-ups. Something that was voiced by academics and students during interviews is the threat to HE due to the misuse of ChatGPT by students that may not be down to their initial intention but rather because of the time pressures they may face during their course. This could be a particular issue where there's bulking of assessments causing students to feel the pressure and to become stressed and overwhelmed during their course [27]. Therefore, it's not just about mindful assessments that academics and educational managers have to think about but also how to spread the assessment load for students so that they have every opportunity and space to develop critical thinking skills. As one academic stated, "*we need our students to be problems solvers and to always be critical thinkers*" and to be able to analyze content and make sense of those conceptual linkages that academics are teaching them on their modules. However, academic standards, integrity and rigor must be protected first and foremost.

Regardless of which stakeholder is using GenAI tools (academics, students, educational managers and administrators), they all need time to explore and play around with this technology to be able to truly understand it and get to grips with how to use it effectively. So, the question has to be asked by HE institutions, if adequate flexibility and resources are being built into the working environment for academics and educational managers (as one academic stated, "*I haven't really had the time to explore it*") to become AI literate. If this is not prioritized as a matter of urgency (and this will have to be an ongoing strategy to keep up with the rapid and continuous developments that we are witnessing with this technology) then the reality will be that students who typically have more time on their hands will take the opportunity to experiment and explore how

Strengths

Useful tool to support learning and studying – *"use it to help you bring together ideas*", "use it to get references or trying to find different sources", *"use it to correct errors, and spelling", "use it to proof-read", "I've used it to explain a lot of this stuff to me"*

Learning support for international students – "*it could act as a learning support for students with learning difficulties or where English is not their first language"*

Learning support for students with additional needs – *"it helps me (with ADHD) as it brings a lot of structure"*

Improve efficiency in research – *"it would make me more efficient as a researcher as a Phd student."*

Removes barriers – *"you're able to ask it anything and it will give you an answer."*

Provides reassurance – *"It is useful particularly for me with autism and how I am and how I operate mentally.", It's definitely a help to kind of someone who kind of overthinks and stuff due to autism."*

Manifests learning – *"I will ask it a question and see whether I'm on the right track whether I've understood what I've meant to do."*

Supports brainstorming and to get started – *"it's a good platform to learn and get ideas", "*structure your assignment"

Constant and immediate support – "*I can instantly ask it. How can I solve this problem"*

High credibility of output – *"generally ChatGPT answers are quite accurate and very detailed and impressive", "It's very ethical", "It's very sensible"*

Weaknesses

Low quality of output – *"if you're asking it a question about a certain theory, it may actually be a bit invalid", "it tends to make up references", "but sometimes, like the answers are not accurate", "ChatGPT can go wrong"*

Low credibility of output – *"It doesn't provide any evidence for it. So you never really know if it's true."*

Opportunities

Improve diversity and inclusivity – *"perhaps it would be able to help students that have got learning difficulties by translating a piece of written text into a medium that makes it more understandable for example."*

Improve communication and administration – *"maybe to use in the classroom for more communication"*

Learn AI skills – *"if lectures could provide that support on how to use ChatGPT that would be very helpful."*

Prepare students for the modern workplace – *"as long as lectures and universities can help students progress with AI using it as collaboration I feel like those people are gonna be much more competitive in the real world."*

Provide more individual support – *"maybe it could be used in the classroom to support learning"*

Streamline learning processes – *"I think it would sort of automate a lot of processes and make the learning process a lot faster and easier for students."*

Development of HE - "*I think they could just bring it [education] to another level", "It's going to lead the entire Higher Education"*

Threats

Undermine the purpose HE – *"I would say that the large proportion of the use of AI at the moment, especially within a higher education context, is to use it to kind of cheat and, you know, undermine the system of academia"*

Access to HE – *"you could get to a point where students get into university when they should never have got into university"*

Unfair processes – *"I think it's just being used on a mass scale to try and yeah cheat and undermine the systems and the assignments that we've got in place and assessments in the university"*

Academic integrity - *"it is concerning really, you know, from an integrity perspective"*

Institutions could destroy themselves long term, I think, by not regulating assignments properly

Value of HE - *"Is there an actual value to a degree? Now.", "T*he value of the lectures becomes quite distorted if they use ChatGPT to generate lecture content."

Prevents learning – *"for a lot of students there is no learning, because they just asked the AI to generate the answer", "some students are literally just cut copy paste", "I have a very big fear that if students go through college with so much assistance where they are misusing generative AI, they won't learn.", "It's kind of being used as a substitute for not having to do the work"*

Limited employability – *"at the end of the day you have to go to workplace and work, and if you have not been able to learn", "work quality probably won't be the same"*

Encourages unfair practice – *"I know that a lot of people who are using it to cheat"*

Skill development – *"So for me, it's not so much about the content that it produces. It's kind of the skills behind it that then students are going to lack in the future.",* you're not learning any skills other

Fig. 2. SWOT Analysis for GenAI and Academia – Students' Perspectives

than using AI", I don't think it presents an accurate representation of what students are capable of if they mark the based on what AI is created rather than what they have done
Limits creativity – *"Is it already frames the conversation in a certain way."*
Personality development* - "How can that be used to help the students to develop themselves?"*
Jobs could get lost – *"It could end up losing people jobs in the end."*
"Hmm, surprisingly, it means to really devaluing your education"
"It could destroy academia or Higher education."

Fig. 2. (*continued*)

to use GenAI more than the academics can. This scenario could potentially lead to a situation where students are more skilled and literate in this area than academics (who should be teaching the students these essential school skills on how to use these AI tools mindfully). Furthermore, when thinking ahead, it is important to understand the thoughts, feelings and attitudes of the HE stakeholders when it comes to the adoption of GenAI tools so that this technology can be harnessed for the good, rather than being misused by students (and potentially staff too).

It is clear however that the critical question for the HE sector at this juncture is how to ensure degrees remain worth something through thoughtful AI policies and guidelines that are clear for all relevant stakeholders. As one student said, "*is there an actual value to a degree now*?" A report written by the Quality Assurance Agency for Higher Education discusses this in some detail and highlight "the need for agility" by the sector so that standards and quality are protected and that those within the sector are able to be responsive to this rapidly evolving technology [28]. It is with this in mind that the next section explores some of the key policy, framework and guidelines being discussed by policy makers and influencers in the education sector.

5 Policy Frameworks within Higher Education

The broad guidance and findings that are discussed in this section to address **RQ2**, will need to be interpreted and implemented in alignment with the needs and practices of the HE institution. Miao et al. [29] discuss that the UN Development Goal 4 considers education a basic human right that should drive forward an agenda of "inclusive and equitable quality education" whilst acknowledging the opportunities and threats AI has with its connection with education. These authors (one of whom is UNESCO), focus on addressing the rapid development in AI used within the education sector by stressing the importance on policy makers to "be guided by the core principles of inclusion and equity" including access to AI technology. It is clear that HE has to protect and maintain academic standards, be that in a learning and teaching environment, research led work or, student assessment and use of GenAI tools. Especially considering it is easier for the general public to create AI-generated content which can be considered both an opportunity and a threat to those within the education sector [30]. From a research perspective, academically used databases are quickly moving toward AI powered interfaces [31]. However, Van Noorden [31] points out that as LLMs can hallucinate and create false references, Elsevier have chosen to overcome this by constraining Scopus AI to give its response based on five to ten paper abstracts only.

The following discussion now looks at policy and frameworks mainly from those who advise on quality and standards from a UK HE perspective. Clear policy and frameworks come into play to maintain academic integrity and to ensure that the value of a degree or academic qualification is actually worth something in the workplace. It is thus important to adjust learning, teaching and assessment strategies to take account of GenAI, something that is discussed by the Quality Assurance Agency (QAA) for Higher Education [28]. They suggest that L&T strategies as well as future assessments are developed in a collaborative manner, this could be with module coordinators, heads of learning and teaching, teaching teams in general, programme teams and examiners with follow-up sessions to share ideas and assess best practice that then feeds into informing policies and guidelines. QAA also stress the importance of taking on board student feedback in this process, particularly during annual programme and module reviews.

A different briefing paper by QAA in this area is "The rise of artificial intelligence software and potential risks for academic integrity: A QAA briefing paper for higher education providers" [32]. This briefing paper discusses maintaining academic standards through assessment, policy and frameworks. The authors set out critical frameworks and guidelines for HE institutions to implement in three key areas. Firstly, engaging students to ensure that they understand how to use GenAI tools effectively and understand the technology's limitations. This covers students' misuse of AI tools and the subsequent serious consequences on their learning, qualifications and employability skills. Secondly, utilizing effective student declarations that outline academic integrity such as appropriate referencing and acknowledgment of AI tools is imperative. Finally, updating current policies, practices and assessments that reflect the presence of GenAI and not relying on AI detectors (as this is a grey area at this present point in time with QAA cautioning against the use of these detectors due to privacy concerns).

Advance HE recently wrote about the governance of AI within HE by capturing the perspectives of different university "governors" and they suggest that there are three critical areas that institutions must look at, namely "internal systems", "how they teach" and "what they teach" [33]. They suggest that institutions must first decide how they will utilize AI for their everyday business to support staff and reduce workloads (for example to generate reports, create marking content, edit work before being finalized by a human, clean data and provide analytics and, to assist with certain recruitment tasks). Advance HE then go on to discuss AI tools within a learning and teaching environment to create more personalized learning that is better able to address the needs of individual students. They point out however that both staff and students will need to be digitally capable of achieving this and that there will be inevitable resource implications that will need to be dealt with and factored into any HE strategies in this area. With regards to ChatGPT and academic misconduct issues around assessments, one governor stressed that they were already carrying out "authentic assessments" at their institution and so, it may just be, that if this is the case in other institutions then the negative impact of ChatGPT in this area may well be quickly and easily mitigated. That said, maybe some schools/departments are doing this better than others with an institution and so that would be an opportunity to share best practice internally for the benefit of the institution and student outcomes.

The emphasis of all of this is on engaging and empowering academics, educational managers, administrators, professional service staff, and students through policies, guidelines, training and support to ensure that they are AI literate, a commitment that 24 Vice Chancellors from Russel Group Universities have endorsed through five key principles [34]. These cover ongoing staff and student support on the use of GenAI and its use in an academic setting, working towards equal access of these AI tools and, ethical use of these tools by ensuring that academic integrity and standards are enforced. These Russell Group universities also acknowledged the need to work in a collaborative manner to keep up with the evolution of this technology and to ensure the sector evolves with it. Part of this would be to ensure cyber security standards and judgement are constantly assessed for any risk to mitigate data protection issues when using GenAI tools [30].

Regardless of the AI policy that HE institutions adopt, the implementation and oversight of them is critical. To address this, Chan [35] suggests implementing a three-dimensional framework. The first dimension being "Governance" whereby senior managers are responsible for the governance and oversight of AI and ensuring equitable access to their stakeholders. Secondly there is the "Pedagogical" dimension where the academics need to think about their assessments to account for AI technology and its developments. Supporting students in their learning environment to be mindful users of AI tools to equip them with relevant employability skills. Thirdly there is the "Operational" dimension which should be addressed by IT staff to support both the learning and teaching side of operations. Ongoing monitoring of AI implementation and AI developments is critical, as is adequate training and support for HE stakeholders. It is thus clear that this is a complex and dynamic area that will require internal and external collaboration to be able to adequately respond to GenAI such that it is harnessed for the benefit of all stakeholders within the HE sector.

To complement the research on AI policy from a previous paper [36] and the above presented guidance of well-known UK HE agencies, a further analysis of the interview data was conducted and three main themes identified: both groups (academics as well as students) stressed the need for specific guidelines on the use of GenAI in teaching and assessments as their main concern through quotes such as *"A framework would be really good to have say the do's and don'ts"*. Additionally, they clearly indicated what the content of such policies should be such as *"having a clearly defined scope for its usage"*. However, it also emerged that academics as well as students are aware that the pure provision of AI policies is not sufficient to ensure an effective, fair and positive GenAI usage: *"I just think it's quite difficult to control it, because everyone has access to it"*.

6 Future Research Direction

The SWOT analysis with HE stakeholders in the area of GenAI for this sector, has produced some important findings for the sector by understanding viewpoints and barriers to adoption. This has also fed into AI policy and considering fair and equitable access to technology with unseen barriers in the way. To build on this, a quantitative data collection phase could be conducted using a widespread survey considered through the lens of GenAI adoption within this sector, using Unified Theory of Acceptance and Use of

Technology (UTAUT) [37] as a base for this quantitative research element. It is from this base that the HE sector can use the findings of this research to implement meaningful AI policies and guidelines and harness GenAI for innovative education that inspires and enthuses the next generation of students coming through the system.

7 Conclusions

This paper discusses in detail the complexities that the rapid evolution of GenAI is having on the HE sector. All acknowledge that there will be challenges for education in the light of this new technology, but there are also many new opportunities that have now come to light, one being the potential for re-shaping the delivery of learning using AI tools with the possibility for personalized and innovative learning environments and assessments. Consideration will need to be given by policy makers and implementers to harness the many strengths and opportunities for education, with the key one being to ensure fair and equitable use by students and making sure that students graduate with the key AI employability skills they will need in the future workplace. This will have to be coupled with the development of mindful and authentic assessments to ensure that the value of HE degrees remains intact and worth something to both students and employers. Finally, adequate resources will need to be built into any strategy to upskill both staff and students so that all are AI literate and that as a business, HE institutions make the most of the benefits AI tools have on offer.

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Factors Affecting Chatbot Resistance to Gain Knowledge About Family Planning Among Arab Women: A Conceptual Paper

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Abstract. Unplanned pregnancies are a serious public health concern in both developed and developing countries. In many developing countries, such as Arab countries, discussing family planning is surrounded by different barriers such as social and cultural stereotypes, and limited access to information. Chatbots provide women with the opportunity to learn about family planning while overcoming issues such as privacy and stereotypes. Although Chatbots have many benefits for Arab women in the family planning domain little research is conducted to study factors affecting women's adoption of chatbots to learn about their family planning options or factors affecting them resisting adoption of this technology. Hence, this conceptual paper comes to focus on factors that might lead women in Arab communities to resist adopting chatbots to learn about family planning options regardless of their benefits. The proposed propositions in this paper are based on the Innovation resistance theory (IRT).

Keywords: Chatbot · Innovation resistance theory (IRT) · Arab women · family health planning

1 Introduction

Unplanned pregnancies are a serious public health concern in both developed and developing countries due to their negative effects on social and health outcomes for moms and children (Alselmi 2023). Therefore, providing access to family planning services is crucial to improve mother and child health, as well as the general health and social well-being of families (AlHamawi et al. 2023).

In 2019, it was predicted that 60.5% of married Arab women wanted to avoid getting pregnant in the next two years, however, 40% of Arab women were not using contraception (UNFP 2023).

The term unmet need for family planning refers to sexually active women who want to postpone their next birth or limit the number of their pregnancies but not using any traditional or untraditional means of contraceptives (Asmamaw 2023).

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In many Arab communities, discussing family planning is surrounded by different barriers such as social and cultural stereotypes, and limited access to information (Hussain et al. 2019).

Taking these limitations into account chatbots- a conversational agent designed to mimic human conversation through user commands (Surani and Das 2022)- comes as a solution to increase access to information.

In the family planning domain, chatbots provide women with the opportunity to learn about family planning and explore their options rather than learning through a one-sided conversation such as mass media (Hussain et al. 2019). Therefore, chatbots could be a great help to family health programs in Arab communities by providing a two-way conversation channel with Arab women. The conversational nature of chatbots may also facilitate the engagement of less health-literate women and aid their engagement with family health program providers (Nadarzynski et al. 2021).

Although Chatbots have many benefits for Arab women in the family planning domain little research is conducted to study factors affecting women's adoption of chatbots to learn about their family planning options or factors affecting them resisting adoption of this technology.

Hence, this conceptual paper comes to focus on factors that might lead women in Arab communities to resist adopting chatbots as a tool to learn about family planning options regardless of their benefits. The proposed propositions in this paper are based on the Innovation resistance theory (IRT).

2 Research Context

Despite the diverse geographic origins and broad dispersion of Arab communities, it can be observed that Arabs adhere to a common set of values that can be characterized as conservative and patriarchal in nature. The community's adherence to conservative views has a significant role in shaping and reinforcing the values, connections, and practices that determine gender norms and behavior. Numerous Arab groups persist in maintaining strong familial connections and relationships. Nevertheless, it is frequently observed that these communities fail to provide an adequate level of personal freedom and autonomy, especially for women. The manifestation of these ideals is evident in subjects pertaining to sexuality and its associated matters, such as the utilization of contraceptive methods. In Arab culture, it is commonly expected that individuals exhibit respect by abstaining from questioning established sexual norms and beliefs as they progress in age. Within the framework of societal norms, the subject of sex is frequently regarded as a taboo and is commonly regarded as a matter of personal privacy (Wahba 2021).

In the Arab world contraceptives plays a major role not only in family planning but it is a tool to empower women (kharif et al. 2017). Looking at the special characteristics of the Arab culture discussing contraceptives is a sensitive topic that might lead to change the dynamic of the Arab culture by enabling women to achieve ideal family size, allow them to postpone having children until they finish their education which will result in financial power and challenge the patriarchal values.

Chatbots are one of the technologies that can create an easy to access channel for women in the Arab cultures to learn more about contraceptives discreetly without violating the Arab code that sees sex and topics related to it as a taboo. Therefore, understanding what factors lead to or hinder its adoption in such as sensitive domain is very important

3 Literature Review

Chatbots are dialogue systems meant to answer questions on a specific topic by mimicking human natural language via a text or voice conversation (Laumer et al.2019). Chatbot's importance has increased in many industries following the COVID-19 pandemic including the healthcare domain (Wang et al.2023). As the presence of chatbots is increasing in the health domain, it is becoming more important to understand what factors affect users' acceptance of chatbot technology in the healthcare domain.

Current research on chatbot acceptance in healthcare has emphasized the technical and social characteristics of chatbots and their impact on user adoption of chatbots. Laumer et al. 2019 developed a research model based on the Unified Theory of Acceptance and Use of Technology (UTAUT) to explain the adoption of chatbots for disease diagnosis. The proposed model suggested that performance expectancy, effort expectancy, and facilitating conditions influence customer adoption of chatbots in disease diagnostics. They have also re-defined social influence, price value, and habit. They also suggested that other factors that are not part of the original UTAUT such as privacy risk expectancy, trust in provider and system, compatibility, experience in e-diagnosis, and access to health systems have affected users' adoption of chatbots in the healthcare domain.

Hussain et al. 2019 employed UTAUT to explore factors affecting women's intention to adopt a chatbot that provides information about family planning and contraceptives. The result of their study showed that if users of the chatbot perceive using it as easy they will also perceive it as useful which intern will affect their intention to adopt the chatbot to receive information about family planning and contraceptives.

The previous studies investigated factors that affect the intention to adopt chatbots in healthcare and as a tool to receive information about family planning. However, the current body of research on the acceptability of chatbots as a source of consultation is modest, characterized by a notable scarcity of experimental studies. For example, the literature does not usually explore factors that lead to rejecting the adoption of chatbots in the healthcare domain and receiving information for family planning (Wang et al. 2023).

The acceptance of a chatbot in healthcare domain is influenced by several factors, including the quality of its content, and the perceived accuracy of health information. Hence, the low acceptability of chatbots can be attributed to the perceived obligation and liability associated with them, as well as the perceived competence of chatbots (Miles et al. 2023a). Therefore, such as factors should be investigated to understand its effect on refusal to use chatbot technology in domain of healthcare in general and contraceptives among Arab women in particular.

The literature also suggested that using chatbot to improve sexual and reproductive health in is not preferred by individuals who encounter significant stigma or encounter barriers in obtaining a personal electronic device (Miles et al. 2023b).

Although there are many potential benefits of chatbots for family health planning which include convenience, accessibility, and disclosure of sensitive and potentially embarrassing topics (Nadarzynski et al. 2021) yet the literature has shown that potential users are refraining from using chatbots to receive information about contraceptives.

A recent review by Mills et al. 2023 answered the question if a chatbot can improve contraceptive knowledge the researchers reported limited user engagement with chatbots. The low engagement with chatbots providing information about family health and contraceptive could be attributed to internal drivers-based factors. For example, reported that participants limited knowledge of technology was one of the reasons they refrained to engage with chatbots (Nadarzynski et al. 2021). Also, the strength of the relationship between the healthcare provider and the patient affected users' decision to use chatbots (Lai et al. 2021).

The previous suggests that there is a gap in the literature regarding what factors lead users to resist adopting chatbots to receive information about family planning options.

4 Theoretical Background and Propositions

Innovation resistance theory (IRT) is a framework that explains individuals' conscious choices to resist a new invention. This framework is based on the concept that individuals are under the influence that the new invention will disrupt the current state of affairs and leads to deviation from their established belief systems. (Hew et al. 2017; Kaur et al. 2020).

The IRT provides a conceptual framework for consumer resistance that encompasses two forms of resistance: active resistance and passive resistance. Active resistance arises as a result of the introduction of innovations that necessitate individuals to modify their entrenched behaviours or habits (Yu and Chantatub 2016). In this study to investigate active resistance, three variables are considered, utilization barrier, value barrier, and risk barrier. On the contrary to active barriers, passive resistance arises as a result of innovations that engender a psychological struggle within the individual. (Yu and Chantatub 2016). TRI considers two variables that represent passive barriers, namely image barriers and tradition barriers (Kaur et al. 2020). However, in this study, we are only considering traditional barrier. Image barrier refers to the image an individual perceives about a technology from multiple resources such as word of mouth and media (Ma and Lee 2019). As chatbot in general is considered a new technology there is not enough word of mouth about it specially in the domain of family planning. Therefore, we will not consider it in this study.

The concept of a usage barrier pertains to a scenario in which the introduction of innovation leads to disruption and incongruity with existing routines or habits (Ram and Sheth 1989). Chatbot in the family planning context is considered a new method of communication. Generally, women are used to face-to-face relationships with their healthcare giver to receive information regarding their family planning options. Asking women to communicate with a machine is a new practice for them. Communicating with chatbots will need to possess specific skills such as using the technology and asking questions in a way that the chatbot will process to provide answers. Asking women to divert from the usual way of communication and learn new ways might overcome the positives of the using chatbot to receive information about family health options, hence, we hypothesise that

H1: There is a negative relationship between the usage barrier and the intention to adopt a chatbot to receive information regarding family planning options

The value barrier refers to a functional barrier that assesses the cost of innovation in relation to its current alternative by considering the performance-to-price ratio (Ram and Sheth 1989). Using the chatbot to receive information about family planning is expected to cost less than visiting a healthcare provider. Therefore, it is expected that women will consider adopting chatbots once they realize that it is cost-efficient. Hence, we hypothesize that

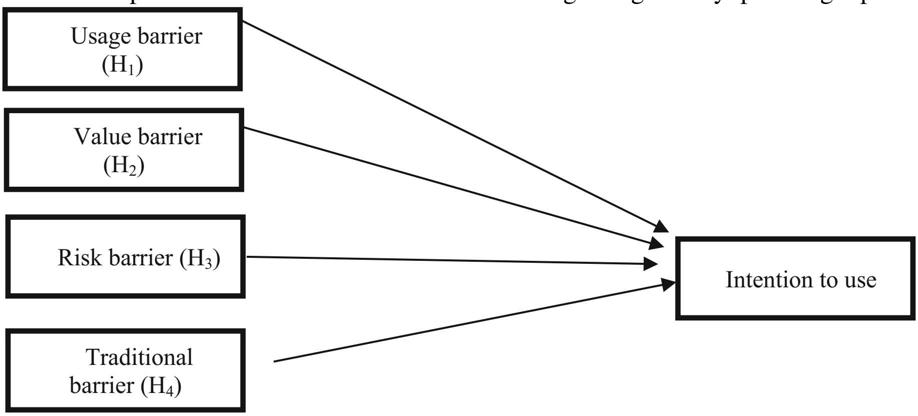
H2: There is a negative relationship between the value barrier and the intention to adopt a chatbot to receive information regarding family planning options

Perceived risk is conceptualized as "the consumer's subjective expectation of suffering a loss in pursuit of the desired outcome" (Pavlou 2001, p.109). Privacy breach is a concern for women who might adopt chatbots regarding family planning (Richiello 2018). Information about family planning is an intimate and private topic which if exposed might cause embarrassment. Hence, we propose privacy breaches as a risk barrier and we hypothesize that

H3: There is a negative relationship between risk barrier and intention to adopt a chatbot to receive information regarding family planning options

The social norm factor indicates the effect of the opinion of people who matters to an individual such as parents and friends in influencing an individual's opinion (Ajzen 1979). Arabic culture is a collectivist culture which indicates that the opinion of others has a great influence on the individual (Hofsted 1987). Using chatbots to receive information about family planning is still a new technology. Therefore, it is not perceived as a norm. Hence, we hypothesize that

H4: There is a negative relationship between the tradition barrier and the intention to adopt a chatbot to receive information regarding family planning options



5 Proposed Research Methodology

This research aims to study factors that prevent Arab women from adopting chatbots to receive information about family planning options. Therefore, the proposed sample for this study is Arab married women in baby bearing ages between (20–35)

To complete this study a quantitative method is recommended.

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AI Adoption in Automotive R&D: A Case Study Method for Prioritization of Inhibitors

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Abstract. Drawing on a case study method, 12 key inhibitors of artificial intelligence (AI) initiatives in the automotive research and development (R&D) unit are identified. The key inhibitors to AI adoption and success are analyzed with industry experts in a semi-structured interview format, helping practitioners formulate suitable strategies. The inter-relationship between each pair of inhibitors is obtained using a survey instrument, and the ISM and MICMAC analyses explored the interconnectedness and categorization. A fuzzy pair-wise matrix of key inhibitors is obtained via focus group discussions (FGD) and prioritized with the fuzzy AHP technique, providing action-oriented insights for the firm. The findings reveal that 'lack of data acumen', 'data-related challenges', and 'ambiguity in vendor services' have higher driving power, and 'lack of employee commitment and ownership' and 'managerial skepticism' have higher dependence. The study finds that 'lack of sustained commitment from the leadership team', and 'insufficient collaboration and coordination within and across the business functions' are the most prominent inhibitors, followed by 'limited experimentation scope', and 'lack of data acumen'. These inhibitors essentially indicate necessary cultural changes towards trust, commitment and ownership, complexity and failure tolerance, AI fitment awareness, and alignments.

Keywords: AI · Automotive · R&D · Inhibitors · Prioritization

1 Introduction

The evolving AI and its constituent technologies are dramatically reshaping industries. The industry sectors hugely depend upon sophisticated digital technologies for new product development, adding up to an expected revenue of $30 trillion over the next five years [1]. The persistence towards digital maturity by automotive companies is reflected in the intensity of the adoption of AI technology [1]. With the reduced time and cost of the product to market as the future value drivers, AI significantly influences the automotive industry [1–3]. AI is gaining traction in all the business functions of automotive value chain activities, such as R&D, strategy, production, supply chain, operations planning, sales and marketing, logistics management, procurement and services, and many more

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[4–6]. AI has enormous potential in reducing the cost of automobiles and improving its sustainable competitive advantage [3, 7–9].

In the product development process, automotive R&D includes the development of conventional assemblies integrated with disruptive trends such as e-mobility, connected, autonomous, and shared mobility topics that demand diverse data-driven functionalities in exploring driver posture, fatigue recognition, driver assistance, safety features, automated diagnostics, automated drive systems, and others [2, 7, 10, 11]. AI-based innovations do not only automate mundane jobs but offer capabilities to handle resource scarcity and overcome challenges to sustainable innovations [12]. The automotive industry leaps forward on emerging technology, such as AI, to capitalize on these disruptive trends and has started building data-driven strategies [13]. Hence, the R&D function helps the company be more innovative and competitive and meet sustainable targets [3, 5].

However, many automotive companies are still on the back foot in incorporating AI. Between 2017 and 2019, the AI implementation at scale increased marginally from 7% to 10%, and companies refraining from usage of AI increased from 26% to 39% [7, 14]. As of April 2023, classical techniques are used ten times more in the digital simulation domain than AI-based techniques with a high maturity level. One-third of organizations have yet to adopt AI, whereas two-thirds have started with pilot projects [1]. The affluence of AI has made organizations jittery at first glance. The circumstance poses a research opportunity to understand the factors associated with the AI adoption phenomenon. Against the backdrop of the paucity of literature exploring AI adoption in automotive R&D, we formulate the research questions (RQs): RQ1. What are the key inhibitors of AI initiatives in automotive R&D? RQ2. How can automotive R&D prioritize the inhibitors to be addressed? We followed a case study approach in an automotive R&D division to respond to these research questions. We developed a hierarchical framework of 12 key inhibitors, subsequently categorizing and prioritizing them. Thereby, we respond to the call of [15] for deep-diving into framework development in providing guidelines to practitioners on AI adoption.

2 Background

The extant literature provides an understanding of inhibitors of AI initiatives in the automotive industry, predominantly in the domains of supply chain [16, 17] and manufacturing [3, 7, 8, 11, 18, 19]. The automotive business involves complex technologies and requires collaboration of various functions in the value chain. The R&D function connects the dots between different domains of the automotive firm and pushes for shorter development cycles and modularization of architectures [5]. Hence, understanding the R&D ecosystem, including the allied domains such as manufacturing and supply chain, provides a broader perspective on AI adoption in the automotive industry. The limited available literature on the AI adoption phenomenon in automotive R&D is skewed highly toward technological dimensions with less attention on organizational aspects.

The recent trends in automotive R&D derive benefits from image processing, voice recognition, facial detection, traffic sign detection, driver assist, lane keeping, entertainment, and more [4, 11]. It implies that there is a need for continuous training of algorithms with a variety of real-time data. The unavailability or insufficient information threatens meeting the functional objectives [5]. It implies a high demand for data preparation, including aggregation and annotation, amounting to about 80% of the time in the execution of AI projects [12, 16]. The improper arrangement of data makes it difficult to access the data for AI usage [17]. With a high emphasis on a data-centric mindset, R&D units are researching conceptual designs using a modern data architecture. It is realized that data in silos is one of the significant challenges to be dealt with [2] in making it a shared asset across the organization. Building AI architecture with contemporary tools and infrastructure calls for investment both in terms of cost and effort in overcoming data-related challenges such as access, storage, integration and interoperability, privacy, confidentiality, safety, security, authenticity, accuracy, governance, modeling, analysis of real-time voluminous amounts of a variety of data [8, 9, 18].

Data awareness and strategic planning, the data-based decision-making culture, research and experimentation culture, collaboration, and strategic alignment [20] within and amongst business and IT functions, leadership commitment, associated structure, AI capabilities, and availability of skilled resources have been the organizational factors researched upon [3, 13, 16, 18]. Employee perception [17, 21] on AI implementation and the industry environment (vendors, suppliers, competition, ethical and legal support by the government) has a significant role to play in AI success [19]. The automotive product development augmented by AI is expected to lead the revenue generation in the next five years for social and economic development. In this context, we see the need to investigate the factors associated with the automotive industry's reluctance to leverage AI technology to its potential.

3 Methodology

As our study focuses on the dynamic process of AI adoption, the case study helps with robust understanding and framing of new strategies specific to the organization under study. In circumstances where no established underpinning theory explains the phenomenon, the case study method is justifiable as it suits the exploratory approach [22]. An automotive passenger cars R&D division at the early stages of AI adoption in digital transformation mode was chosen for the case study.

3.1 Expert Interviews for Selecting Key Inhibitors

Considering the study's exploratory nature, we relied on inputs from the domain experts and a literature review to understand the 'why' and 'how' phenomena [23] of AI adoption in the R&D unit. We contacted 23 professionals leading AI projects. With the assurance of anonymity of identity and responses, 15 experts in the capacity of project leads, group leads, and function heads agreed to share their expertise and experiences in semi-structured interviews belonging to various R&D functions, limiting the input bias. The average overall industry experience of the participants is 16.4 years, and experience in the current organization is around 9.3 years, with AI domain experience of 3.2 years. The interviews, spanning 45 to 60 min, consisted of open-ended discussions on their AI journey. Subsequent questions were related to the specific inhibitors of AI initiatives.

By the completion of 15 interviews, information saturation was observed, indicating the sufficiency of the number of participants. Responses were documented in handwritten notes and digitized. Extraction of insights (by comparison of code/constructs from each interview by at least between two of the authors) with converging evidence from literature resulted in the identification of 12 key inhibitors.

3.2 ISM and MICMAC Analyses: Survey Inputs

For the collective understanding of the complex and mentally inconceivable interrelationship of inhibitors, ISM is a widely used technique [22] for comprehensive visual representation [24]. The expert inputs in the form of a pair-wise relationship of inhibitors were obtained over a template in the form of a self-structured interaction matrix (SSIM) over four weeks. The validity and reliability of the final SSIM are ensured with feedback loops. The initial reachability matrix is derived by replacing a binary combination of 0 and 1 on SSIM. The transitivity principle is applied to obtain the final reachability matrix. Using the reachability and antecedent sets derived from the final reachability matrix, a diagraph is developed [22] as a hierarchical model of inhibitors. Each inhibitor's driving power and dependence obtained from the final reachability matrix provide cluster variables as a MICMAC graph, categorized as dependent, independent, linkage, and autonomous variables.

3.3 Fuzzy AHP for Prioritization: Focus Group Discussions

In the Multi-Criteria Decision Making (MCDM) process, while representing realistic human judgments with increased sensitivity to the relationship between variables, fuzzy set theory is widely used [25, 26], increasing the reliability of inputs. AHP seeks expert relative opinion on the inhibitors through pairwise comparisons indicating the preferences for decision-making. In getting the consensus of experts' understanding and viewpoints, focus group discussions are appropriate [27]. FGD with three panels consisting of 5 experts each was conducted, and it lasted 90 min. First, they were all briefed on the scale for the intensity of importance [28]. A pair-wise comparison template was presented to each panel, and they were asked to discuss and fill up the template. At the end of FGD, all three panels debated the pair-wise importance and converged to the fuzzy pair-wise matrix [29]. The 15 expert participants were optimal to provide diverse viewpoints and manage the FGD. Using a fuzzy pair-wise matrix, the weights of each inhibitor are calculated for ranking.

4 Research Findings

4.1 Key Inhibitors of AI Adoption

The AI inhibitors collated from the literature and insights from interviews with automotive R&D experts led us to identify 12 key inhibitors.

Lack of Individual Commitment and Ownership (I1). The reluctance is prominent due to a lack of abilities such as combined business and technical acumen, inappropriate interpretation of data and its outcomes, and the fear of unknown consequences.

Functional/Delivery Manager Skepticism (I2). Low data literacy and the lack of data acumen are detrimental to AI adoption. Despite their willingness to explore AI, operational disturbance and resource management are the priority challenges.

Lack of Data Acumen (I3). There is a lack of knowledge on whether and where to apply AI. Most are unaware of the strategic value of firms' data troves and the application of AI for business problems.

Lack of Leaders' Sustained Commitment (I4). It is essential to secure a continued commitment from the leadership team and not just lip service. Adopting AI requires a series of strategic transformations at the organizational level.

Cost of AI Infrastructure and Ecosystem (I5). AI ecosystem requires contemporary and user-friendly infrastructure to store, process, and analyze vast data and models. The available legacy IT infrastructure needs to be compatible and sufficient.

Data Challenges (I6). Data unavailability, inaccessibility, proprietorship, various data streams and structures, translating historical data, data redundancy, storage, and computation are the prominent challenges in establishing the right data architecture.

Conservative Change Process (I7). People's mindsets and structure-level actions need emphasis. Insufficient attention to cultural aspects, organizational structure and collaboration, and leadership communication would be detrimental to AI adoption.

Insufficient Alignment (Intra and Inter-Department) (I8). The conflicts within the firm end up with mediocre outcomes from AI. The relational influences, alignments, and effective coordination efforts make AI initiatives successful.

Limited Experimentation Scope (I9). AI initiatives, being complex, face a high possibility of failing to achieve the desired outcomes in the initial stages. There is a need to overcome conservative and deterministic styles against probabilistic AI solutions.

Functional Silos (I10). Individual AI specialists working in their silos without awareness of the horizontal spread of topics across the units cannot multiply the benefits of AI. Breaking the functional silos helps avoid divergent and duplicate efforts.

Talent Shortage and Retention (I11). AI specialist needs deep conceptual understanding and skills in business processes, decision-making, modeling, analytical tools, and data management amalgamating with domain expertise.

Ambiguity in Vendor Services (I12). With the fast-changing AI ecosystem, vendor-developed component integration demands OEMs to identify the vendors matching up to the incorporated technology.

4.2 ISM Framework and MICMAC Analyses

The pair-wise interlinkage of AI inhibitors collated in consensus with the automotive R&D experts is tabulated in Table 1.

Letters V, A, X, and O denote the degree of association between the pairs. V indicates, inhibitor i needs addressing before inhibitor j; A indicates the converse; X indicates the need to address inhibitors i and j simultaneously; and O indicates no relation.

Table 1. SSIM matrix of inhibitors

	I12	I11	I10	I9	I8	I7	I6	I5	I4	I3	I2
I1	O	A	O	A	O	A	A	O	O	A	X
I2	O	A	O	A	A	A	A	O	A	A	
I3	X	V	V	V	V	V	V	O	O		
I4	O	V	V	V	O	V	O	A			
I5	A	O	O	V	A	O	O				
I6	O	O	O	O	V	V					
I7	O	O	X	O	A						
I8	O	O	X	V							
I9	O	O	V								
I10	O	V									
I11	A										

Following the procedure described in Sect. 3.2, an ISM model representing the hierarchical framework of AI inhibitors is developed (see Fig. 1).

The diagraph of the AI inhibitors framework has five levels. At level 1, the inhibitors I1 and I2 indicate higher dependence on other identified inhibitors. Inhibitor I11 is at level 2 of the hierarchical model and is the antecedent for inhibitors at level 1. The inhibitors I4, I5, I7, I8, I9, and I10 act as antecedents to I11 and are a consequence of I6 at level 4 of the diagraph. The inhibitors I3 and I12 at the last level are the antecedents of I6, having the highest driving power in the hierarchy.

The ISM framework provides a direct relationship among the inhibitors. MICMAC analysis offers to classify these inhibitors and helps us understand the indirect relationships and characteristics as dependent, independent, linkage, and autonomous variables (see Fig. 2). No variable is classified as an autonomous variable, indicating a strong connection of selected inhibitors amongst each other.

4.3 Fuzzy Analytical Hierarchy Process (Fuzzy AHP)

In deliberations with experts, it was decided to consider the ten inhibitors, except I1 and I2 with high dependency, for prioritization using fuzzy AHP. The below steps [29] summarize the process of fuzzy AHP with results.

The pair-wise comparison matrix of AI inhibitors obtained through FGD (see Table 2) is fuzzified to derive a fuzzy pair-wise matrix. The consistency of the pair-wise relationship is verified [29]. The Consistency Index (CI) is found to be equal to 0.1073. The Random Index (RI) is the average CI over numerous random entries of the same order reciprocal matrices equal to 1.40 [28]. The Consistency Rate (CR) is the ratio of CI to RI, equal to 0.0766, which is less than 0.1, indicating that inputs are consistent and acceptable. The AHP is performed using the fuzzy geometric mean (FGM) method. The FGM (r_i) for lower, medium, and upper matrices using fuzzy number multiplication is calculated, followed by fuzzy weights w_i.

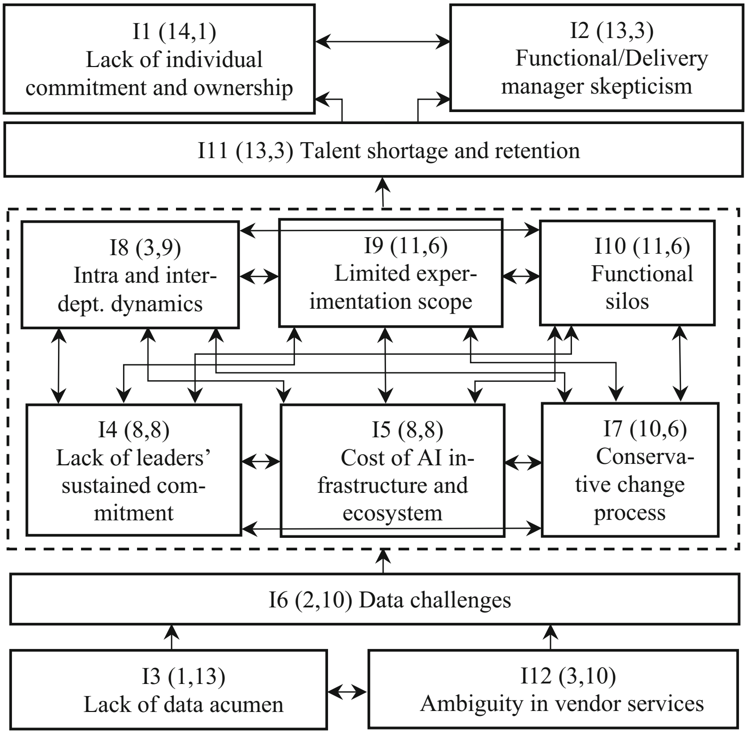

Fig. 1. ISM framework for AI inhibitors

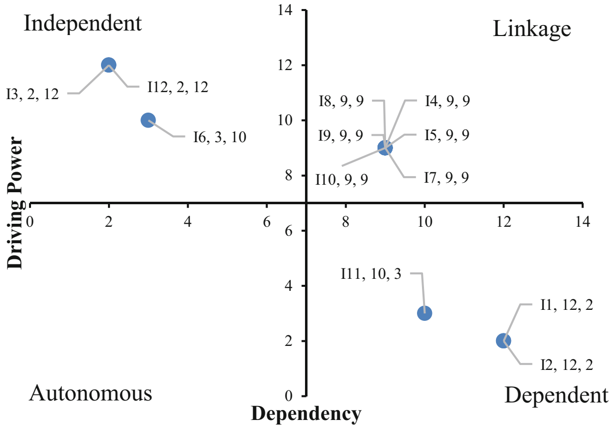

Fig. 2. MICMAC graph for AI inhibitors

Table 2. Pairwise comparison matrix of AI inhibitors

	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12
I3	1	1/3	7	3	5	1/5	1/3	5	1	7
I4	3	1	9	5	7	1	3	5	7	7
I5	1/7	1/9	1	1/5	1/3	1/7	1/7	1/3	1/5	1
I6	1/3	1/5	5	1	3	1/5	1/3	3	1	5
I7	1/5	1/7	3	1/3	1	1/5	1/5	1	1/3	3
I8	5	1	7	5	5	1	3	7	5	7
I9	3	1/3	7	3	5	1/3	1	5	3	5
I10	1/5	1/5	3	1/3	1	1/7	1/5	1	1/3	3
I11	1	1/7	5	1	3	1/5	1/3	3	1	3
I12	1/7	1/7	1	1/5	1/3	1/7	1/5	1/3	1/3	1

$$r_i = (l_{i1} * l_{i2} \cdots l_{in})^{1/n}, (m_{i1} * m_{i2} \cdots m_{in})^{1/n}, (u_{i1} * u_{i2} \cdots u_{in})^{1/n} \quad (1)$$

$$w_i = r_i * (r_1 + r_2 + \ldots + r_n)^{-1} \quad (2)$$

De-fuzzified weights are obtained using the arithmetic average of fuzzy weights. Normalized weights and prioritized inhibitors in the automotive firm's R&D division are derived (see Table 3).

Table 3. Fuzzy geometrical mean, fuzzy weights, de-fuzzified weights, normalized weights, and priority

Inhibitor	Fuzzy geometrical mean (r_i)	Fuzzy weights (w_i)	De-Fuzzified weights	Normalized weights	Priority
I3	1.282, 1.553, 1.888	0.072, 0.104, 0.153	0.109	10.46%	3
I4	3.232, 3.839, 4.389	0.181, 0.256, 0.356	0.264	25.26%	1
I5	0.228, 0.261, 0.309	0.013, 0.017, 0.025	0.018	1.76%	6
I6	0.803, 1.000, 1.246	0.045, 0.067, 0.101	0.071	6.77%	4
I7	0.413, 0.508, 0.634	0.023, 0.034, 0.051	0.036	3.45%	5
I8	3.194, 3.809, 4.389	0.179, 0.254, 0.356	0.263	25.13%	1
I9	1.692, 2.197, 2.781	0.095, 0.147, 0.225	0.156	14.87%	2
I10	0.413, 0.508, 0.634	0.023, 0.034, 0.051	0.036	3.45%	5
I11	0.836, 1.025, 1.231	0.047, 0.068, 0.100	0.072	6.85%	4
I12	0.247, 0.291, 0.360	0.014, 0.019, 0.029	0.021	1.99%	6

The results of fuzzy AHP highlight I4 and I8 as the most prominent inhibitors for AI initiatives, with about 25% weightage each. Inhibitor I9, with about 15% weightage, is followed by I3, which has about 10% weightage. The challenges of I6 and I11 are the next set of inhibitors to be addressed, each carrying about 7% weightage. The remaining inhibitors, I7 and I10, have relatively low weights with about 3% each, followed by I5 and I12, which have a weightage of around 2% each.

5 Discussion and Implications

The case study of an automotive R&D division reinforces and enhances the understanding of the inhibitors mentioned in the past literature. The top four inhibitors predominantly relate to organizational culture (trust, commitment, complexity and failure tolerance, AI fitment awareness, and alignments) that comprise 75% of weightage. It is crucial to translate the results of AI into a language that the leadership team understands. Data-driven story-telling skills aligned with business objectives help the leadership team orient more towards the adoption and sponsorship. Coordination and co-creation with different functional teams, including the IT function, enhance the possibility of multi-fold benefits of AI projects.

Being considerably complex, AI projects generally take 18 to 36 months for a cycle and possibly face initial failures. This may lead to discouragement and diverting the efforts toward conservative and low ROI approaches. In such scenarios, there is a need for the leadership team to exhibit a failure-tolerant culture. Identifying and focusing on high-benefit use cases by partnering with AI experts yields an above-average benefit. Data governance helps bring transparency across the organization and harness more value out of data. Proactive upskilling of employees helps scale AI initiatives and overcome talent acquisition challenges. The swiftness in change management to address technology and infrastructure incompatibility leads to AI success.

5.1 Theoretical Implications

We explore the AI adoption phenomenon in automotive R&D in technological and organizational dimensions. Our work contributes to the body of knowledge with an action-oriented perspective by researching AI initiatives in automotive R&D. We contribute to the evolving AI domain by identifying 12 distinct inhibitors and enhancing the understanding of their connectedness and prioritization in the context of automotive R&D. The proposed framework of prioritization helps researchers to study further interactions and relationships amongst inhibitors including their causal relationships. The extant literature on AI adoption draws upon various theories such as the resource-based view [3, 20], institutional theory [3], affordance theory [11, 13], socio-technical system view [13], organizational information processing theory [16], dynamic capabilities view [19], entanglement view of socio-materialism [20], technology-organization-environment framework [21], and much more. With the case study approach, we contribute to theory elaboration by reconciliation of the general with the particular [30]. The multi-dimensional, evolving, and complex AI adoption phenomenon underpinned by many frameworks is a sign of the possible emergence of a new theoretical foundation.

5.2 Managerial Implications

The developed framework can address real-time concerns of AI adoption and help managers develop solutions. We list the key takeaways: *Workforce skills* - It is easier to get immersed in today's processes and project deliveries. Managers need to focus on contemporary technologies such as AI and get awareness of incorporation in ongoing projects. Upskilling of managers and individual contributors through training keeps them well informed to instill commitment and ownership towards AI initiatives. *Focus on data culture* - There is no dearth of data in automotive R&D. It is critical to capitalize on the available information and drive digitalization initiatives by adopting AI initiatives. AI, being an explorative domain, allows room for experimentation and failures. In minimizing failures, collaborating with multiple stakeholders, learning, and sharing best practices play a prominent role. *Be strategic* - Knowing the right AI problem is half the solution. Align each AI initiative with the organization's core strategy and digital strategy. As AI infrastructure and talent are cost-intensive, make appropriate decisions, including in-house development and outsourcing, depending on the organization's maturity to handle the projects in scale. The AI initiatives require the leadership team's commitment, continuous review, and intervention.

5.3 Limitations and Future Research Directions

The study was conducted in an automotive R&D division in India, and the expert participants' inputs were instrumental in developing the prioritization framework for AI inhibitors. Although due care is exercised in overcoming individual biases arising from individual experiences and subjective inferences, certain inhibitors may be overlooked. We used one of the fuzzy AHP techniques (FGM) to identify the most prominent inhibitor and the subsequent weights for inhibitors. The other multi-criteria decision-making (MCDM) techniques in AHP [25], Analytical Network Process (ANP), Best-Worst-Method (BWM), and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) are not explored in this study. Future research can study different MCDM prioritization techniques in testing and validating our findings. Although the case study approach helped gain in-depth insight, the findings may not be generalizable. Further research is required to explore different industries and contexts in proving and generalizing our findings. Further studies should study the inter-relationships of inhibitors in greater detail, including the causal relations with empirical validation. Future research also should focus on the significance of AI initiatives in R&D on other functions of the automotive industry.

6 Conclusion

This case study attempts to provide a critical view of AI inhibitors in the automotive R&D domain. The findings highlight 12 key inhibitors extracted from extant literature and expert opinions. The key inhibitors identified are 'lack of individual commitment and ownership', 'functional/Delivery manager skepticism', 'lack of data acumen', 'lack of leaders' sustained commitment', 'cost of AI infrastructure and ecosystem', ‘data challenges’, ‘conservative change process’, ‘insufficient alignment (Intra and Inter-department)’, ‘limited experimentation scope’, ‘functional silos’, ‘talent shortage and retention’, and ‘ambiguity in vendor services’. We used ISM and MICMAC techniques to develop the hierarchical framework of inhibitors and categorized them into dependent, independent, linkage, and autonomous variables. The fuzzy AHP technique was used to prioritize the AI inhibitors in the firm. As an outcome, ‘lack of sustained commitment from leadership teams’, and ‘insufficient collaboration and coordination within and across the business functions’ were identified as the most prominent inhibitors to be prioritized by the firm for successful AI initiatives. ‘Limited experimentation scope’ and ‘lack of AI acumen’ are the following immediate inhibitors to be taken care of. In essence, these four inhibitors are primarily indicative of organizational culture. The study provides theoretically guided and action-oriented information for the automotive R&D unit in adding business value from the success of its AI initiatives.

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Role of Two-Dimensional (2D) and Virtual Reality (VR) in Effectiveness of In-Game Advertising

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Abstract. In-game advertising technology is shifting from two-dimensional to virtual reality graphics. This study aims at examining how a digital game that is either played in a two-dimensional (2D) or head-mounted-display (HMD) virtual reality (VR) graphics is perceived and experienced by the players. More specifically the study illustrates the effect of 2D technology vs. HMD VR technology on players' feeling of presence and brand recall. Results indicate that subjects who played HMD VR game reported higher level of presence than 2D game players. However, HMD VR players showed lower rates of brand recall than 2D players. This study provides insights for academicians as well as marketing practitioners from the perspectives of attention and elaboration considering 2D and HMD VR technology as important elements for designing effective games in the context of in-game advertising.

Keywords: In-Game Advertising · Two-Dimensional Game (2D) · Head-Mounted-Display (HMD) Virtual Reality (VR) · Presence

1 Introduction

Today, marketers are using different innovative ways to persuade their customers. One such medium is in-game advertising (IGA). Advertisers use these incredible tactics to make their brands more attractive to consumers. Firms have progressively accepted different digital marketing tactics that differ from traditional advertising, and this drift gives a range of opportunities to the marketing and advertising practitioners as firms look for augmenting digital consumer experience and enjoyment [1]. Digital games have been embraced as they easily haze the line between entertainment and advertising and thus hardly distract or irritate consumers [2]. Likewise, digital games have an exclusive power to fascinate individuals unlike conventional media [2]. Also, digital games make an augmented experience in the form of virtual reality (VR) wherein the individual plays the game.

Virtual reality is perceived as an environment or a kind of atmosphere that is made by a computer or other media and in which the player has a sense of being present in the environment. In recent times, a technological change has been observed in the digital

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games zone. As an alternative of a conventional two-dimensional virtual environment, now individuals can play digital games in a head-mounted-display (HMD) based virtual reality environment. A head-mounted-display (HMD) environment is considered to be more realistic, candid and vibrant than a two-dimensional environment [3]. In spite of being a comparatively new industry, the worldwide revenue within the VR gaming industry is estimated to grow from 0.4 billion U.S. dollars in 2017 to 2.4 billion U.S. dollars by 2024 [4]. However, the knowledge about role of HMD VR technology in increasing the effectiveness of IGA is very limited. Hence, the present research makes an attempt to examine how the gamers' feelings of presence and brand recall get influenced, depending on whether they play an identical digital game in a 2D context or an HMD VR context.

2 Literature Review and Hypotheses Development

2.1 Effect of Technology on Presence

In the context of digital gaming, there is a huge difference between the two-dimension technology games (2D) and Head Mounted Display (HMD) VR games. 2D games are usually flat and simple games as there are only two axes wherein the objects can move only left, right, up and down. On the other hand, HMD VR games provide a greater number of options in terms of movement such as high depth and volume [5]. The player in an HMD VR game can move, flip, jump, dive 360° and senses like in the real tangible world.

In 2D games, each sprite has only two coordinates (x and y), which define its position in the space. The sprites in the 2D environment are unable to interact with the environment and can do only a few prearranged animations. Thus, 2D games depict only one side of the game and the rest of the environment is created and imagined by the player. Conversely, VR games give unlimited options of interaction with the game environment by completely exploring the space which makes the game more interesting [6], for instance, things such as sound, light, air blow, jumps, waves, other movements etc. happen in the same way as in real life. Further, the camera in 2D games is very static, i.e., it only shows any one side of the game-screen and every sprite in the 2D space has only two points i.e., start and endpoint which makes the 2D camera very simplified one.

However, in case of HMD VR games, one can view the game world from different angles which makes the interface more distinct, immersive and makes it more enjoyable [1]. This gives a strong feeling to the player of being present in the real world [5]. In HMD VR games, the player gets completely involved and drown in the computer-simulated reality fictitious three-dimensional environment. Also, the interaction level of the player with the game-environment is very high wherein he/she gets fully sheltered from the outer world which enhances the realistic nature of the virtual game as compared with that in case of 2D games [6]. This gives a very strong feel to the player as if he/she is in the real world. Based on the above-mentioned rationales, following hypothesis is proposed:

H1: An HMD VR game results in higher level of presence than a 2D game.

2.2 Limited Capacity Model of Attention (LCMA) and Effect of Technology on Brand Recall

To explain the effect of technology on brand recall, we propose one possible convincing prognosis that the game-technology (2D vs. HMD VR) generally impacts a gamer's capacity to process and elaborate the brands embedded in the game. We approach this issue from attention and elaboration perspectives i.e., the degree to which an IGA game-player is capable for processing and elaborating upon the existing information in the game. One of the main marketing objectives of advertisers is enhancing brand awareness by embedding brands in games. Usually, it is hypothesized that the number of individuals playing a game is equal to the number of individuals actually paying attention to the brand identification elements implanted in the game. The game-playing task for a player is the activity that inhabits player's chief attention. Most perceptive experts argue that attention is the process of apportioning cognitive or mental or attentional capacity to an object or task [7]. Usually in the context of attention two aspects are discussed, i.e., the selective aspect and the intensive aspect [7, 8]. The intensive aspect of attention is the amount of attentional capacity that is assigned to a specific task, whereas the selective aspect of attention refers to the selective apportionment of cognitive capacity to a particular task in preference to others. The Limited Capacity Model of Attention (LCMA) was established to describe these selective and intensive aspects of attention [7].

According to the Limited Capacity Model of Attention (LCMA) [7–9], at any given point of time individuals can have a limited sum of mental resources. If an individual performs multitasks at a time, then his/her total mental capacity gets divided into two parts: capacity devoted to the primary task and capacity required for the secondary task. Capacity used for the secondary task is the spare capacity and the capacity which gets used for the primary task cannot be used for the secondary task.

In the context of IGA, playing the game is the primary task for the game players and processing the in-game placements is the secondary task [10]. The more mental resources that are required for playing the game, the less will be remaining for processing in-game placements.

Therefore, it is predicted that when a subject is exposed to an HMD VR game, his/her involvement with the game will be very high as an HMD VR appeals very immersive to the gamer and hence, more perceptual load is required for the game-play, unlike a 2D game wherein the object movements is quite simpler as compared to that in case of an HMD VR game. Thus, in HMD VR game, more amount of gamer's attentional capacity gets used for the game-play and he/she is left with less mental resources which are not high enough to process the in-game brand placements. This may result in inferior brand recall in an HMD VR game than a 2D game. Based on the above-mentioned rationales, following hypothesis is proposed:

H2: A 2D game results in higher level of brand recall than an HMD VR game.

3 Research Methodology

3.1 Development of Stimulus Material

A pretest was conducted before carrying out the main study to develop stimulus for the independent variable, game-technology (2D vs. HMD VR) which was manipulated during the study. The pretest was performed in three steps. In step-1, a focus group of 8 students that regularly play games were invited to provide insights about suggesting a game-theme and designing appropriate games for the main study. In step-2, a game-developer was approached to design the required games for the study. In step-3, 20 students were randomly selected and invited to participate in the pretest in a computer lab, wherein they were randomly assigned to play either a 2D game or an HMD VR game. 10 students played 2D game and 10 played HMD VR game for a time period of 8 min. Later, they were asked to rate the game-technology of the assigned games using a three-items seven-point scale. The items were: (1) how much you rate the animation in the game in terms of graphics (1 = "very less" to 7 = "very high"), (2) how much you rate the movement of the objects in the game (1 = "simple movement" to 7 = "multi-angel movement"), (3) how much you rate the reality of the game (1 = "not real" to 7 = "very real"). Reliability was checked for both HMD VR and 2D, and found to be satisfactory ($\alpha = .78$). Based on feedback, HMD VR game and 2D game were selected for the study.

3.2 Study Participants and Procedure

The participants were selected from a large Indian University. Studies reported that 72% of teens are gamers [11], which supports the use of student sample for this study. Gamers selected were between the age group of 17–19 years. For the participants below 18 years of age, the consent was taken from their parents. First, a random selection of students was conducted from a list of all the University undergraduate students. After seeking their game playing interest, they were randomly assigned to different games to be played in the computer lab. After the game-play task, the participants were asked to fill up the questionnaire, with items of manipulation checks and eliciting their responses to presence and brand recall.

3.3 Independent and Dependent Measures

Game-technology is an independent and manipulated variable used in the study. It was measured using the same scale employed in the pretest. In this study, presence and brand recall are the dependent variables.

Presence was measured by using a three-items seven-point scale, adapted from Nicovich (2005) [12]. The items were: (1) While game playing, how much did you feel like you were really there in the game environment (1 = "there" to 7 = "not there"), (2) While game playing, how much did you feel like the game environment was a real place (1 = "real" to 7 = "not real"), (3) While game playing, how much did you feel like other characters in the game were real (1 = "real" to 7 = "not real"). Reliability was checked and found to be satisfactory ($\alpha = .85$).

Brand recall was measured by asking the participants to mention the names of the brands that appeared in the games. Two coders, who were blind to the treatments, coded the number of brand names recall. If a participant listed an advertised brand correctly, it was coded as a correct response by the coder. An answer was coded as an incorrect response if the participant did not list the advertised brand or listed a non-advertised brand name. The numbers of correct responses ranged from 0–4 as there were four different brands embedded in the games. Intercoder reliability was checked and found successful ($\alpha = 0.79$).

4 Results

4.1 Manipulation Check

To inspect the manipulation of game-technology (2D vs. HMD VR), respondents were asked to rate the game-technology using the same measure used in the pretest.

A one-way ANOVA showed a significant difference between ($F(1, 9) = 330.31$, $p < 0.05$) between 2D game ($M = 1.88$) and HMD VR game ($M = 6.72$). Results of the study showed that the manipulation was successful.

4.2 Hypothesis Testing

To test the hypotheses, independent sample t-tests were performed with game-technology as independent variable, i.e., 2D and HMD VR as grouping variables and presence and brand recall as dependent variables. Table 1 summarizes the results of the analysis.

Table 1. Independent samples t-test (game-technology)

	Technology	N	Mean	SD	df	t-value	Sig
Presence	2D	36	6.02	1.01	60	12.21	0.000
	2D	32	2.60	1.20			
Brand Recall	HMD VR	36	3.10	0.52	60	17.18	0.000
	HMD VR	32	1.09	0.45			

Results indicated that subjects who played HMD VR games reported higher level of presence than those who played 2D games (M2D game presence = 2.60, SD = 1.20; MHMD VR game presence = 6.02, SD = 1.01, p = 0.000). Thus, H1 was supported. Further, subjects who played 2D games reported higher rates of brand recall than that of HMD VR game-players (M2D game brand recall = 3.10, SD = 0.52; MHMD VR game presence = 1.09, SD = 0.45, p = 0.000). Thus, H2 was supported.

5 Discussion and Implications

The findings of our study are relevant for game developers, marketers and researchers. This study contributes to research and theory in various ways, since it empirically examines the evaluation of digital games and the brand placements within the games, by directly comparing players' reactions to 2D games and Head-Mounted Display (HMD) VR games. Our results indicate that VR leads to higher presence, i.e., to a pronounced feeling of "being in the game" and lower rate of brand recall than a 2D game. This is an important finding, because it shows that an enhancement in technology from 2D to VR does lead to higher involvement of the player in the game but does not necessarily lead to a better memory. This is because of the additional depth perception in the multi-dimensional environments and the increased presence led to a higher cognitive load and also come along with negative aspects such as dizziness and eye fatigue that probably weaken digital game memory.

Subjects who played the VR game in particular reported higher levels of dizziness and motion-sickness while playing the game. Hence, the fact that the brand recall was not bad in the 2D condition as compared to the HMD VR condition indicates that the game developers can still be quite successful by continuing to offer "traditional" 2D digital games. Also, this finding presents a strong implication to the game developers of VR games that they must be aware that the VR experiences can come along with negative results that could possibly harm game memory, so they need to develop digital games in which the advantages of VR use clearly outweigh these associated disadvantages.

Also, the research provides implications for brand placements in 2D and VR video games, which are important for both, marketers who want to promote their brands, as well as for game developers who often seek placements to contribute to meeting the production costs and as a means to enhance the perceived reality of the games. According to the results of the study, memory for the brands placed is negatively affected by enhancement in technology, i.e., in the VR game, players remembered a lower number of the brands, as compared to the 2D game.

The finding that memory is lower with enhancement in technology is an important finding as it indicates that marketers may stick to 2D games when they seek to promote their brand via placements in digital games. In the HMD VR condition, it seems very likely that the player needs more resources for the game play, resources that are then no longer available for the processing of the brands placed in the game. Hence, the findings of this study can help the advertisers to develop effective IGA games in such a way that what combination and resolution of game-elements must be embedded in the IGA games so that marketers can achieve their goals of engaging customers to the highest limit and increasing players' brand recall.

6 Limitations and Avenues for Future Research

There are a few limitations in this study that should be acknowledged. First, only two levels of game-technology were taken for the study. Future research can also test the effect of 3D technology on the dependent variables. Second, the effect of game-technology was tested only on presence and brand recall, hence, future studies can test this effect on other variables such as, brand attitude, brand advocacy and game-attitude. Third, a different measure for measuring the perceptual load can be used, like, dual-task methodology or by electroencephalography. Fourth, the effect of game-technology can also be tested on gamers' visual attention and hence, a reliable eye-tracking device can be employed for the same in future research. Fifth, a longitudinal study can be done to check the long-term effect of the game-technology in the context of IGA.

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Factors Influencing the Readiness for Artificial Intelligence Adoption in Indian Insurance Organizations

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Abstract. Artificial intelligence (AI) technology is being adopted across industries. Adoption is a three-phase process- pre-adoption, adoption, and post-adoption. In this study, a systematic literature review is conducted to extract factors that influence the pre-adoption phase or readiness of the organization for adopting AI. These factors are narrowed down to 20 based on the discussion with the domain experts. These factors are mapped to Technology-Organization-Environment-Individual (T-O-E-I) framework that is derived from the technology-organization-environment (T-O-E) and human-organization-technology fit (H-O-T fit) frameworks. The experts ranked these factors independently. These rankings are used to calculate the global ranking of the factors using the Rough Step-wise Weight Assessment Ratio Analysis Method (R-SWARA), a multi-criteria decision-making (MCDM) method. The top seven factors are the following - perceived benefits of AI, AI system capabilities, data ecosystem in the organization, perceived compatibility of AI systems, perceived ease-of-use of the AI systems, IT infrastructure of the firm, and support from the top management. Sensitivity analysis shows that the ranks are robust.

Keywords: Multi-criteria decision making · Systematic Literature Review · TOEI framework · Rough SWARA · Pre-adoption phase

1 Introduction

The term artificial intelligence (AI) was coined by John McCarthy in 1956 [26]. Artificial intelligence is the ability of machines to solve complex problems by mimicking human intelligence, learn from experiences, and improve their performance in the process. AI is categorized based on cognitive, emotional, and social intelligence as analytical, human-inspired, and humanized AI, respectively [20]. AI could be used for automating processes, obtaining cognitive insight from data, and cognitive engagement with humans [8]. AI is classified as mechanical, feeling, and thinking AI [16]. AI systems are being adopted in all major industries across the globe. The insurance industry has been a traditional industry and is seen as a laggard in adopting digital transformation [27].

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Insurance industry needs to adopt digital initiatives and innovations for transformation of culture and value proposition. The strategic importance of information technology (IT) in the insurance industry was established in the context of Italian insurance firms [30]. The adoption of AI systems in Indian insurance sector is commencing [12]. The insurance industry in India is going through a transformative phase, focused on creating an integrated data ecosystem to facilitate the adoption of AI systems across the organization [12]. AI systems have a wide range of applications and immense potential to transform the insurance industry [11].

Adoption is accomplished in three phases- pre-adoption, adoption, and post-adoption [38]. In the pre-adoption phase, an organization determines its readiness for AI. During the adoption phase, AI systems are deployed, and this phase has a lot in common with any other Information System adoption. Adoption readiness affects adoption intention, and positive intention leads to the initiation of implementation of technology [3]. Thus, it is important to determine the factors and their relative importance for AI adoption readiness that in turn affects adoption intention. A factor may represent an attribute of the organization or an individual. Hence, we have created a new technology-organization-environment-individual (T-O-E-I) framework that is an adaptation of TOE framework [42]. The T-O-E-I framework incorporates organizational as well as individual level factors into one. We have done a systematic review of literature to identify the factors. The identified factors were refined using expert opinion and feedback. Experts from insurance and IT industry ranked the final set of factors. The factors and their rankings have been processed using a novel MCDM method, R-SWARA to obtain final ranking of the factors. We review the relevant literature in Sect. 2 and present our methodology in Sect. 3. Results are presented and discussed in Sect. 4. Conclusions are shared in Sect. 5.

RQ1- Identify factors that affect AI adoption readiness in an organization through systematic literature review.

RQ2- To establish a hierarchy of factors that exert a substantial impact on the readiness to adopt AI in the Indian insurance industry using R-SWARA.

2 Literature Review

2.1 Artificial Intelligence in Insurance

The application of AI systems in the insurance processes is currently discrete and addresses specific tasks. AI chatbots are adopted in insurance firms to answer customer queries and thus empower customers to use online channels [11]. AI systems are used to improve prediction accuracy for individual mortality risk scores and underwriting [8, 25]. AI systems are adopted for claims management, i.e., claim reporting, inspecting the damage, calculating the adequate claim amount, and payment of the claim to the customer [1]. In operations, AI systems are adopted to analyze, detect, and flag potentially fraudulent transactions [8, 11]. AI systems are implemented in the customer service space for sentiment detection to enhance the quality of customer service [11, 16]. AI systems extract information from the data collected by sensors and IoT devices which are used for product innovation and personalization. AI systems identify potential customers for cross-selling and up-selling insurance products. AI systems determine premium pricing and loadings for insurance products based on customers' risk profiles. To test the impact of the new technologies on insurance processes and customers, a regulatory sandbox [18] is used. It is a closed, controlled environment for insurance firms to apply and test new technologies before presenting them to consumers.

2.2 Adoption of Artificial Intelligence

Our focus in this paper is the pre-adoption phase wherein the readiness of an organization is influenced by many factors. A conceptual framework at the level of the organization using the T-O-E framework suggested 7 factors [2, 3]. These factors are Relative Advantage, Compatibility (T), Top Management Support, Organizational Support, Resources (O), Competitive Pressure, and Government Pressure (E). These factors have been further modified and elaborated based on expert opinions [35]. [14] narrowed down compatibility to complexity, resources to financial readiness and added two new factors-technological competence and market dynamics. The factors were verified based on the feedback from 358 insurance industry employees obtained through a questionnaire. Interestingly, the factor of technological competence was found to be insignificant. In addition to the organization, the readiness of its people [36] has been explored, wherein characteristics of Machine Learning have been expanded into perceived benefits, perceived barriers, and tool availability. TOE framework has been extended to TOEH by including a Human dimension to study AI adoption using R-SWARA method [9, 23]. Further, TOEH framework has been used to explore factors that influence pre-adoption as well as adoption phases. For instance, competitive pressure is to be considered before the adoption, whereas change management is relevant during the adoption. The study of the factors that affect AI adoption readiness in an insurance organization is scant in the literature.

2.3 Theoretical Model for Identifying Major Criteria and Sub-criteria

The factors that affect AI adoption have been studied using the T-O-E framework and Human-Organisation-Technology fit (HOT-fit) [9, 23]. In this study, we will incorporate the technology, organization, environment, and individual (human) (T-O-E-I) framework to classify the factors. The factors that affect AI adoption are extracted from the literature [14, 32].

2.3.1 Technology Factors

[35] mention that the characteristics of AI systems are different from other technology that require exploration. One of the technological factors is the anthropomorphism of the AI systems. Anthropomorphism is perceiving the human-like characteristics in a non-human entity. AI systems exhibit anthropomorphic qualities [15, 31, 32]. AI systems possess a wide range of capabilities that could transform the various aspects of the business [8, 16]. Major AI capabilities include AI-powered robot process automation (RPA) [24], analytical capability, predictive capability, generative capability, empathetic capability, etc. The lack of clarity regarding the type of AI capabilities needed in the firm's business process could inhibit AI adoption [2]. The knowledge of perceived benefits of

AI systems in top management could be crucial for AI adoption in an organization [14, 41]. The benefits could include enhanced business processes and operational cost reduction [8, 37]. However, the complexity of AI systems negatively influences adoption intention [14, 41]. The complexity is due to a lack of understanding of technology, low perceived control over technology, and higher effort expectancy [39]. Compatibility of the AI systems with the organizations' existing IT infrastructure plays a crucial role in determining AI adoption intention [3, 19, 35, 37]. The transparency and explainability of AI systems are important as the outcomes significantly affect the customer experience [21, 33]. The information quality, system quality, and service quality also affect adoption intention [4, 40].

2.3.2 Organization Factors

The support of top management is considered to be quintessential for the adoption of AI systems [14, 22]. Top management support enables financial and other resources [41]. Financial readiness of an organization strengthens the intention for the adoption of AI systems [14, 19, 35, 37, 41]. AI systems need to be strategically aligned with the organization's business goals, customer expectations, and regulatory requirements [7, 19, 37]. The organization's existing IT infrastructure impacts AI adoption intention [19]. IT infrastructure encompasses the technical competence of human resources, computing hardware, and software [6]. AI systems need suitable data; a data ecosystem including a strategy for the acquisition and curation of data is indispensable [7, 43]. A siloed and fragmented data architecture could inhibit AI adoption in an organization [12, 28]. Cybersecurity (confidentiality, authenticity, and non-replicability of data) is an important criterion for AI adoption intention [10, 31, 33, 48]. The technical competence of the employees has a positive and significant effect on the adoption intention [3, 41]. The lack of technical expertise and technology resources could pose a challenge to AI adoption in an organization [8].

2.3.3 Environment Factors

Firms could adopt AI systems to gain a competitive advantage in the market [3, 14] or due to competitive pressure [37]. The availability of support from technology partners determines the adoption intention [34, 44]. Adopting AI in an insurance firm raises regulatory concerns over the explainability, transparency, and fairness of the results [14, 21, 28]. Regulators have laid guidelines for the cybersecurity policy in an insurance firm [17].

2.3.4 Individual Factors

In addition to organization-level factors, we have also explored individual-level factors. These factors arise from the individual's perception and knowledge related to technology [9, 23]. Perceived ease of use and perceived usefulness determines the degree of acceptance of technology [5]. These factors affect AI adoption in various sectors [13, 29]. Users' trust in AI systems is crucial for adopting AI [45]. Adoption of AI-powered chatbots in insurance firms is influenced by perceived trust. The black box nature and a lack of explainability of AI systems could lead to trust deficiency in the users [21, 28, 31, 46]. The users' perceived privacy concern significantly affects individuals' adoption intention [31, 40].

3 Methodology

The factors were extracted through a comprehensive literature review. Research papers were searched and reviewed using the following major databases- IEEE Xplore, Science Direct, Emerald Insight, AIS Electronic Library, Springer Link, Harvard Business Review, Sage Journals, and Hawaii International Conference on System Sciences. The keywords used for searching these databases are "artificial intelligence adoption + adoption factors,"; "artificial intelligence adoption + insurance,"; "technology adoption + insurance,"; "artificial intelligence adoption/acceptance + drivers/motivators/enablers,"; "Artificial intelligence adoption + TOE/TAM framework." Using snowball sampling, the references of the selected paper are searched manually to identify suitable papers. The keywords were used again to search for relevant research papers on the Google Scholar website. The selection of keywords was based on the topics of the papers and the key research themes found in the extant literature. The selected factors were shortlisted after a thorough discussion with the Insurance professionals and the senior academics. The major criteria were categorized as technology, organization, environment, and individual factors. The final factors consisting of major criteria and sub-criteria in the T-O-E-I framework are shown in Table 1. In the second phase, to evaluate the relative importance of the criteria, Rough Stepwise Weight Assessment Ratio Analysis Method (R-SWARA) was used [47]. For getting priority of criteria, experts were chosen from the field of insurance and IT consultancy. One set of experts is managers handling sales, marketing, operations, underwriting, claims, and customer service in insurance firms. The other experts are managers in IT consultancy services, technology solution provider firms, and management consultancy. The relevant work experience of all the experts was around ten years. The responses were collected through social media, emails, and in-person interviews. Responses from 20 experts are used for the data analysis.

3.1 R-SWARA

R-SWARA is a multi-criteria decision-making (MCDM) method [47]. It calculates the relative weight of the criteria involved in the decision-making process. Its predecessor is the SWARA method, to which rough numbers were added to reduce the subjectivity and uncertainty and improve the weights to reflect the relative importance of the criteria. R-SWARA has been used as MCDM in the context of AI adoption and implementation [9, 23]. The perceived most important criterion is given priority as 1, and the perceived most insignificant criterion is given the least priority number. The advantage of this method is its simplicity, objectivity, and user-friendliness. Moreover, it requires lesser pair-wise comparisons of the criteria than other MCDM methods, such as AHP and BWM [9]. The following steps are involved in the R-SWARA.

Step 1: Identify and shortlist the criteria that are involved in the decision-making process. We have shown the criteria in the first column of Table 1. There are 4 major criteria.

Table 1. Factors affecting AI adoption in an organization

Major criteria	Sub-criteria	References
Technology (TEC)	Anthropomorphism of AI systems (TEC_1)	[15, 31, 32]
	AI system capabilities (TEC_2)	[8, 16, 24]
	Perceived benefits of AI systems (TEC_3)	[14, 16, 37]
	Perceived complexity of AI systems (TEC_4)	[14, 39, 41]
	Perceived compatibility of AI systems (TEC_5)	[3, 19, 35, 37]
	Interpretability/Explainability (TEC_6)	[21, 33]
	AI system Quality (TEC_7)	[4, 31, 40]
Organization (ORG)	Support from top management (ORG_1)	[14, 22, 41]
	Information Security/Cybersecurity (ORG_2)	[10, 31, 33, 49]
	Data ecosystem in the firm (ORG_3)	[7, 28, 43]
	Financial readiness/Financial competence of the firm (ORG_4)	[14, 19, 35, 37]
	IT infrastructure of the firm (ORG_5)	[3, 19, 41]
	Strategic alignment of AI systems (ORG_6)	[7, 19, 37]
Environment (ENV)	Competition (ENV_1)	[3, 14, 37]
	Availability of the technology vendors/partners (ENV_2)	[34, 44]
	Regulatory Environment (ENV_3)	[14, 21, 28]
Individual (IND)	Perceived ease-of-use (IND_1)	[5, 13]
	Perceived usefulness (IND_2)	[5, 29]
	Perceived Trust (IND_3)	[28, 31, 45]
	Perceived privacy concerns (IND_4)	[31, 40, 46]

Step 2: All experts provide a rank for each criterion, 1 indicates most important, and 4 indicates least important, as we have 4 criteria. The ranks provided by 20 experts are shown in Table 2.

Step 3: Every individual response k_1, k_2,…, k_{20} from the experts needs to be converted into a rough group matrix RN(Cj) (Eq. 1 below, Eqs. 1–6 in [47]). The matrix RN(Cj) of major criteria is shown in Table 3.

$$RN(C_j) = \left[c_j^L, c_j^U\right]_{l\times m} \tag{1}$$

Step 4: The matrix RN(Cj) is normalized to obtain the matrix RN(Sj) (Eq. 2 below, Eqs. 17–19 in [47]), j = 2 to m. The first row of the matrix is formulated to be –

$$\left[S_1^L, S_1^U\right] = [1.00, 1.00], RN\left(S_j\right) = \left[\frac{C_j^L}{\max C_r^U}; \frac{C_j^U}{\max C_r^L}\right]_{l\times m} \tag{2}$$

Step 5: The matrix RN(Kj), is obtained (Eq. 3 below, Eq. 21 in [47]). This operation makes the ranks proper.

$$RN(K_j) = \left[S_j^L + 1, S_j^U + 1\right]_{l \times m} \quad j = 2, 3, \ldots, \text{ m} \tag{3}$$

Step 6: The weight matrix RN(Qj) is repopulated using (Eq. 4 below, Eq. 23 in [47]).

$$RN(Q_j) = \left[q_j^L = \begin{cases} 1.00 j = 1 \\ \frac{q_{j-1}^L}{K_j^U} j > 1 \end{cases}, q_j^U = \begin{cases} 1.00 j = 1 \\ \frac{q_{j-1}^U}{K_j^L} j > 1 \end{cases} \right] \tag{4}$$

Step 7: The matrix of relative normalized weight values RN(Wj) is shown in Table 4 (Eq. 25, [47]).

Table 2. Expert's priority ranking for major criteria affecting AI adoption in organization

Major criteria	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
TEC	1	2	1	2	2	1	2	1	1	1
ORG	2	1	2	4	1	2	1	2	3	2
ENV	4	3	3	3	4	3	3	4	2	4
IND	3	4	4	1	3	4	4	3	4	3
Major criteria	**E11**	E12	E13	E14	E15	E16	E17	E18	E19	**E20**
TEC	4	1	3	2	1	1	2	1	1	4
ORG	1	2	2	1	2	3	1	2	3	1
ENV	2	4	4	4	4	4	3	4	4	3
IND	3	3	1	3	3	2	4	3	2	2

4 Data Analysis and Results

The Rough-SWARA has been used to calculate the weights and ranks for all the major criteria and sub-criteria based on the inputs provided by the experts. The response of the experts regarding the priority for the major factors affecting AI adoption intention is shown in Table 2. Technology criterion has been chosen by 11 out of 20 experts as the most significant factor. Seven out of 20 experts gave top priority to the organization criterion. Individual criterion was given the top priority that affects AI adoption by only 2 experts. The values of rough group matrix RN(Cj), RN(Sj), RN(Kj), RN(Qj) and RN(Wj) are calculated using the R-SWARA method. We have shown RN(Cj) and final weight table RN(Wj) in Tables 3–4. We have not shown intermediate tables as these are simple calculations using Eqs. 18–19, 21, and 23 from [47]. Experts also ranked sub-criteria for each major criterion that was also processed using the R-SWARA method. Finally, the global weight of each sub-criterion was calculated and ranked to obtain global ranks of the sub-criteria depicting their relative importance in affecting AI adoption readiness in an insurance organization (shown in Table 5).

Table 3. RN(Cj) of criteria

RN(C_{TEC})	[1.197, 2.286]
RN(C_{ORG})	[1.415, 2.423]
RN(C_{IND})	[2.350, 3.500]
RN(C_{ENV})	[3.070, 3.808]

Table 4. RN(Wj), weights and rank of major criteria

RN(Wj)	[Min, Max]	Crisp	Rank
RN(W_{TEC})	[0.411, 0.516]	0.463	1
RN(W_{ORG})	[0.230, 0.376]	0.303	2
RN(W_{IND})	[0.107, 0.232]	0.169	3
RN(W_{ENV})	[0.047, 0.128]	0.087	4

4.1 Discussion

Theoretical implications: The study listed the factors from the literature that affects the adoption readiness of artificial intelligence systems in an insurance in the context of India, the fifth largest economy of the world. Based on the results obtained after applying R-SWARA, technology (TEC) factors are found to be most significant for determining the AI adoption intention, followed by organization factors (ORG), individual factors (IND), and environment factors (ENV) in that order. The perceived benefits of AI (TEC_3) have the highest rank among all the 20 sub-criteria, which is in conformance with the food supply chain domain and insurance organizations [9, 14]. The artificial intelligence system capabilities ranked second among all the sub-criteria, a factor found in conceptual frameworks but rarely explored in empirical work in extant literature. We found that the interpretability of outcomes and explainability of the AI systems are important for determining adoption readiness and in turn, adoption intention. These unique characteristics of AI systems have not been explored so far. The anthropomorphism of AI systems turned out to be the least important of all factors, as the current AI systems have hardly achieved this property. The state of the data ecosystem is ranked very high; this is an ignored factor in the literature that requires more empirical verification. Our study shows that existing IT infrastructure in the firm significantly affects the AI adoption intention. A related factor, technological competence, has been found to be insignificant by [14]. We need to explore further if insurance organizations have in-house or outsourced IT infrastructure. Financial competence turned out to be a low-ranking factor which is quite understandable as insurance companies are cash-rich, and willing top management makes the resources available. At the level of individuals, ease of use and privacy concerns are among the top ten factors. The regulatory environment that includes insurance regulators and laws of the country is an important factor. Competition among firms has the least importance among environmental factors as the adoption of AI systems in insurance firms is in its

Table 5. Global ranks for all the sub-criteria affecting AI adoption intention in an insurance organization.

Major Criteria	Weight	Sub-criteria	Local weight	Global weight	Major criteria rank	Global rank
Technology (TEC)	0.463	TEC_1	0.017	0.0079	7	20
		TEC_2	0.263	0.1217	2	2
		TEC_3	0.328	0.1518	1	1
		TEC_4	0.064	0.0296	5	12
		TEC_5	0.183	0.0847	3	4
		TEC_6	0.113	0.0523	4	8
		TEC_7	0.034	0.0157	6	16
Organization (ORG)	0.303	ORG_1	0.188	0.0569	3	7
		ORG_2	0.059	0.0178	5	15
		ORG_3	0.357	0.1081	1	3
		ORG_4	0.029	0.0088	6	19
		ORG_5	0.268	0.0812	2	6
		ORG_6	0.11	0.0333	4	11
Environment (ENV)	0.087	ENV_1	0.159	0.0138	3	18
		ENV_2	0.297	0.0258	2	14
		ENV_3	0.573	0.0498	1	9
Individual (IND)	0.169	IND_1	0.499	0.0843	1	5
		IND_2	0.156	0.0263	3	13
		IND_3	0.085	0.0143	4	17
		IND_4	0.281	0.0474	2	10

initial stages. The impact of competitive pressure in determining the adoption intention is comparatively less.

Managerial implications: The top management support and the strategic alignment of AI with the business goals are of high importance. Our study confirms that management's lack of knowledge of AI systems capabilities could inhibit AI adoption [2]. Most of the Indian firms are transforming their data architecture from silo-ed data at business units to integrated firm-wide data lakes [12]. The complete transformation of the business processes is time-taking. Thus, in the initial stage, the perceived compatibility significantly affects the adoption intention of AI systems. Our findings show that the compatibility of the AI systems with the existing business processes and practices is important and has been ranked high in other industries [9]. The guidelines issued by the insurance regulator regarding the diffusion of the technology in the insurance firms and the cybersecurity measures that should be in place in the organization determine the adoption readiness for the AI systems. Interpretability and explainability are crucial for meeting regulatory requirements and instilling trust in managers and customers [21]. Technology vendor and partner support is important, which is a natural reflection of the fact that IT is not the core expertise of insurance firms. Hence, complexity-related issues are externalized and less important for the host organization.

Sensitivity analysis is performed to test the variations in the global ranks of the sub-criteria, observed by varying the global weights of major criteria as input [9, 23]. The results suggest that the resultant ranking of sub-criteria using R-SWARA is robust and could be used by managers for decision-making.

5 Conclusion

The study explored the factors that affect AI adoption intention. The study resonates with the prior findings in the literature that technology adoption is a three-phase process constituting the pre-adoption, adoption, and post-adoption phase. The study identified the factors from extant literature. The factors have been mapped to the T-O-E-I framework derived from T-O-E and H-O-T frameworks. The 20 factors that affect the AI adoption intention were finalized based on discussions with experts from industry and academia. The study used the response of 20 domain experts from the insurance and IT industry. The MCDM method used in this study is R-SWARA that evaluates the global weights of major criteria and sub-criteria. The 20 sub-criteria were ranked based on their global weights. The study concludes that most experts consider technology the most important factor, followed by organizational factors, individual factors, and environmental factors. The most important factors from sub-criteria that affects AI adoption intention based on expert's responses are perceived benefits, system capabilities, data ecosystem in the firm, perceived compatibility of AI systems, perceived ease-of-use of the AI systems, the IT infrastructure of the firm, and support from the top management. This study provides a roadmap for managers in India, the fifth largest economy in the world, to prioritize the relative importance of the factors while preparing to adopt AI in their organization.

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Assessing the Net Benefits of Generative Artificial Intelligence Systems for Wealth Management Service Innovation: A Validation of the Delone and Mclean Model of Information System Success

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Abstract. Generative Artificial Intelligence (GAI) can impact wealth management services; financial institutions actively integrate technology into their operations to acquire a competitive edge and foster innovation. This paper examines the information system success factors that influence the adoption of GAI in wealth management services via the lens of information system success theory. Participants responded to the online structured questionnaire, and structural equation modelling was used for data analysis. Findings indicate that system and service quality significantly influenced generative Net Benefit, whereas Information Quality did not affect generative artificial intelligence adoption. Further moderation of perceived risk on the relation between GAI and net benefit was found to be significant. Also, generative artificial intelligence adoption significantly influenced the net benefits of the information system.

The findings indicate that the suggested model can help decision-makers and consumers evaluate the adoption of GAI, improving wealth management efficiency. Wealth management demands sophisticated tools to optimise financial plans and entails complex decision-making. GAI" has demonstrated promise in creating models, data, and strategies.

Keywords: GAI · Information System Success Model · Wealth Management · System Quality · Service Quality · Information Quality

1 Introduction

People's perceptions of AI's capabilities have evolved due to the recent development of GAI. Robotic advisers and GAI models are revolutionising the financial advisory industry. AI has benefited financial organisations in many ways, and recently, the banking sector has embraced GAI and is heavily utilising its power as a crucial tool for its operations. Even though textual analysis and machine learning have significantly increased our understanding of finance, both approaches still need to be more constrained by pre-specific structures or human supervision [1].

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A complex language model called ChatGPT, or Chatbot Generative Pre-trained Transformer, was created by OpenAI. GAI offers a new alternative to assist potential portfolio managers in choosing the best portfolio and maybe acting as financial advisors to regular investors [2, 3]. GAI models can simulate several scenarios and analyse past market data to forecast potential hazards in investment portfolios. These models can aid wealth managers in more efficiently identifying and reducing risks. Massive amounts of unstructured financial data, news stories, analyst reports, and sentiment from social media can be processed by AI-powered NLP models to produce real-time insights and sentiment analysis for smarter investment choices. Financial institutions actively integrate GAI into their operations to acquire a competitive edge and foster innovation. Therefore, despite the potential of AI, human skills will still be crucial. When genuine data are highly confidential, generative models that produce high-fidelity synthetic data offer an alternate method for sharing information and collaborating [4]. ChatGPT faces several difficulties, including data security flaws, financial regulation compliance, and cybersecurity vulnerabilities [5]. GANs have made significant progress in their financial applications [6]. To reduce these dangers, financial institutions should deploy GAI tools on closed networks, secure training data, strong security measures, personnel training, and active output monitoring [7, 8]. GAI impacts finance, affecting its capacity to handle complex financial requests, look for answers, and support wealth management services. Through studying financial data and scenario forecasting, GAI may offer advice on strengthening the individual's financial stability [9, 10]. During business applications, it is essential to carefully analyse GAI implementation's ethical, legal, social, and economic implications [11]. Therefore, it is essential to identify the benefits and drawbacks of the GAI under actual circumstances while considering wealth management services. This study focuses on the following research question.: -What are the essential information system success factors contributing to adopting and using GAI in wealth management services?

The objective of this study is as follows.

- To investigate the influence of service, information, and system quality on adopting GAI for wealth management services.
- To test the moderating impact of perceived risk on the relation between GAI adoption and net benefits for wealth management services.

Thus, In this study, we investigate the feasibility of developing a model for assessing information system success (ISS), i.e., GAI for wealth management services, based on the concepts of DeLone and McLean's IS success model [12]. The study follows a clear framework, starting with Sect. 1's introduction before moving on to Sect. 2's thorough literature analysis and discussion of General Artificial Intelligence (GAI) in wealth management applications. While Sect. 4 provides an overview of the study methodology and analysis techniques, Sect. 3 focuses on developing hypotheses. The study digs into the details of data analysis in Sect. 5, while Sect. 6 presents the results and prompts discussion. The theoretical and managerial ramifications are explored in Sect. 7 before a brief conclusion is offered in Sect. 8. A reference section that has been carefully chosen closes the essay.

2 Literature Review

2.1 GAI Vs Traditional AI

Traditional AI, sometimes called Narrow AI or Weak AI, is concerned with successfully fulfilling a single task. These AIs have been programmed to perform specific tasks and adhere to strict regulations. [13]. GAI is a more flexible AI that can produce fresh data. Iterative learning allows the model to continuously improve its performance with more data and training [14, 15]. Traditional AI systems generally analyse data and forecast outcomes, whereas GAI takes a step further by creating new data comparable to training data. In other words, GAI thrives at pattern creation, whereas standard AI gives at pattern recognition [16]. Human professionals often construct these rules, and the AI's task requires particular programming [17]. It entails teaching models to recognise patterns and structures in data, allowing them to create new, unique material rather than relying on pre-programmed rules.

2.2 GAI for Wealth Management Services

GAI has several applications in the banking business, changing how wealth management services work and improving client experiences. Individuals can benefit from individualised financial plans created by GAI based on their wealth management goals, risk tolerance, risk management, and banking solutions. These programs can include customised advice on saving, investing, and retirement strategies [18, 19]. GAI can analyse and manage risk by creating simulations and stress tests for financial portfolios. This can assist wealth managers in making data-driven strategic investment decisions.

2.3 IS Success Model

The information systems success model, also known as the Delone and McLean IS success model or the IS success model, is an information systems (IS) theory that aims to provide a thorough understanding of IS success by identifying, describing, and explaining the relationships among six of the most critical success dimensions that are frequently used to evaluate information systems. The DeLone and McLean IS success model (D&M model) is the most used and widely accepted metric. The D&M model was introduced in 1992 and revised with some changes in 2003 [20, 12].

2.4 Conceptual Model

Adopting the IS Success Model, the current study proposes that the net benefits of using generative AI for wealth management services can be presented in Fig. 1.

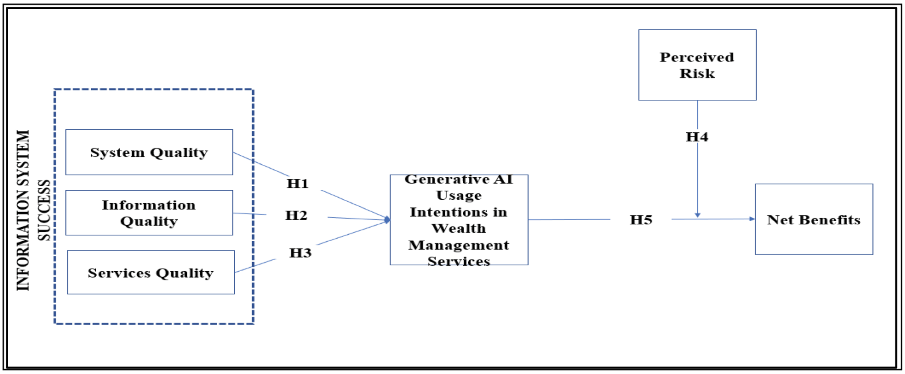

Fig. 1. Conceptual Model

3 Hypothesis Development

3.1 System Quality of GAI

In the context of GAI, system quality refers to the rates and traits that specify the usability, availability, reliability and adaptability of an AI system that uses generative methodologies. In GAI, fresh data, information, or insights are produced based on patterns discovered from previously collected data. The following are some crucial system characteristics for productive AI systems:

Usability.: A well-designed system should make it simple for the customer to enter their queries, preferences, and data and should display the insights understandably produced by AI

Availability: Wealth managers may make informed decisions at any time as it is open 24 h a day, seven days a week, in several time zones, with constant access to AI-generated insights and suggestions.

Reliability: The outputs of the AI should be consistent with market trends and historical data, budgeting, and the system should be continually updated to include the most recent data and knowledge.

Adaptable: With these technologies, it is possible to reduce workloads, increase output, spend more time and resources engaging with clients, develop long-lasting relationships, and provide customised solutions.

Customers should be able to quickly enter queries or preferences and comprehend the customers' needs, considering the following hypothesis.

H1: System Quality of GAI has a favourable impact on GAI usage intentions in Wealth Management services [21].

3.2 Information Quality of GAI

Information quality results are significantly influenced by accuracy and relevance, which help improve the decision of the information produced by the AI system. Information quality and GAI in wealth management are related as follows:

Completeness: Ensuring the AI generates a comprehensive view is essential because incomplete information could result in uninformed conclusions.

Understandability: Information generated by GAI should be easy for professionals and laypeople to understand. Ensuring understandability aids users in understanding the consequences of AI-generated data and enables them to make wise decisions.

Security: Security entails preventing unauthorised access, alteration, or breaches of AI-generated data. Strong security measures in wealth management are crucial because this industry deals with sensitive financial data.

Accuracy: One essential component of information quality is accuracy. Information produced by AI should closely match data and trends from the real world.

H2: Information Quality of GAI has a favourable impact on GAI usage intentions in Wealth Management services.[22].

3.3 Service Quality of GAI

Customers' satisfaction and continuing engagement with GAI-driven services are influenced by the entire experience and value they receive from using them. GAI applied in wealth management should result in this. The following is a relationship between service quality and GAI in wealth management:

Collaboration: GAI can make it easier for finance experts to work with AI systems. The system may continuously enhance its performance and adapt to the unique needs and preferences of the business through iterative training and fine-tuning.

Enhanced Data Analysis: Using extensive financial data analysis, GAI can find patterns, correlations, and anomalies that can be hard for people to notice independently.

Encourage Adaptability and Scalability: The capacity to scale smoothly is essential. With GAI, customers can accommodate the expanding amount of financial data and reporting needs, allowing you to manage growing reporting expectations effectively (and the technology can adapt as these demands change).

H3: Service Quality of GAI has a favourable impact on GAI usage intentions in Wealth Management services [13].

3.4 Perceived Risk

A person's subjective judgement of the possible drawbacks or uncertainties of using a new technology, such as generative artificial intelligence, is perceived risk. These risks may include worries about the precision of AI-generated suggestions, data security, the loss of human expertise, regulatory compliance, and reputational hazards in wealth management.

The gains advantage wealth management professionals believe from utilising GAI is the percentage of returns. These advantages include improved decision-making, increased productivity, better portfolio management, speedier data processing, and more precise risk assessment of wealth management professionals' overall gains and benefits.

H4: Perceived Risk is a significant moderator for the relationship between GAI usage intentions in Wealth Management services and the Net Benefits of GAI

3.5 Net Benefits of GAI in Wealth Management Services

The finance and banking sectors have seen an increase in the popularity of GAI due to its potential to increase accuracy and efficiency. With advanced trading algorithms that recognise market patterns and trends, GAI can aid in developing automated trading strategies and speedier decision-making.

H5: GAI usage intentions in Wealth Management services favourably impact the net benefits of GAI.

4 Research Methodology

An empirical investigation using a structured questionnaire for data gathering has validated the proposed framework. The proposed information success model was the foundation for the questionnaire's design.

4.1 Measures

The questionnaire consists of six constructs: service quality, system quality, information quality, GAI adoption intentions, net benefits and perceived risk, with 24 statements adapted from previous IS Success Model studies [20]. A seven-point Likert-type scale with anchors ranging from "Strongly agree" to "Strongly disagree" was used to ask the participants how much they agreed or disagreed with each component of an information system's success.

4.2 Data Collection

Several academicians, fintech professionals, Information system professionals and end-customers were targeted for purposive data collection. Five hundred participants working in academics and financial organisations in India were selected purposively based on their experiences in information system usage. 317 questionnaires in total were returned, yielding a 63.4% response rate. Table 1 displays the distribution of the sample received by gender, marital status, source of income and educational attainment. The data were subjected to a multivariate analysis utilising the PLS-SEM (Partial et al. Equation Modelling) tool. The G*Power tool and Apriori power analysis were used to calculate the sample size. 317 samples were more than enough for our empirical study.

Table 1. Showing the Demographics Data

Demographic Data		Frequency	Percentage (%)
Gender	Male	168	53%
	Female	149	47%
Marital Status	Married	182	57%
	Single	123	39%
	Divorced	12	4%
Education	Undergraduate	116	37%
	Post graduate	169	53%
	PhD	32	10%
Income Source	Service	242	76%
	Family Support	41	13%
	Pension	34	11%

5 Data Analysis

Researchers used the SmartPLS Version 4.0 (Partial Least Square) tool to estimate the measurement model and to examine structural models through Bootstrapping. Scale reliability and construct validity, including convergent and discriminant validity, were considered by the study to evaluate the measurement model (Sarstedt et al. 2021).

5.1 Measurement Model

Model examination ensured Cronbach's alpha was more significant than 0.7. Three criteria were used to assess convergent validity: (1) factor loadings above 0.70, (2) composite construct reliability (CR) above 0.80, and (3) average variance extracted (AVE) above 0.50. According to Fornell and Larcker (1981), discriminant validity is established when the value of the square root of the AVE of each construct is greater than the correlation of the construct with all other constructs, as shown in Table 2.

5.2 Structural Measurement

Researchers examined the conceptual model using bootstrapping with 7000 subsamples to determine the path relevance in the structural model. The R2 (Coefficient of Determination) value, which quantifies the proportion of each endogenous construct's variance that can be explained, is displayed in Table 3.

The structural link between independent and dependent factors is displayed in Table 4. According to H4, the moderating impact of consumers' perceived risk was examined concerning the relationship between the use of GAI and the net benefits of such use for wealth management services.

Table 2. Construct Reliability and Validity

CONSTRUCT	AIU	INFO-Qual	NB	PR	SERV-Qual	SYS-Qual	α Value	CR	AVE
GAI Use (AIU)	**0.787**						0.807	0.867	0.619
Information Quality (INFO- Qual)	0.562	**0.785**					0.831	0.851	0.616
Net Benefits (NB)	0.464	0.248	**0.752**				0.801	0.808	0.565
Perceived Risk (PR)	0.335	0.452	0.443	**0.737**			0.816	0.877	0.543
Service Quality (SERV- Qual)	0.421	0.364	0.186	0.432	**0.747**		0.802	0.847	0.558
System Quality (SYS-Qual)	0.326	0.321	0.235	0.264	0.532	**0.795**	0.814	0.846	0.632

Table 3. Endogenous Construct's Variance

Endogenous latent construct	R^2
GAI usage (AIU)	0.458
Net benefits (NB)	0.582

Table 4. Structural Relationships and results of hypothesis testing

Hypothesis	Relationship	β	t-statistics	Decision
H1	SYS-Qual - > AIU	0.721	5.267***	Supported
H2	INFO-Qual -> AIU	0.006	0.209	Not Supported
H3	SERV-Qual -> AIU	0.406	3.452***	Supported
H4	PR*AIU -> NB	0.332	2.849***	Supported
H5	AIU -> NB	0.424	4.195***	Supported

6 Findings and Discussion

This study aimed to investigate the GAI usage by consumers for wealth management services and the factors that influence the net benefits of GAI usage. GAI is an innovative technology that is still diffusing among consumers for finance and wealth management services. Information system success theory was used to explain better the GAI's net benefits for wealth management services. For testing hypotheses, the statistical significance of the path coefficients is examined. In light of the findings in Table 3, the total effect of variables, like SYS-Qual, INFO-Qual, and SERV-Qual, on the AIU was 45.8%. The further effect of AIU on NB was 58.2%, enabling us to understand the net benefits of GAI usage in wealth management services.

The outcomes of the path analysis are shown in Table 4. The Findings were in line with H1: (β = 0.721, t-value 52.67) SYS-Qual, H3: (β = 0.406, t-value 3.452) SERV-Qual, drives GAI usage positively. GAI system quality was perceived as Usability, Availability, Reliability, and Adaptability (Zaied, 2012). Also, GAI services quality has characteristic features like Facilitating collaboration, Enhancing data analysis, and fostering scalability and adaptability (Alnawas & Al-Khateeb, 2022). As per H2,: (β = 0.006, t-value 0.209), INFO-Qual did not significantly influence the GAI usage for wealth management services. It shows that consumers were apprehensive about the Completeness, Understandability, Security, and Accuracy of information provided by GAI in wealth management services. Further, as per H4: (β = 0.332, t-value 2.849), PR*AIU significantly moderates the relationship between productive AI usage and net benefits of practical AI usage for wealth management services. The security and privacy of personal financial information is one of the main issues with GAI. These AI systems could be the subject of hacker attacks or unauthorised access if they are not adequately guarded, potentially resulting in data breaches and monetary losses (Hasan et al., 2021). It was interesting to find that as per H5 (β = 0.332, t-value 2.849), GAI usage significantly influenced the net benefits of the information system. Thus, the Positive final success variables from the viewpoint of the individual influence and reinforce subsequent “use” and “customer satisfaction.” Appropriate risk management measures must be in place to address the possible net benefits connected with GAI in wealth management. GAI should enhance rather than completely replace human expertise. In addition to automating repetitive processes like portfolio rebalancing, risk analysis, and trade execution, AI-powered solutions may generate highly personalised investment strategies and financial plans.

7 Implications- Theoretical and Managerial

7.1 Theoretical Implications

This research incorporated the Information System Success theory With the Moderating variable of perceived risk leading to a net benefit. Users’ willingness to adopt new technology for net use is influenced by how much trouble they feel. The research will add to the literature on Information system success theory to use GAI for wealth management services. Addressing perceived risks in wealth management can enhance beneficial outcomes, leading to net gains, including better investment selections and enhanced client relationships. The study acknowledges that new wealth management technology is significantly influenced by perceived risk; hence, users could be reluctant to adopt it. Therefore, the study explores how the perceived risk affects the link between ISS and the actualised net benefits. This establishes the significant influence of system and service quality, leading to a net benefit of GAI for wealth management services.

7.2 Practical Implications

Several conclusions were drawn from this study based on actual evidence. First, the empirical analysis's findings showed that the success of GAI for wealth management services was not influenced by information quality. System designers should emphasise the completeness, understandability, security, availability, and accuracy of wealth management information to increase the net benefits of using GAI. Confusion and misinterpretation might result from complicated technical language or unclear explanations. The breach could result in theft, fraud, or misuse of confidential information, harming clients' finances and the wealth management firm's reputation. If the event that customers feel their financial information has been revealed, they can decide to disengage. Unreliable GAI insights could result in poor investing choices.

Second, as system quality significantly impacts the effectiveness of GAI, system designers should actively look for ways to achieve usability, availability, reliability and adaptability. Usability helps improve the ability to derive insightful information. Reliability guarantees the accuracy of AI-generated suggestions, lowering risk and improving investment results. The AI system's adaptability enables it to learn from changing market patterns and deliver current insights in the constantly shifting financial scene. When taken as a whole, these characteristics give Wealth Management practitioners a potent tool that enhances decision-making, risk management, and customer satisfaction. Third, the findings also showed that service quality has a favourable impact on GAI success. In addition, it can help improve system usage, affecting productive AI success [8].

Improved data analysis skills allow for more thorough insights, helping practitioners to make wise decisions based on a deeper grasp of the market. The high level of service quality also encourages scaling and adaptation, enabling smooth integration with changing market dynamics and growing client bases. GAI helps streamline operations and promote more successful investment strategies. Last but not least, the tested model and its factors demonstrated that they might be helpful for decision-makers in organisations to assess the deployment of GAI systems [23, 24].

8 Conclusion and Future Scope

The finance and banking sectors have seen an increase in the popularity of GAI due to its potential to increase accuracy and efficiency. With advanced trading algorithms that recognise market patterns and trends, GAI can aid in developing automated trading strategies and speedier decision-making. The links at the individual rather than the organisational level, concentrating on the customer's perspective in evaluating suggested dimensions' influence on GAI success for wealth management services. However, it makes more sense to conceptualise productive AI success regarding the organisation's response to the information system.

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Unveiling Emotions in Virtual Reality: Exploring Personal Narratives of US Veterans on VR Chat

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Abstract. The surge in popularity of social virtual reality (VR) social platforms, exemplified by platforms like VR Chat, underscores a growing trend of individuals seeking social interactions through immersive digital environments. These platforms offer participants a unique avenue for connection, often attributed to the anonymity of avatars. However, empirical exploration of the depth of personal and emotional experience sharing within such platforms remains limited. This article addresses this gap by investigating the emotional content and nuanced experience shared by US veterans on a prominent social VR platform. Drawing from a dataset of seven YouTube videos from the channel "@syrmor," capturing conversations on VR Chat, this study employs thematic segmentation to identify recurring topics of discussion. Noteworthy themes include drug abuse, mental health, pre-military circumstances, PTSD, and physical injuries. Furthermore, emotional analysis, utilizing the BERT (Bidirectional Encoder Representations from Transformers) language model, unveils prevalent emotions within these interactions such as fear, sadness, and anger, with significant contrasts to emotions like love and joy. Radar charts visualize these emotions across segments, painting a comprehensive picture of the emotional dynamics within each conversation. Overall, this study sheds light on the significance of VR social platforms as digital spaces for personal narratives and emotional sharing.

Keywords: Virtual Reality · Social VR · Mental health · US Veterans · VR Chat · Analysis

1 Introduction

Over the past few years, numerous technological advancements have facilitated the creation of innovative digital products that have profoundly transformed social interaction. Skype, Zoom, and WhatsApp are prime examples of these technologies that revolutionized how we interact with and experience social content. Virtual Reality (VR) technologies are slowly gaining popularity as VR allows users to experience immersion, interactivity and presence [1–3]. VR is a computer-generated simulation or artificial environment that offers users immersive and interactive experiences. It is a human-computer interface that simulates a realistic environment [1]. Social VR platforms, like VR Chat, have increased in popularity with many people turning to these platforms to experience

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social connection, including a rapid influx of users during the COVID-19 pandemic. Participants of social VR reported positive wellbeing benefits, mostly attributed to the anonymity provided by avatars and perceived safety within digital worlds and communities of practice [4]. These offer a range of activities and interactions, fostering social connections and providing an avenue for users to engage with others [5–7].

VR chats, like other social media platforms, serve as spaces for making friends, sharing images, and engaging in various activities [8]. However, VR chat stands out from other platforms due to its feature that enables users to fully customize that goes beyond mere appearance and extends to aspects like gender, age, demographics, and the possibility to adopt non-human forms. This aspect offers a level of anonymity, and control over self-representation, which has attracted the attention of researchers [9]. Researchers have explored the interactions within VR chatrooms and their relevance for social support [10–12], by investigating the effects of affordance of VR on user behavior, self-disclosure, empathy, and the formation of social connections [12–14]. Overall, prior work reveals that in social VR environments (such as VR chat rooms) users feel comfortable disclosing their emotions, firsthand experiences, and personal information as it provides a conducive environment for users to engage in open and authentic communication [15]. Social VR platforms offer a unique opportunity for individuals with social anxiety to engage in social situations in a safe and controlled environment [4]. This has found practical applications also, for instance EMMA, virtual reality (VR) application, is used for the treatment of stress-related disorders [16]. But, To the best of our knowledge, no prior studies have attempted to provide empirical support for the actualization of experience sharing that is personal and emotional on VR platforms. Our study aims partially address this as we investigate VR chat records for their *facilitation of the sharing of nuanced details during social conversations, such as interviews.* More specifically, this paper investigates the emotions expressed by the US veterans as they shared their experiences on a social virtual reality (VR) platform. The term "veterans" refers to former members of the armed forces. The analysis primarily focuses on *exploring the topics discussed by veterans and the emotions that arise during those conversations.*

Data used for this study was sourced from a YouTube channel known for hosting interviews conducted by the proprietor of the channel "Syrmor", who engages in insightful conversations with people from diverse backgrounds. The findings presented in this study concentrated on a selected subset of seven distinct videos chosen from this channel involving conversation with US military veterans. Our analysis involved thematic analysis to identify the key topics and ideas discussed by the veterans during the interviews. Next, we performed an emotional analysis of the generated transcripts. By examining the emotional aspects mapped to topics, we present insights that VR platforms that allow the expression of nuanced experiences and emotions on the social VR platform. Our findings also inform the need for the development of supportive environments for veterans to share their experiences as it could enhance their well-being.

2 Related Work

Our literature review revealed a growing interest among researchers and practitioners in virtual reality (VR) platforms for social interactions [17–19]. Previous studies (summarized in Table 1) have demonstrated that users feel comfortable disclosing their emotions, personal experiences, and personal information in social VR environments [20–22]. The embodiment of people as Avatars helps in better communication, expression and a sense of anonymity [23–25]. VR technology has emerged as a promising approach to address complex anxiety and mental health issues [26]. Studies show that VR has the potential to be used as a support tool for addressing post-traumatic stress disorder (PTSD) [27]. PTSD in military veterans and people on the warfront often manifest because of exposure to traumatic events like combat, sexual assault, or severe injury [28, 29].

Previous studies have examined the use of VR in the context of PTSD and yielded noteworthy findings. For instance, [27, 30] demonstrated the effectiveness of VR interventions in reducing PTSD symptoms and improving the well-being of individuals. Additionally, VR has been explored as a tool for delivering cognitive-behavioral therapy techniques, such as stress inoculation training and virtual reality exposure therapy, with promising results [31, 32]. However, most of these studies (see Table 1) have relied on perception data gathered through interviews, surveys, or discussions on forums like Reddit, limiting the direct observational analysis of interactions on VR platforms, particularly VR Chat. There is a need to explore the application of VR technology beyond clinical interviews, particularly in enabling the expression of emotions during general conversations. This creates an opportunity to investigate the use of VR chat-based interviews with veterans as a suitable empirical context for further exploration. This line of inquiry is expected to provide us with valuable insights into the potential of VR for fostering emotional engagement and communication, which can contribute to the development of enhanced virtual environments and communication tools.

Table 1. Review of previous studies on social VR

Study	Empirical Context	Data collection and analysis methods	Key findings
[2]	N/A theoretical paper	Literature review	Proposes relationship between VR design elements, user experiences (such as immersion and presence) leading to outcomes such as skill development
[3]	Social VR such as Minecraft, Roblox, etc.	Comparative analysis of virtual worlds	Multimodal social interaction in VR during gameplay increase engagement among children

(*continued*)

Table 1. (*continued*)

Study	Empirical Context	Data collection and analysis methods	Key findings
[4]	Social VR such as VR chat	Open ended survey and semi structured interview, thematic analysis	VR aids in reducing loneliness and continued use could improve users' wellbeing and confidence
[4]	N/A Theoretical Paper	historical account of research	Effects of anonymity on behavior within the virtual environment, emphasizing its role in shaping crowd dynamics and communication patterns
[20]	Social Virtual Reality	experimental approach	Find relationship between self-disclosure and privacy in social virtual reality
[22]	Social VR like VR Chat	Questionnaire and qualitative analysis on data	VR Chat serves as a valuable tool for promoting social connectedness and wellbeing and enhances mental health and overall sense of wellbeing
[26]	Virtual Reality System	Empirical studies, systematic review	VR for the rehabilitation of aphasia is being used for predominantly impairment-level interventions with non-definitive evidence of positive outcomes
[30]	Social VR	thematic analysis	Social virtual reality could provide a haven that's safe and supportive connections for LGBTQ users, illustrating how these platforms fulfill the need for inclusive spaces
[31]	VR Systems	content analysis	Documents participants' concerns and perceptions about the privacy and security aspects of VR

(*continued*)

Table 1. (*continued*)

Study	Empirical Context	Data collection and analysis methods	Key findings
[35]	VR studies	literature review of journals	Immersive virtual reality has the potential to enhance various aspects of human experiences and quality of life
[37]	Virtual Environments	experimental approach	Reveals that virtual reality scenarios have the potential to elicit emotional arousal, providing insights into the emotional impact of virtual experiences
[38]	Virtual Reality System	experimental approach	unveils that virtual characters' appearance and motion play significant roles in influencing users' emotional reactivity
[40]	Virtual Reality System	literature review	Argues effectiveness of virtual reality technology as a therapeutic tool for anxiety and other psychiatric disorders
[41]	Virtual Reality System	experimental approach	Empirical evidence showcasing the effectiveness of virtual reality technology as a therapeutic tool for anxiety and other psychiatric disorders
[42]	Virtual Reality	meta-analysis	Reveals that virtual reality exposure therapy is an effective intervention for treating posttraumatic stress disorder (PTSD)

3 Data Collection

For this study, we took 7 videos from a YouTube channel - "@syrmor[1]." Syrmor, widely known in the VR chat community for his videos, is also known as 'The Dr. Phil' of Virtual Reality for his contributions. The main aim of the channel is to let people talk about the things that need to be said while also preserving their anonymity. The videos were selected based on our objective to point out that VR Chatrooms provide the speakers with certain features that enable them to conversate about stigmatized and taboo topics. Veteran problems have been our primary focus. See Table 2 for more details of the videos. The dataset utilized in this study encompassed a total of transcripts of seven videos. The transcripts were generated from a site that produces transcripts for any YouTube video link. The generated transcripts were then corrected manually by listening to the videos and reading the corresponding transcripts to verify them.

Table 2. Description of Data (videos used for analysis)

Video Title (at time of data collection)	Video Bio (paraphrased by authors)
Guy in VR talks about his worst day as a soldier	The veteran talks about his motivation for joining the military and the incidents that led to him becoming an aerial gunner
Guy in vr talks about his ptsd	The veteran talks about their smoking addiction before he joined the military and mission that lead to PTSD experience
Marine in vr talks about their near-death experience	US marine talks about his personal perspective and opinions on combat experience, the time he got blown up and working at the VA (Veteran Affairs)
Ex-navy talks about cutting out family	Mike talks about joining the navy and his experiences with a toxic household
Guy in vr chat talks about being a soldier for hire	Air force veteran talks about his time serving in the air force including his experiences doing a post-service job as a mercenary its impacts on his mental health
Marine veteran talks what he lives with	Marine veteran that used to work at the VA talks about the harsh realities of trying to get help and the aftereffects of enlisting
Army recruiter exposes dark truth	US Veteran and army recruiter talks about his perspective on drug use, lying recruiters, and the reality of how army recruitment works

[1] Link to the youtube channel - https://www.youtube.com/watch?v=MiXZECAe094&list=PL75qCJnD3qpnoWVr7iC0QDWyG_tnizYKO&pp=iAQB.

4 Result

4.1 Analysis and Finding: Thematic Segmenting

Segment identification was achieved through a combined approach of transcript analysis and video observation. Rather than relying on topic modeling techniques, a manual coding approach was opted, involving careful listening to the videos and reading corresponding transcripts to discern distinct segments based on identified topics. The topics involved, i.e., language and meaning can be highly contextual and nuanced, especially in spoken language. Manual analysis allows consideration of these nuances [33]. Table 3 provides details on the number of segments and average length of the segments and the words in each segment. Table 4, 5 and 6 summarizes all the segments in all the videos including the phase of life in relation to veteran's service duration is being talked about in the segment.

Table 3. Descriptive Summary

Video	Number of Thematic Segments	Average length of segments in video	Average words per segment
1	8	2 min 42 s	599
2	3	2 min 30 s	493
3	7	6 min 49 s	893
4	6	3 min 4 s	682
5	9	3 min 22 s	600
6	5	2 min 10 s	320
7	8	4 min 41 s	879

Next, sentiment Analysis was done on the dataset. We used syuzhet packages that contained multiple lexicons to analyse sentiment [34]. For each video the segments as text files were read and split into sentences. For each segment, the sentiment score for each word was calculated and the average of the score was taken as the score for the segment. The positive and negative sentiment was calculated taking a + 1 value for a word with positive sentiment and a − 1 value for a word with negative sentiment. Out of 46 segments, only 4 segments had a higher positive sentiment and 2 had both positive and negative sentiments as the same. The other 40 segments all had a higher negative sentiment score. Further, emotional analysis was then performed using the BERT (Bidirectional Encoder Representations from Transformers) language model to train test data. The fine-tuning part of the model consists of attaching a fully connected network later at the end which contains our dataset where learning is performed to get the desired results. To gain a more comprehensive idea of the emotions portrayed in the

Table 4. Summary of Thematic Segments identified in video (**Post Military**)

Video	Segment	Title
1	**1**	After effects of Killing Civilians
2	**2**	Opening up
	3	PTSD and its effects
3	**1**	Dad's death
	2	Civilian Life
	5	Mental Health
	6	TBI
4	**5**	Regret
5	**4**	Conclusion
	5	Mental Health
	6	Mercenary Job
	7	Meeting wife
6	**1**	PTSD
	2	Physical Trauma
	3	Smoking
	4	Injury Aftermath
	5	VA neglect
7	**6**	Mental health
	7	Recruitment
	8	Training

videos, radar charts were employed to visualize the emotions within each segment (See Fig. 1 and 2). Radar charts allow us to depict an arbitrary number of segments facilitating identification of patterns that are made more apparent in a radar chart following bar graphs. This visualization approach allowed for a more nuanced exploration of emotional dynamics across different video sequence.

Table 5. Summary of Thematic Segments identified in video (Pre-Military)

Video	Segment	Title
1	**6**	Recruitment
	7	Starting out
2	**2**	Cigarettes
4	**1**	Drug Abuse
	2	Parents
	3	Mental Health
5	**1**	Section Assignment
	8	Motivation to join
	9	Examination Process
7	**1**	Drugs
	2	Enrolment

Table 6. Summary of Thematic Segments identified in video (During-Military)

Video	Segment	Title
1	**2**	Killing Civilians
	3	Experiences
	4	Hardships of flying aircrafts
	5	1st time killing
	8	Training
3	**3**	Iraq
	4	Joining Wadi
	7	Wadi
4	**4**	Joining Military
	6	Domestic Abuse
5	**2**	Befriending in military
	3	Boot Camp
7	**3**	General
	4	Assault
	5	Leadership

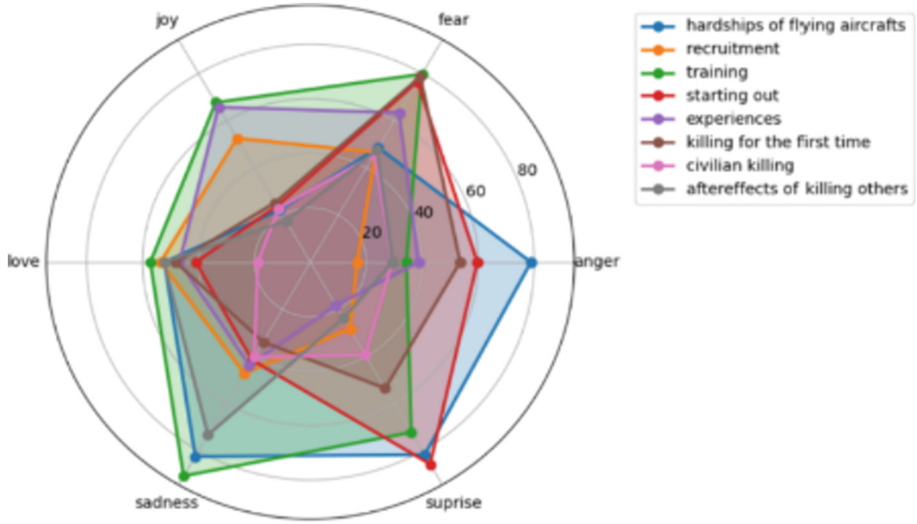

Fig. 1. Radar chart for video 1

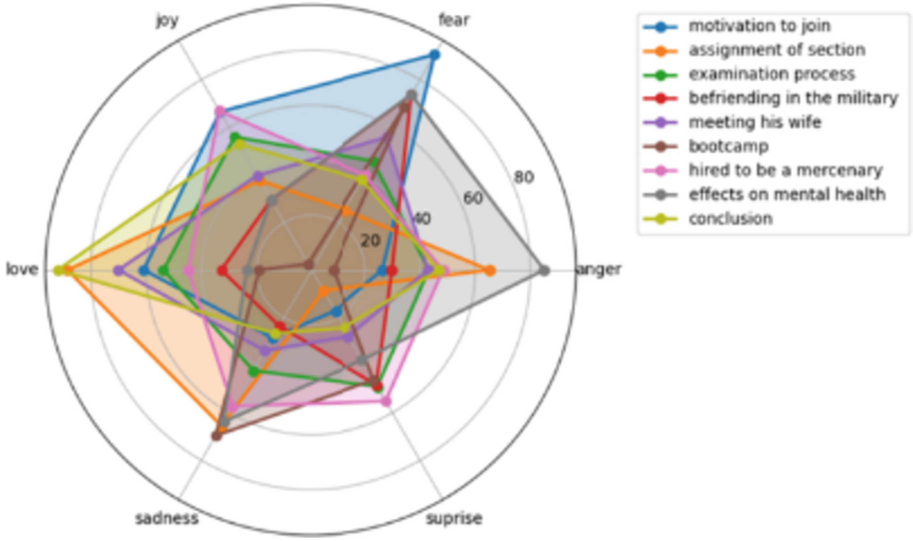

Fig. 2. Radar chart for video 5

5 Discussion and Conclusion

Our findings reveal that various common themes were spread across the segments. Topics such as drug abuse, mental health, situations leading up to joining the military, PTSD and physical injuries are talked about more than once. An enormous amount of research has been conducted on PTSD in the military and veterans [37–39]. It is undeniable that VR Chatrooms provides the speaker a safer environment and ensures anonymity [11, 12], enabling the speaker to talk about more sensitive topics than they would when the basics of VR Chatrooms such as full anonymity are removed from the equation. The emotional analysis revealed high values for fear, sadness anger and surprise compared to the values of love and joy. From all the videos we can see that the emotion tends overwhelmingly towards sadness, anger, fear then surprise, joy and love.

In video 6 segment 3, the veteran talks about how the VA does not help much with his injuries and how he suffers every day which is possibly why the emotion score for anger is so high.

> *"It's not a pulled muscle man physical therapy ain't gonna do shit, it's bone on bone put something in there. So yeah, and they would send me to physical therapy like three times, all right, you're good. Sure, whatever man, whatever you say. I feel it, when I wake up when I go to sleep, and the entire time in between."*

Previous work in this field consisted of results from surveys and polls, in this study we took the research a step further by using NLP libraries to assess the emotions and draw inferences. The results of sentiment and emotional analysis underscore several recurring themes that evoke comparable emotions when veterans discuss personal experiences, mental health issues, physical trauma and complexities of military involvement. These outcomes emphasize the imperative need for support systems and resources for military personnel, both during active and post-retirement. Furthermore, our findings underscore the therapeutic potential of VR Chatrooms (social VR) and calls for further investigation into their role in mental health support.

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Augmented Reality Immersion in Cultural Heritage Sites: Analyzing Adoption Intentions

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Abstract. This research delves into the adoption of Augmented Reality (AR) technology within the domain of cultural heritage tourism, examining the influence of key determinants on users' behavioral intentions. Expanding the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) model to include personal innovativeness and perceived risk, this study delves deep into the fabric of factors that exert an influence on users' intentions to embrace AR. Analysing data obtained from 435 participants through a snowball sampling technique, the results emphasize the significant impact of performance expectancy, facilitating conditions, hedonic motivation, and personal innovativeness on behavioral intention, while revealing the negative effect of perceived risk. These findings significantly illuminate the canvas of technology adoption in cultural heritage tourism, providing invaluable insights into how the fusion of these influential factors can effectively foster the integration of AR technology.

Keywords: Augmented Reality · Cultural Heritage Tourism · Adoption · UTAUT2

1 Introduction

In the ever-evolving landscape of modern business, emerging technologies have consistently shaped and redefined the way industries operate, communicate, and engage with their audiences. The rapid progression of technology has led to revolutionary shifts in business models, customer expectations, and market dynamics [1–3]. Among these technological marvels, the fusion of digital innovation and reality has given birth to transformative experiences, ushering in a new era of engagement and interaction. Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR), and the burgeoning concept of the Metaverse have emerged as pivotal players in this digital revolution [2].

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AR, VR, and MR stand as one of the important pillars of this evolution, each offering distinct yet interconnected ways to immerse users in virtual environments [4]. Augmented Reality offers a seamless integration of digital content into the real world, thereby enriching the user's perception and interaction within their environment as illustrated by He et al. [5]. VR transports users to entirely virtual realms, providing a complete sensory experience that can transcend the boundaries of time and space and whereas MR, the hybrid of AR and VR, interweaves the virtual and real worlds, enabling users to interact with both in real time [6].

Within this spectrum of technologies, Augmented Reality and Virtual Reality has emerged as a particularly promising tool with the potential to revolutionize the tourism industry, especially in the context of cultural heritage [7]. Cultural and heritage tourism, characterized by its emphasis on historical significance and local culture, provides a unique platform for the integration of AR [8, 9]. By bridging the gap between past and present, AR has the power to breathe new life into ancient artifacts, monuments, and landmarks, offering visitors a dynamic and immersive journey through time [5, 10–12].

While previous research has explored the applications of AR in enhancing user experiences within cultural heritage tourism [e.g. 14], a noteworthy gap remains in understanding the determinants impacting the adoption of Augmented Reality (AR) technology, in this context. In this pursuit, researchers have turned to established models such as the Technology Acceptance Model (TAM), the Unified Theory of Acceptance and Use of Technology (UTAUT), and the Theory of Reasoned Action (TRA) to shed light on the factors influencing technology adoption [7, 13–15].

Despite the advances in research on AR adoption, studies specifically targeting its implementation within cultural heritage tourism remain sparse [10]. This paucity of research not only underscores the unexplored potential of AR in this domain but also highlights the need for comprehensive insights into the drivers of AR adoption among cultural heritage tourists. This research is crucial as it not only addresses a gap in current literature but also holds the key to unlocking new dimensions of immersive and immersive encounters for tourists exploring heritage sites of cultural value [6]. Understanding the determinants of AR adoption in this context can inform the development of tailored AR experiences, potentially leading to increased visitor engagement, enhanced cultural heritage preservation, and a boost in tourism revenue. By shedding light on these critical factors, this research not only contributes to academic knowledge but also offers valuable insights for those actively involved in promoting and preserving our cultural heritage.

Hence, the present study aims to bridge this research gap by utilizing an extended version of the UTAUT-2 model with personal innovativeness and perceived risk. The central focus of this study revolves around a fundamental research question:

- (RQ1) What are the determinants of adoption intention of Augmented Reality among visitors engaging in cultural heritage tourism?

Through a systematic exploration of the factors influencing AR adoption, this research seeks to contribute valuable insights to the field of cultural heritage tourism, laying the foundation for a more comprehensive understanding of the potential impact of AR technology on visitor experiences.

2 Literature Review

2.1 Theoretical Background

Cultural tourism, as defined by Silberberg [16], involves travelers from outside communities motivated by historical, artistic, scientific, or heritage elements in a specific area. It's globally recognized for its economic and societal contributions [17]. Cultural tourists typically have higher incomes, education levels, and longer stays (Han et al., 2019), seeking historic sites and monuments [18]. In tourism, unique and immersive experiences are essential, and Augmented Reality (AR) has been explored to enhance cultural tourism [6, 11]. AR seamlessly integrates digital content into the real world [5], benefiting cultural experiences [8]. This study examines AR adoption in cultural heritage tourism using the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) model. The UTAUT2 model was selected for this research due to its comprehensive framework, which encompasses factors crucial for understanding AR adoption in cultural heritage tourism. Its proven applicability across diverse technology adoption contexts and strong predictive power make it a suitable choice for exploring the determinants of AR adoption intentions in this specific domain. Independent variables include Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Facilitating Conditions (FC), Hedonic Motivation (HM), Habit (HA), and Price Value (PV). Behavioral Intention to Adopt (BI) is the dependent variable. Additionally, the study extends the UTAUT2 model by adding three constructs: Personal Innovativeness (PI), Perceived Enjoyment (PE), and Perceived Risk (PR). See Fig. 1 for the conceptual model.

2.2 Hypotheses Development

Performance Expectancy

Performance expectancy, stemming from users' perceptions of tangible benefits and enriched experiences offered by AR technology in cultural heritage tourism, emerges as a potent driving force behind their fervent behavioural intention to embrace this transformative digital tool [7, 14]. These studies underline the pivotal role of perceived advantages in igniting users' eagerness to adopt AR and enhance their engagement with cultural heritage sites [20]. Hence the hypothesis: *H1: (PE) has a significant positive influence on (BI) to adopt AR technology.*

Effort Expectancy

Effort expectancy, marked by users' perceived ease and straightforwardness of utilizing AR technology within cultural heritage tourism, exerts a substantial impact on their predisposition and preparedness for adoption, thereby shaping their behavioral intentions towards embracing this immersive digital encounter [14, 19]. These works highlight the pivotal role of perceived simplicity in influencing users' willingness to integrate AR technology seamlessly into their exploration of cultural heritage sites, enriching their overall experience and engagement [20]. Hence the hypothesis: *H2: (EE) has a significant positive influence on (BI) to adopt AR technology.*

Social Influence

Social influence, stemming from the sway of peer recommendations, cultural influences, and societal norms, assumes a central role in shaping individuals' behavioral intentions towards AR technology adoption in the context of cultural heritage tourism [7, 14]. The collective endorsement and shared experiences fuel eagerness to engage with this innovative immersive platform, elevating the significance of social influence as a potent motivator for adoption [19]. Hence the hypothesis: *H3: (SI) has a significant positive influence on (BI) to adopt AR technology.*

Facilitating Conditions

Facilitating conditions, encompassing the presence of requisite resources, technical assistance, and robust infrastructure, intricately mold users' behavioral intentions towards AR technology adoption in the realm of cultural heritage tourism [20]. The seamless accessibility and provision of essential prerequisites endow individuals with the means to wholeheartedly embark on this immersive and intellectually rewarding digital expedition [19]. Hence the hypothesis: *H4: (FC) has a significant positive influence on (BI) to adopt AR technology.*

Hedonic Motivations

Hedonic motivation, arising from the pleasure, enjoyment, and emotional fulfillment experienced through interactions with AR technology in the realm of cultural heritage tourism, assumes a pivotal role in propelling users' behavioral intentions towards adoption [7]. The enticement of immersive and captivating encounters serves as compelling factors for embracing this innovative digital realm, further underscoring the profound impact of hedonic motivation as a driving force [21]. Hence the hypothesis: *H5: (HM) has a significant positive influence on (BI) to adopt AR technology.*

Price Value

Price value, encapsulating users' evaluations of the affordability and value proposition of AR technology within cultural heritage tourism, holds a profound sway over their behavioral intentions for adoption [7]. The intricate interplay between cost and perceived benefits assumes a pivotal role in moulding their inclination to embrace this transformative and enriching digital encounter, thereby shaping the decision-making process [19]. Hence the hypothesis: *H6: (PV) has a significant positive influence on (BI) to adopt AR technology.*

Habit

Habit, nurtured by recurring engagements and acclimatization to AR technology within cultural heritage tourism, holds considerable sway over users' behavioral intentions for adoption [21]. The deeply ingrained usage patterns and inherent comfort associated with habituation naturally incline individuals towards embracing this dynamic and evolving digital medium, thus catalyzing their adoption predisposition [7]. Hence the hypothesis: *H7: (HA) has a significant positive influence on (BI) to adopt AR technology.*

Personal Innovativeness

Personal innovativeness, defined by an individual's inclination to embrace novel technologies and pursue innovative encounters, emerges as a compelling determinant impacting users' behavioural intentions towards AR technology adoption in cultural heritage tourism [7, 14]. This proclivity towards exploration and experimentation enhances their likelihood of enthusiastically embracing this cutting-edge and transformative digital platform, aligning with the evolving landscape of technology adoption [12]. Hence the hypothesis: *H8: (PI) has a significant positive influence on (BI) to adopt AR technology.*

Perceived Risk

Perceived risk, stemming from apprehensions regarding potential drawbacks and uncertainties linked to AR usage in cultural heritage tourism such as concerns about eye strain and headaches can exert a notable influence on users' behavioral intentions toward adoption. The mitigation of these concerns assumes a critical role in fostering their acceptance of this immersive digital experience, underscoring the significance of addressing perceived risks to encourage wider adoption [12, 19]. Hence the hypothesis: *H9: (PR) has a significant positive influence on (BI) to adopt AR technology.*

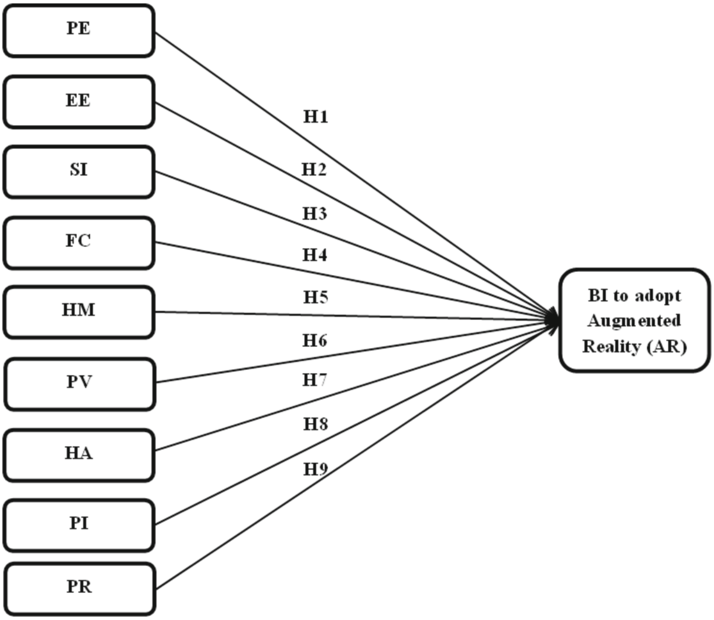

Fig. 1. Conceptual Framework

3 Methodology

Utilizing a cross-sectional design and quantitative methodology, this research meticulously devised a structured survey, subjecting it to rigorous validation and reliability testing via a pilot study. The survey, executed through Google Forms, encompassed a variety of multiple-choice questions aligned with a Likert scale, effectively capturing perspectives on AR adoption within cultural heritage tourism. Concentrating on ardent enthusiasts of cultural heritage tourism in India, the study accumulated data from 435 respondents over a span of two months. To address selection bias, the research employed a snowball sampling technique, which helped to reduce bias by leveraging existing connections and networks within the target population. This approach allowed for a more diverse and representative sample of enthusiastic enthusiasts of cultural heritage tourism in India. This approach facilitated the comprehensive exploration of adoption intentions and patterns. The sample size of 435 was chosen to maintain a 95% confidence level with a 5% margin of error, considering the size of the target population of cultural heritage tourism enthusiasts in India and resource constraints. The respondent demographic showcased a gender split of 56% males and 44% females. Age-wise, 24% belonged to the (18–25) group, 34% to (25–34), 36% to (35–44), and 6% were aged (45 & above). Occupation-wise, respondents comprised 58% employed, 26% self-employed, 13% students, and 3% encompassing households and retirees.

3.1 Measures

The scales for this study were adopted from UTAUT-2 developed by Venkatesh et al. [21], namely, PE, EE, SI, FC, HM, PV, HA and BI. Further, the PI scale sourced from [22]. PR scale was sourced from sourced and modified from [23].

4 Results

The collected data underwent thorough analysis utilizing the SMART-PLS software, incorporating 5000 bootstrap iterations. This meticulous analytical approach ensured the attainment of robust and dependable outcomes, affirming the validity and precision of the study's findings.

4.1 Reliability and Validity

Composite reliability was employed to evaluate the reliability of the measurement model, surpassing the recommended threshold of 0.7 as proposed [24], with values spanning from 0.761 to 0.877. Furthermore, Cronbach's alpha values, ranging from 0.745 to 0.876, signified robust internal consistency reliability, in accordance with [25] standards, as displayed in Table 1. Convergent validity, as assessed by Average Variance Extracted (AVE), demonstrated satisfactory results within the range of 0.660 to 0.801, in accordance with Fornell and Larcker's [26] criteria, affirming the robustness of the measurement model. The study effectively adhered to the discriminant validity guidelines outlined by [26], assuring that each item exhibited its strongest loading on the designated construct, and additionally, that the square root of the AVE for each construct exceeded its correlation with other constructs, as demonstrated in Table 2. This rigorous validation process underscores the distinctiveness and reliability of the measured constructs.

Table 1. Reliability and Convergent Validity

Construct	Item	Factor Loading	AVE	Composite Reliability	Cronbach's Alpha
Performance Expectancy (PE)	PE1	0.850	0.744	0.832	0.828
	PE2	0.892			
	PE3	0.845			
Effort Expectancy (EE)	EE1	0.884	0.801	0.877	0.876
	EE2	0.896			
	EE3	0.905			
Social Influence (SI)	SI1	0.840	0.717	0.803	0.802
	SI2	0.863			
	SI3	0.836			
Facilitating Conditions (FC)	FC1	0.734	0.660	0.775	0.745
	FC2	0.848			
	FC3	0.849			
Hedonic Motivation (HM)	HM1	0.863	0.754	0.841	0.837
	HM2	0.874			
	HM3	0.868			
Price Value (PV)	PV1	0.833	0.699	0.794	0.786
	PV2	0.868			
	PV3	0.807			
Habit (HA)	HA1	0.875	0.724	0.817	0.809
	HA2	0.822			
	HA3	0.854			
Personal Innovativeness (PI)	PI1	0.775	0.675	0.761	0.758
	PI2	0.870			
	PI3	0.817			
Perceived Risk (PR)	PR1	0.788	0.692	0.779	0.776
	PR2	0.859			
	PR3	0.846			

(*continued*)

Table 1. (*continued*)

Construct	Item	Factor Loading	AVE	Composite Reliability	Cronbach's Alpha
Behavioral Intention (BI)	BI1	0.899	0.730	0.817	0.813
	BI2	0.859			
	BI3	0.801			

Table 2. Discriminant Validity

	BI	EE	FC	HA	HM	PE	PI	PR	PV	SI
BI	0.854									
EE	0.647	0.895								
FC	0.671	0.611	0.812							
HA	0.700	0.636	0.662	0.851						
HM	0.719	0.764	0.575	0.759	0.868					
PE	0.700	0.544	0.537	0.628	0.597	0.863				
PI	0.767	0.712	0.649	0.799	0.744	0.638	0.822			
PR	0.576	0.618	0.712	0.711	0.600	0.644	0.707	0.832		
PV	0.710	0.702	0.647	0.708	0.718	0.524	0.746	0.655	0.836	
SI	0.624	0.639	0.661	0.674	0.688	0.616	0.657	0.707	0.583	0.847

Table 3. Structural Paths

Hypothesis Number	Hypothesis Relationship	Estimate	S.E	P Values	Hypothesis Results
H1	PE -> BI	0.336***	0.063	0.000	Supported
H2	EE -> BI	−0.027	0.085	0.754	Not Supported
H3	SI -> BI	0.023	0.089	0.799	Not Supported
H4	FC -> BI	0.264***	0.073	0.000	Supported
H5	HM -> BI	0.163*	0.077	0.038	Supported
H6	PV -> BI	0.202	0.103	0.051	Not Supported
H7	HA -> BI	−0.004	0.092	0.964	Not Supported
H8	PI -> BI	0.311***	0.095	0.001	Supported
H9	PR -> BI	−0.274***	0.077	0.001	Supported

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

4.2 SEM Analysis

The results of the SEM structural model are summarized in Table 3. According to the immediate effects between all independent and dependent variables, Hypothesis H1, H4, H5, H8 and H9 are supported as PE ($\beta = .336$, SE $= .063$, $p \leq .001$), FC ($\beta = .264$, SE $= .073$, $p \leq .001$), HM ($\beta = .163$, SE $= .077$, $p \leq .05$), and PI ($\beta = .311$, SE $= .095$, $p \leq .001$) have a significant positive influence on BI to adopt AR for cultural heritage tourism and on the contrary PR ($\beta = -.274$, SE $= .077$, $p \leq .001$) showed to have significant negative impact on BI. Hypothesis H2, H3, H6, H7 are not supported as EE ($\beta = -.027$, SE $= .085$, $p = .754$), SI ($\beta = .023$, SE $= .089$, $p = .799$), PV ($\beta = .202$, SE $= 1.03$, $p = .051$), and HA ($\beta = -.004$, SE $= .092$, $p = .964$) have no significant influence on BI.

5 Discussion

The study addressed the research question with nine hypotheses. H1 was accepted, indicating that (PE) positively influences (BI) towards AR adoption in cultural heritage tourism, consistent with previous research [7, 14]. The service industry is undergoing swift expansion, generating abundant prospects for these technologies [27]. Tourists expect improved experiences and insights with AR, motivating their intention to adopt this technology. This aligns with technology acceptance literature, emphasizing tangible benefits as drivers for embracing innovations, highlighting AR's potential to enhance cultural heritage tourism. H2 and H3 were rejected, revealing that (EE) and (SI) had no significant relationship with (BI), consistent with prior findings [7]. In cultural heritage tourism, users may find AR interfaces intuitive, reducing barriers, and personal connections and curiosity may outweigh external opinions in technology adoption. H4 was accepted, indicating that (FC) significantly influences (BI), consistent with [19] and contradicting [7]. Accessible resources, technical support, and user-friendly infrastructure boost confidence in AR use at heritage sites. H5 was accepted, revealing a significant positive relationship between (HM) and (BI), consistent with [7]. AR's immersive nature aligns with the desire for enjoyable experiences, driving BI for cultural heritage exploration. H6 and H7 were rejected, showing no significant relationship between (PV) and (HA) with (BI), similar to previous findings [7]. Visitors prioritize experiential and educational value over cost considerations, and habitual tendencies may have limited influence in this context. H8 was accepted, indicating a substantial positive relationship between (PI) and (BI), consistent with previous studies [7, 12, 14]. Those open to innovative experiences are more likely to embrace AR, enhancing cultural heritage tourism. H9 was accepted, showing a substantial negative relationship between (PR) and (BI), consistent with previous studies [12, 19]. Higher perceived risk reduces confidence in AR's effectiveness and safety, hindering BI towards adoption and exploration of cultural heritage sites through AR.

6 Conclusion

Integrating personal innovativeness and perceived risk into the extended UTAUT2 framework enhances our understanding of AR adoption in cultural heritage tourism, aligning it with the unique heritage context. Personal innovativeness signifies openness to new experiences, while perceived risk explores technology uncertainties in historic settings, shedding light on motivations and barriers. Practical implications benefit tourism businesses, managers, and AR developers. Firms can tailor marketing to visitor segments' innovation openness and risk concerns. Managers can craft bespoke experiences, reducing risk perception and boosting visitor engagement. AR developers should prioritize user-friendly interfaces and clear communication, ensuring positive user experiences in cultural heritage tourism. However, the research's limitations include its focus on a specific Indian demographic, limiting generalizability. Unexplored factors like cultural norms and contextual cues may impact AR adoption. Future research could broaden demographics, explore cultural variations, and examine factors like contextual cues or emotional resonance in AR adoption, deepening our understanding of this evolving landscape.

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Trends and Developments in the Use of Machine Learning for Disaster Management: A Bibliometric Analysis

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Abstract. The frequency of the occurrence of disasters, and the severity of their effects have both been significantly rising over the past few decades across the world. Recognizing the potential of Artificial Intelligence (AI), particularly its subset, Machine Learning (ML), this study delves into its application in disaster management. More specifically, this study adopted the bibliometric analysis methodology to examine the most active authors, countries, and institutions in research related to the use of ML in disaster management and to investigate the trending themes associated with ML use in disaster management. Based on the results, it can be concluded that the citation networks demonstrate the close collaboration between the USA, India, China, and Australia. India had the most articles cited with 1672 citations, despite China having the largest production of research related to the use of ML in disaster management. Furthermore, besides "disaster management" and "machine learning" which were expected to be part of the key drivers in this research area, "remote sensing" also emerged as a trending topic. Based on the thematic analysis of the various articles retrieved in this study, future research must include fourth industrial revolution (4IR) technologies, as they are crucial to disaster management.

Keywords: Bibliometric Analysis · Disaster · Disaster Management · Machine Learning

1 Introduction

In recent decades there has been a marked increase in both the incidence and magnitude of global disasters [1]. The inherent disaster risks, already substantial, are projected to escalate further without timely and adequate emergency interventions. In the formulation of strategies to enhance disaster resilience, the deployment of advanced technological solutions emerges as a potential game-changer [2]. Social media technologies like Facebook and Twitter have successfully been used in various contexts to spread communication on disaster-related issues like earthquakes, floods, terrorist attacks, road riots, civil unrest, fire and many others [3, 4]. Despite the fact that social media gives users the chance to

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interact, exchange, and seek information, as well as organize rescue and relief operations during disasters [4], it is unable to foretell and predict the future from a well-informed position.

The newest disaster management techniques aim to combine disaster management theories and practices with cutting-edge digital technology solutions, where Machine Learning (ML) applications are the most common [1, 5]. As part of disaster management, mitigating natural disasters can be accomplished by accurate and trustworthy assessment [6]. In fact, ML is perceived as one of the Artificial Intelligence (AI) technologies in the management of disasters [7]. Precisely, [8] posits that ML algorithms can effectively detect floods, with an accuracy level of up to 90%. The capability of ML models to extract information directly from data without making preconceived assumptions is their primary advantage in disaster prediction, such as floods [9].

The widespread use of bibliometric analysis in business research is not a passing trend; rather, it is a result of its value in managing enormous amounts of scientific data and generating highly influential research [10]. Bibliometric analysis is particularly effective in detecting changes and increases in scientific production over time [11]. Utilizing the bibliometric analysis technique allows for a comprehensive assessment of the volume and scope of research in a specific domain [12]. Such an evaluation profoundly influences the direction of subsequent research endeavours and aids in discerning the prevailing thematic trends in the field [13]. Given the exponential growth in the volume of academic literature over the past few years, the bibliometric analysis technique may be a viable strategy for revealing intricate patterns of linkages among a huge body of literature [14], making it easy to track changes and increases in scientific knowledge over time [11].

The purpose of this paper is to analyze the trends and developments in the use of ML for disaster prediction and management. Therefore, the objectives of the study are to examine the most active research authors, countries, and institutions in ML use in disaster management and to investigate the trending themes associated with ML use in disaster management.

2 Background

A disaster is described as an undesirable occurrence over a brief or lengthy period that has a profound impact on the community or society as a whole and causes significant damage to the economy, infrastructure, environment, and human population [15]. Locating and providing immediate assistance to adversely affected communities is one of the fundamental elements in reducing the effects of a disaster [5]. Therefore, disaster management is the process of allocating resources and duties to mitigate the effects of a catastrophic occurrence [5, 16]. Rapid emergency resource deployment can greatly help in mitigating the impact of loss due to disaster.

Despite the preparations made by disaster relief organizations, a significant number of deaths are reported each year because of disasters. This calls for researchers to develop effectively optimized techniques that may be used in situations involving disasters [17]. The disaster management cycle was developed to reduce the disaster risks and alleviate impending dangers in a disaster event, with the following phases: pre-disaster, emergency response, and post-disaster [16, 18]:

- the *pre-disaster phase* (preparedness, early warning, and mitigation are the key activities at this phase; attempts to prepare for catastrophes, considering the necessary emergency response mechanisms and procedures, emergency management initiatives, the preparation of evacuation sites, and the supplies and equipment needed for infrastructure and facility restoration).
- the *emergency response phase* (assessing the situation, searching for, and rescuing victims, meeting basic requirements, protecting vulnerable populations, and repairing infrastructure and facilities) and
- the *post-disaster phase* (public service enhancement and rehabilitation to stabilise the community, rebuild damaged buildings and infrastructure, and restore public services to normal).

There is evidence in the literature that ML can enhance disaster management and many other forms of risk reduction [19]. In Indonesia, a study was carried out using ML techniques with the goal of expediting the response time of search and rescue teams and increasing victims' survival rate by considering victim priority-setting, combined with mobile disaster applications [16]. In the study, the suggested approach demonstrated that victims can be given priority based on the prediction's significant accuracy.

To identify and categorize transport disasters in Nigeria, five ML classification methods, namely, Bidirectional Encoder Representations from Transformers (BERT) model, Random Forest Classifier (RFC), Decision Tree (DT), Support Vector Machine (SVM), and eXtreme Gradient Boosting (XGBoost) were applied to tweets obtained from the Twitter Application Programming Interface (API) [3]. The developed model had a performance accuracy of 82%, and it was concluded that it was a good prediction technique.

In Hiroshima, Japan, a study on the applicability of different ML models during a disruption of the transportation network was carried out [20]. In the study, the RF, SVM, XGBoost, shallow Feed-Forward Neural Network (FFNN), and Deep Feed-Forward Neural Network (DFFNN) were used, with a focus on their propensity to predict traffic states and the interpretability of the results. The findings show that while Deep Neural Network (DNN) models offer better outcomes in terms of the results interpretability, RF and XGBoost approaches produced the best results in terms of prediction accuracy. These results showed that the best model for forecast accuracy is not necessarily the best model for practical application because it does not mirror the mechanics of congestion formation.

As a significant step towards disaster prevention, sustainability, and decision-making, 11 provincial administrative regions in coastal China were used as the study areas to estimate Storm Surge Disaster Loss (SSDL). RF, XGBoost, Logistic Model Tree (LMT), and K-star were used to build the estimation model of SSDL grades [21]. The findings demonstrated that the K-star model is the ideal SSDL estimation model, with the benefits of accurate estimate, good generalization, and reduced workload.

3 Methodology

Bibliometric analysis entails the use of quantitative/statistical tools to analyze patterns in scholarly publications (journal articles, conference proceedings, and other research articles) [22]. In this paper, bibliometric analysis was chosen as the preferred methodology because it seeks to determine quantitatively the development patterns, research foci, and potential future research directions in a specific research area. The two basic data analysis methods used in bibliometrics are science mapping and performance analysis. Science mapping strives to display the trends, dynamic evolution, and knowledge structure in a particular subject while performance analysis uses bibliometric data to evaluate the influence of activities by scientific actor groups like researchers, institutions, and countries [23].

Due to the multidisciplinary nature of the scope of this paper, the Scopus academic database was chosen from the many recognized indexing and abstracting databases since it is a highly multidisciplinary reputable, robust, and trustworthy database [10]. The following search string was run in the Title, Abstract and Keywords sections of the Scopus database (the query was run on 29 July 2023): ((“machine learning” OR “artificial intelligence”) AND (“disaster prediction” OR “disaster management”)). The period of search was automatically set from 1987 to 29 July 2023. Various document types were considered, including journal articles, conference proceedings, review articles, books, book chapters, conference reviews and editorial articles. There was no restriction on the language(s) used.

4 Results

A total of 972 original articles were retrieved from the Scopus online database. The articles were written by 3263 authors, contained 5847. A significant level of collaboration between authors from numerous countries was evident in these articles, as corroborated by the international co-authorship rate of 24.38%.

This section will describe the results based on the growth trends and publications, the network analysis, highly cited papers, the mostly used keywords and trending topics in the use of ML in disaster management.

4.1 Growth Trends and Publication Output

The number of articles on the application of ML in disaster management expanded rapidly between 1987 and 2023. From the year 1987 to 1996, there were only two publications in the subject area of ML use in disaster management. Between 1997 and 2004, there were isolated instances where a single publication would be produced per year. The scientific production of articles gained positive traction from 2009, with a record of 218 articles published in 2022. Most notably, 88% of the articles were published within the last decade (857 articles).

To properly comprehend this trend, the leading countries, sources, authors, and their affiliations were analyzed. The 10 most prolific countries, sources, authors, and their affiliations are presented in Table 1. A total of 63 countries, 561 sources, 2 513 authors,

Table 1. Top 10 countries, sources, authors, and affiliations for ML use in disaster management.

Countries	F	Sources	F	Authors	F	Affiliation	F
China	126	*Sustainability (Switzerland)*	21	Munawar HS	6	Beijing Normal University	12
India	111	*ACM International Conference Proceeding Series*	18	Kim J	7	National Taiwan University	12
USA	75	*Natural Hazards*	18	Li H	7	University of New South Wales	12
Australia	30	*International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*	17	Park S	6	China University of Geosciences	11
South Korea	30	*Advances in Intelligent Systems and Computing*	13	Wang Y	12	University of Chinese Academy of Sciences	11
Germany	23	*Proceedings of the International Astronautical Congress, IAC*	13	Chen J	9	Duy Tan University	10
Iran	22	*Water (Switzerland)*	13	Fan C	4	Texas AANDM University	10
Turkey	17	*IEEE Access*	12	Hammad Awa	4	University of Tehran	10
Canada	15	*International Journal of Disaster Risk Reduction*	12	Mosfavi A	4	Hacettepe University	9
United Kingdom (UK)	14	*IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*	11	Wang X	9	Islamic Azad University	9

and 1 427 affiliations are represented in the table. Of the 63 countries involved in research on the use of ML in disaster management, China published most of the articles (126, n = 972, accounting for 13.0%), followed by India (111, n = 972, accounting for 11.4%), and the USA (75, n = 972, accounting for 7.7%). From a total of 561 sources, the journal

Sustainability published most of the articles with 21, followed by *ACM International Conference Proceeding Series* and *Natural Hazards* with an equal number of publications (18 articles). A total of 2 513 authors contributed to the publications, with Munawar, H. S. (6 publications), Kim, J. (7 publications), and Li, H. (7 publications) being the top three (note: these authors may not necessarily have received the most citations). Beijing Normal University, National Taiwan University, and the University of New South Wales were the top-ranking institutions in the use of ML in disaster management research, with each having 12 publications.

4.2 Network Analysis

4.2.1 Country Collaboration Map

Figure 1 depicts author collaboration across the world in the production of the articles. The USA, India, China, and Australia had the strongest major collaboration amongst themselves and with many countries globally, with minor collaborations that included Canada, Norway, and few South American countries. In fact, the strongest collaborations were between India and the USA (17), China and the USA (11) and Saudi Arabia and Egypt (7). Africa is conspicuous in its absence, with only Nigeria and South Africa collaborating independently with India.

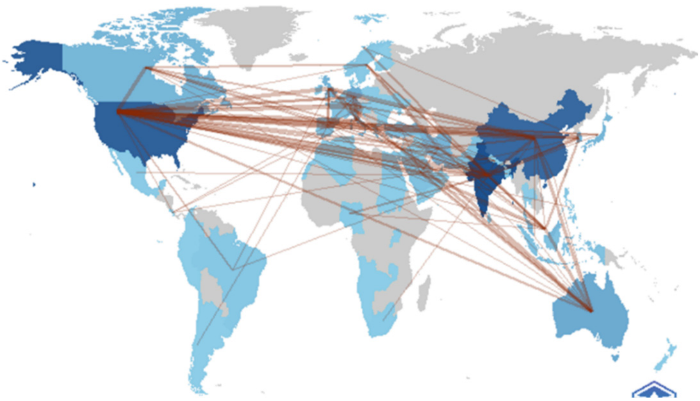

Fig. 1. Country collaboration map

4.2.2 Author Collaboration Network

The potential for research on a particular subject can be determined by an analysis of author collaborations [24], which was done to measure the extent of ML use in disaster management research. Figure 2 displays the authors with the most notable research collaboration, with Imran, M. and Ofli, F; Munawar, H.S. and Hammad, A.W.A.; Beydoun, G and Othman, S.H.; Liu, Y. and Zhang, X.; Mostafavi, A. and Zhang C. having a significant level of collaboration. Zhang, C., Wang, Y., Liu, Y., Zhang, X., Wang, X. and Chen, J. are the most active in terms of collaboration with various other authors.

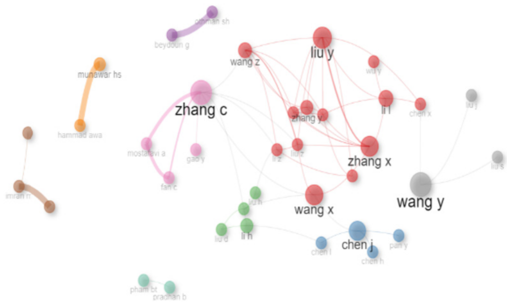

Fig. 2. Collaboration network

4.3 Highly Cited Papers

Papers that receive many citations are typically ones with high academic worth and significant professional influence. Table 2 depicts the various articles in terms of their sources, authors, titles, total citations (TC) and total citations per year (TC/Year).

The articles comprised reviews, modelling using ML, and surveys. Due to the limitations in terms of the maximum allowed length of this paper, we describe the top 2 in the list only. On top of the list was, Chamola, V., Hassija, V., Gupta, V., and Guizani, M. with a publication titled *A comprehensive review of the COVID-19 pandemic and the role of IoT, drones, AI, blockchain, and 5G in managing its impact.* The article, published by *IEE Access* in 2020, attained 700 citations (with 176,25 average citations per year). The study assessed how the Internet of Things (IoT), Unmanned Aerial Vehicles (UAVs), AI, blockchain, and 5G could be used to help minimize the COVID-19 pandemic's negative effects and speed up the recovery process. The study described how numerous emerging technologies, including the IoT, UAVs, AI, blockchain, and 5G, can work together to mitigate the effects of the COVID-19 pandemic [25].

Second on the list, Muhammad, K., Ahmad, J., and Baik, S.W. received 261 citations with 43.50 average citations per year. Their article titled *Early fire detection using convolutional neural networks during surveillance for effective disaster management* was published in 2018 by *Neurocomputing* journal. The research suggested a framework for early fire detection utilizing specialized Convolutional Neural Networks (CNNs) for Closed-Circuit Television (CCTV) security cameras, which could recognize fire in various indoor and outdoor scenarios [26].

4.4 The Most Frequent Words

Influential concepts in ML use in disaster management were derived based on word count totaling 5,847 keywords. Based on the results, "disaster management" had the highest frequency, with a count of 587. This was followed by "disaster prevention", with a count of 556, and "disasters", "artificial intelligence" and "machine learning" recording a count of 532, 368 and 320 respectively. Figure 3 depicts the top 50 frequently used keywords in a tree map.

Table 2. Top 10 papers with the most citations.

Sources and Authors	Title	TC	TC/Year
IEEE Access, Chamola et al. (2020)	A comprehensive review of the COVID-19 pandemic and the role of IoT, drones, AI, blockchain, and 5G in managing its impact	705	176,25
Neurocomputing, Muhammad et al. (2018)	Early fire detection using convolutional neural networks during surveillance for effective disaster management	261	43,50
Environmental Earth Sciences, Tien et al. (2016)	GIS-based modeling of rainfall-induced landslides using data mining-based functional trees classifier with AdaBoost, Bagging, and MultiBoost ensemble frameworks	221	27,63
Int. Journal of Information Management, Ragini et al. (2018)	Big data analytics for disaster response and recovery through sentiment analysis	220	36,67
IEEE Access, Alsamhi et al. (2019)	Survey on collaborative smart drones and Internet of Things (IoT) for improving smartness of smart cities	199	39,80
Geoscience Frontiers, Islam et al. (2021)	Flood susceptibility modelling using advanced ensemble machine learning models	173	57,67
Environmental Research Letters, Sun & Scanlon (2019)	How can Big Data and machine learning benefit environment and water management: a survey of methods, applications, and future directions	169	33,80
Remote Sensing, Shahabi et al. (2020)	Flood detection and susceptibility mapping using sentinel-1 remote sensing data and a machine learning approach: hybrid intelligence of bagging ensemble based on K-Nearest Neighbor classifier	158	39,50
IEEE Communications Surveys and Tutorials Jahanbakht & Hanzo (2021)	Internet of underwater things and big Marine data analytics - A comprehensive survey	131	43,67
Int. Journal of Information Management, Fan et al. (2021)	Disaster City Digital Twin: A vision for integrating artificial and human intelligence for disaster management	131	43,67

Fig. 3. Tree map chart for the 50 most used words

4.5 Thematic Map

The analysis of the significance and development of study topics related to the use of ML in disaster management was done using thematic maps. Based on density (Y axis) and centrality (X axis), thematic maps were separated into four quadrants (motor themes (Q1); niche themes (Q2); declining themes (Q3) and basic themes (Q4)) [27, 28]. The relevance of the themes is established by centrality, while their development is determined by density [29]. The topics in the motor themes quadrant have been created and serve as significant pillars of the research area [28]. The niche themes quadrant contains themes that are highly developed and specialized [28]. The themes in the quadrant for emerging or declining themes are minor in the research area and have a poor level of development [27]. The weakly developed basic themes are represented by the quadrants at the lower right of the theme map, which have higher values for centrality and lower values for density [29]. This is depicted in Fig. 4. "Disaster prevention", "disasters", and "artificial intelligence" fall within the emerging or declining themes quadrant (Q3). This means that "disaster prevention", "disasters" and "artificial intelligence" are the least investigated themes in the context of the use of ML for disaster management. On the other hand, "disaster management", "machine learning" and "remote sensing" are the key driving themes with respect to the adoption of ML in disaster management. These are the central and developed themes in the research area.

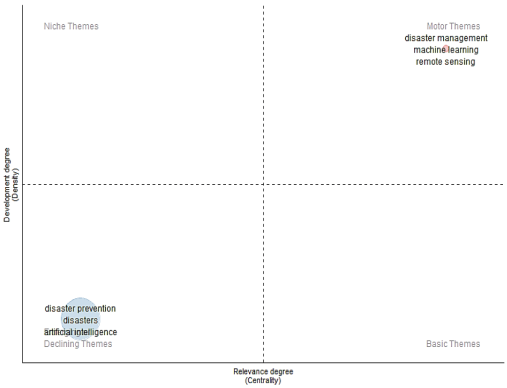

Fig. 4. Thematic map

5 Discussion

The results of the bibliometric analysis have yielded various inferences and interpretations that can be discussed in detail.

China and India (Asian countries) lead in terms of the production of articles on the use of ML in disaster management. Furthermore, 8 out of 10 of the most relevant affiliations were institutions within the Asian continent with China as depicted in Table 2. This further reiterates the proactiveness of Asian countries in relying on technologies like ML to proffer solutions that help mitigate the impact of disasters. The same can be levelled for authors in that all the top 10 authors are affiliated with Asian institutions except for Munawar H.S. who is affiliated with an Australian institution. Such findings are supported by [30] who indicated that India, China, Iran, and Turkey, together with the USA, are among the top-ranked risk countries in terms of natural disasters. This could be the motivating factor why the countries, institutions and even prominent authors are originating from these countries.

The reliance on technology in proffering solutions to any form of disaster is reiterated by the thematic map. Indeed, "machine learning" and "remote sensing" are the emerging themes, which are the key drivers in disaster management. The thematic map indicates "disaster prevention", "disasters" and "artificial intelligence" as either emerging or declining themes. Therefore, there is a need for continuous engagement and development on nurturing emerging themes like "artificial intelligence" in "disasters" and "disaster management" so that they develop and mature. Although "artificial intelligence" emerged in the emerging or declining quadrant, it stands out to be one of the key drivers of disaster prevention. There are cases which can be referenced to substantiate the use of ML in disaster alleviation mechanisms. In a case study carried out in Karachi in Pakistan [31], flood locations were determined using ML models to determine rainfall quantities. Equally, four major categories of natural disasters, including earthquakes, floods, cyclones, and wildfires, were classified using the Convolution Neural Network (CNN) designs [32]. For the purpose of making emergency decisions and ensuring economic sustainability in China, the XGBoost model was also utilized to precisely predict the typhoon storm surge disaster loss (TSSDL), according to a study [33].

As [34] posited, the application of ML can significantly enhance flood susceptibility mapping, providing a more accurate method of prediction.

Remote sensing is exponentially gaining momentum in disaster-related issues. In their study, [35] stressed the significance of remote sensing as an emerging technique that has lately been actively used in research on disaster risk zoning. For landslip susceptibility prediction and modeling, remote sensing utilizes satellite imagery to offer key environmental element layers, such as land cover, topography, and anthropogenic activities [36]. This is the perhaps the reason why remote sensing is perceived as a driving theme in relation to disaster management mechanisms, as informed by the thematic map in Fig. 4. Therefore, flood risk maps may be created properly using remote sensing technology [34].

6 Conclusion

This article analyzed research studies that were published between 1987 to 2023 using bibliometric analysis tools and methods. Using the Scopus online database, 972 original documents were retrieved. Analysis was done based on the trends in growth and production output, collaboration amongst the authors, countries, and affiliations. The analysis of the top journals and authors in the publications largely focused on the total number of publications and the number of citations. The most frequently used words in the use of ML in disaster management were also examined, with the evolving trends in the use of the identified keywords. Equally, the study analyzed and deduced the development of study themes surrounding the use of ML in disaster management.

Based on the bibliometric analysis results, “disaster prevention”, “disasters” and “artificial intelligence” are the least investigated themes in the context of the use of ML for disaster management and, therefore, future research should focus on these areas. Additionally, many additional large collections can be included in the scope of the articles, as opposed to the use of the Scopus database only. Integration of other online databases in the search process may result in a comprehensive yet robust analysis, with more insightful results. For researchers interested in this topic across the globe, this article offers some reference value.

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Emerging Next Generation Technology and the Challenge of Expanding Agility Across the Enterprise: An Engaged Scholarship Approach

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Abstract. Emerging Next Generation technology such as metaverse, AI systems and Conversational AI are largely open and fluid requiring the enactment of a similarly fluid and agile adoption approach across the enterprise. However, organisations continue to face cultural challenges in their attempts to enact agility despite their formalistic endorsement of it. This study adopts an engaged scholarship approach based on design science research to theoretically and practically develop a tool that supports organisations in their effort to enact and embed agility across the enterprise. The developed tool has been evaluated through a series of interviews, workshops and observations. The finding shows that it acts as a boundary object amongst members of an agile team that helps create a common understanding of the desired agile values and reduces the discrepancy between the endorsement of the values and their enactment through everyday practices. This study contributes to theory and practice by supporting the enactment of the necessary fluidity required for the successful adoption of emerging technology.

Keywords: Emerging technology · emerging technology adoption · agile enactment · agile culture · visual inquiry tool · value enactment · boundary object

1 Introduction

The adoption of emerging Next Generation technology such as Metaverse, AI and Chatbots is open-ended, characterised by high fluidity where both the technology and use cases continue to evolve within the organisation [11, 13]. This fluidity, characterised by constant movement and change, brings on new challenges as it blurs existing and known categories and boundaries and calls for different ways of perceiving the world and researching it [4]. Hence, its successful adoption hinges on adopting agile development approaches across the enterprise (i.e., scaling agile [10]) and moving from only

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endorsing agility to enacting agility in everyday practices [18]. One of the identified key challenges in adopting agile approaches at scale is the embedding and enacting of agile culture [22]. Culture is largely intangible and complex involving values, cognitive schemas, and behaviours [32]. While the endorsement of agile could speak to the cognitive schema, values and behaviour remain to change. Scholars argue that values can be endorsed (talked) but not necessarily enacted (practiced in everyday) [34]. Hence, while a team might adopt agile methods and artefacts, this adoption can be limited to routinised rituals and does not necessarily translate into a wider change in practices. Furthermore, despite the use of a shared vocabulary (e.g., values from the Agile Manifesto [5]) the enactment (meaning behind the values and the resulting practices) can differ from team to team and person to person [14]. This highlights a semantic boundary as described by Carlile [7], where individuals use a common language but interpret and practice it differently. This nebulousness and lack of a common understanding adds to the challenges organisations face in their wide adoption of agile approaches to support emerging technology adoption.

This study adopts an engaged scholarship approach based on design science [20] to develop an artefact; a tool that helps organisations cross the chasm between the endorsement of agile values and the enactment of those values in everyday practices and achieve common practical understanding between teams members that influence their everyday behaviour. It answers the research question: *How to develop a tool to help organisations enact agility in everyday practices?*

Through a series of interviews, workshops and observations, the study develops and validates a visual tool that allows a shared visualisation and supports a common understanding and evaluation of everyday practice [2]. We performed three design cycles including co-design sessions [30] with agile coaches and an exploratory focus group with agile coaches and agile teams [40]. We then evaluated the efficacy, efficiency, ease-of-use [2] and perceived usefulness [9] of the resulting artefact via expert interviews and a confirmatory focus group [40]. The designed artefact presents a visual and practical boundary object termed the Agile Team Canvas (ATC). Specifically, the ATC is a visual inquiry tool [2] that helps its users reach a common understanding of their enactment of agile values and aligns the actions they do with their agile vision, thus reducing the semantic boundary and subsequently inviting them to formulate actions and commitments to enact the vision via everyday practices.

The study contributes to practice and theory by crossing the chasm between the endorsement of agility and the practicing of it in everyday supporting the enactment of the necessary fluidity required for successful adoption of emerging technology. Regarding practice, the study offers an efficient, easy-to-use and useful tool that improves the connection between endorsed agile values and the enactment of these values in everyday practices and hence supports organisations scaling agile. Regarding theory, the study contributes to the design knowledge [3] by advancing the emerging literature on visual inquiry by extending it to closely link the visual inquiry tool to actions and commitments in the organisation and in doing so crossing the chasm between identification and actions.

The remainder of the paper unfolds as such: in Sect. 2 we provide a theoretical background for the study. In Sect. 3 we discuss the research design and process. Section 4 presents the ATC and the subsequent section, presents its evaluation. Finally, in Sect. 6 we conclude the study by bringing forth its contributions and main limitation.

2 Background Literature

2.1 Agile Value Enactment

The notions of flexibility, speed, and willingness to adapt and learn are not particularly new [8], however, emerging technologies are increasingly fluid and their successful adoption hinges on organisations enacting agility in everyday practices.

While the adoption of agile approaches can be successful in some teams, its wide adoption and enactment in everyday practices is difficult and encounters many obstacles including the expansion from endorsement and formalistic adoption to the enactment of practical behaviour in everyday encounters [17, 24]. It is the enactment of agile values and culture that influence the adoption of emerging technologies [24]. Components of agile culture include the ability to self-organise, flexibility and adaptability, autonomy, collaborative team spirit, open information sharing, continuous improvement, trust climate and innovation climate [29].

An organisational culture is intangible and intricate, consisting of underlying assumptions, values and visible artefacts [32]. Scholars find that everyday practices can be changed through everyday framing [1], this suggests that the enactment and integration of the desired values can start from endorsement, but requires further interventions to move the endorsement to everyday behaviour and action. In their study, Sheldon and Krieger [34] uncover a discrepancy between the endorsement of values and their enactment. They refer to the endorsement as the "talking" and the enactment as the "walking" and identify that individuals tend to talk more than they walk. To sustain the change and anchor the new learnings and practices (the walk), behaviours should be internalised by individuals in the organisation [31]. To ease this, individuals are encouraged to observe and explore their current situation and are later invited to develop personalised solutions that align with their characteristics [31]. In addition to the current situation, it is necessary to have a common and well-defined understanding of the desired vision [31]. Concurrently, Willcoxson and Millett [43] argue for the need to thoroughly recognise and comprehend the features of the current and target culture prior to acting on it. However, to establish a common understanding of the desired vision, individuals must overcome the semantic boundaries between them.

2.2 Semantic Boundaries and Visual Inquiry Tools as Boundary Objects

The move from the endorsement of agility to the everyday practice of it is embedded by semantic boundary which is described by Carlile [7] as when individuals use a common language but interpret and practice it differently. Semantic boundaries can impede everyday action and practice since communication and collaboration, even when there is a shared language and syntax, is hindered by different interpretation [7]. For example, although individuals may use the same vocabulary, such as agile values [5], their interpretation and enactment differ [14]. Hence, there is a need for objects to cross this boundary chasm to allow users to represent and create a common practical understanding. These objects should possess sufficient adaptability to encompass diverse meanings that stem from various settings or groups yet, they should remain robust enough to uphold a consistent structure across the settings and are thereby recognisable [36]. A boundary object can be either conceptual such as a theory [35], or physical such as an artefact [16]. In IS, boundary objects have been studied for example through the lens of digital boundary objects for innovative software products [44] or as a means to sway group interactions and creation of ideas for business model innovation [16].

In particular, *Visual* artefacts as boundary objects have proven to be successful in creating a common and comprehensive understanding of the issue at hand [e.g., 2, 15]. Examples of such tools are the widely adopted Business Model Canvas [27] and the Brand Identity tool [15]. Joint inquiry is a process where together, people explore a problem space and ideate on the possible solutions [37]. A canvas is a *visual inquiry tool* that allows its users to jointly and visually explore a problem and ideate on possible solutions. According to Avdiji et al. [2], it bears the following characteristics: *functionality* suggests that the shared visualisation (i.e., canvas) must support the directions of use. *Arrangement* relates to how the association between the empty design spaces must be visually suggested. Third, *facilitation* concerns the affordance of the tool that must be facilitated by having a tool that is easily understood by its users and thereby, parsimonious.

3 Research Design and Process

To meet the objective of this study, we adopt the Design Science Research (DSR) paradigm [20]. DSR aims to develop a new or improved artefact to solve a real-world issue through iterative building and evaluation of the designed artefact with insights from both the environment (i.e., field) and existing knowledge base (e.g., body of literature and different theories) [20]. To this end, we structure the DSR project around the process model proposed by Peffers et al. [28] that lists the following steps: (1) Identify and motivate the problem, (2) define objectives of the solution, (3) design and development, (4) demonstration and evaluation and (5) communication as follows.

3.1 Identify and Motivate the Problem

Our entry point to the selected DSR process model was problem-centred [28] and to ensure the generalisability of the problem space, in this study, we identified the problems through a multi-grounded approach, containing both empirical and theoretical sources: a nine-month field study, expert interviews, and existing literature (Table 1).

From our multi-grounding approach, we identified and motivated a two-fold problem teams faced when agile is being scaled at large: The first concerns the discrepancy between endorsement and enactment [34]. Although AviaCorp had implemented and adopted Scrum ceremonies, they were merely a façade. As an example, teams would carry out retrospectives which are a Scrum ceremony where team members must reflect on what went well in the past few weeks and what could be improved and how [33]. However, they proved to be ineffective as no one felt comfortable voicing their thoughts and highlighting

Table 1. Input knowledge for problem identification and motivation

Research activity	Objective	Description
Field study (9 months, in 2020)	Collect problems	We partnered up with AviaCorp: a large, Swiss, state-owned (1.500 employees) organisation operating in the aviation industry. AviaCorp had been conducting a scaled agile transformation since 2018. We engaged with employees in nascent and mature agile teams, performed internal document analysis, conducted interviews and took part as participant-as-observer [19] in agile team meetings (ref. For further detail blinded for review)
Expert interviews (2021)	Collect and confirm/validate problem	We interviewed seven senior agile coaches (45–60 min) from different organisations to ensure that our findings from the field study could be traced back to a class of problems. We recorded and manually coded the interviews verbatim for analysis accuracy
Literature	Create foundation for study, confirm problem and identify existing solutions	We reviewed existing literature on agile, organisational culture, value enactment and endorsement, and boundary objects

team issues. As a result, they were not able to effectively exploit the Scrum ceremony that intends to sustain the learning, exchange of information and improvement of the team functioning [33]. Therefore, while a team may adopt agile methods and artefacts, it does not necessarily result in a broader shift in behaviour and underlying values. Hence, AviaCorp had endorsed its intention to be agile along with the values that went along (talked), they were not however enacted (walk) because, as per the previous example, individuals did not feel safe to speak their minds and communicate. Second, we identified that there was a general misunderstanding of what being agile practically entailed and that the vision of agile differed from group to group and from person to person. We observed that despite the use of a shared vocabulary based on the values of the Agile Manifesto [5] for example, individuals and teams still struggled with understanding what it concretely meant for them to be agile, thus leading to asking "*What does it mean for us to be agile as a team?*" (from field study). This represents a semantic boundary

[7], where although everyone in an organisation is using a common vocabulary, its interpretation and practices differ. An interviewee (from the expert interviews) gave us an example: self-management, which is a tenet of agile, is enacted differently and to a different degree from one team to another. Therefore, a same value may mean something different in practice from team to team, and person to person, and it is for the team to develop and institute common understanding and practices. This is important because a common understanding and agreement on the desired vision must be defined prior to the change [31].

3.2 Objectives of a Solution

We derived requirements and formulated design principles by drawing on the literature (main points presented in justificatory knowledge, Table 2) and our empirical sources (field study and expert interviews in Table 1).

Table 2. Requirements and Design Principles for ATC

Requirement	Justificatory knowledge	Design principle
R1: When being used, the ATC should allow teams to inquire about their culture jointly and visually	When addressing such type of intangible problem, it is recommended to jointly and visually inquire on the topic [2]	DP1: To allow teams to inquire jointly and visually, the ATC should be a visual inquiry tool [2] that acts as a boundary object [7]
R2: When being used, the ATC should allow teams to identify their as-is, their to-be (their desired agile culture) the gap between them and formulate (everyday) actions to enact the to-be (reduce the gap)	To act on culture, individuals must first identify the characteristics of the current culture to then be able to identify the gap [31, 43]. To reduce the gap, an everyday reframing through the internalisation of new practices is recommended [1]. Walking the talk [34]	DP2: For the ATC to allow teams to identify their as-is, the gap between the as-is and to-be and formulate everyday actions to enact the to-be (reduce the gap) it must contain visual spaces for those elements and represent the appropriate flow of use
R3: When being used, the ATC should allow teams to create a common understanding of their desired agile vision (to-be)	Recognise and comprehend the elements of the desired culture [31, 43]	DP3: To allow teams to create a common understanding of their desired agile vision (to-be), the ATC must offer a visual space to do so

3.3 Design and Development

To develop the ATC, in 2021–2022, we conducted three design cycles and drew on the design principles for the ATC (Table 2) and the design theory for visual inquiry tools [2] that proposes guidelines for the proper design of a visual inquiry tool: (1) the development of a parsimonious *conceptual model* that frames the subject of interest, (2) its instantiation into a *shared visualisation* by creating empty design spaces, and (3) the development of *directions of use* that allow for joint inquiry.

Design Cycle 1: The aim of this first design cycle was to instantiate the adopted conceptual model of agile culture [29] into a shared visualisation and derive directions of use (as per the design theory for visual inquiry tools [2]). To do so, we conducted a co-design [30] workshop which included an agile coach (4 years of experience) and a user experience (UX) designer (5 years of experience). The workshop lasted two hours. The agile coach is the domain expert, and his role was to inform us about his day-to-day job and thus help us further understand the addressed problems. The expertise of a UX designer is the user-artefact interaction. Given that, his role during the workshop was to help us ideate on the use case. We began the co-design workshop by presenting the conceptual model of agile culture to the agile coach and UX designer. The conceptual model served as a basis for the ideation process. We used paper prototyping as boundary object between the workshop participants and us to instantiate the first version of the ATC.

Design Cycle 2: We conducted an exploratory focus group [40] which lasted 90 min. The objective of exploratory focus groups is to improve the artefact through increments [40]. Our research objective was to test the first version of the ATC and collect insights and feedback from participants to refine its design. To that end, we recruited 13 agile practitioners (working in an agile team) and agile coaches who were willing to participate in the exploratory focus group voluntarily through the Swiss Agile Association. Two moderators observed and took notes to avoid subjective bias. Therefore, while the participants were using the ATC, we acted as observer-as-participants [19] whilst taking notes of participants' behaviours, interactions and dialogues [39]. We concluded the exploratory focus group with a 45-min moderated discussion with the 13 participants. We collected feedback regarding participants' feelings, opinions and ideas [39]. Finally, to improve the accuracy of the analysis, we video- and audio-recorded the workshop to refer to it when needed (i.e., when the notes had failed to capture the elements of interest).

Design Cycle 3: The objective of the one-on-one workshop was to improve the ease-of-use of the ATC, thereby enhancing its *arrangement, functionality* and *facilitation* [2]. In that regard, we conducted a 120-min one-on-one workshop with an experienced agile coach (5 years of experience in working with large multinational organisations scaling agile). We refer to workshops in the sense of Thoring et al. [39] that have suggested workshops as a way to design and evaluate artefacts in design science research. Accordingly, during the workshop, we delved deep into the ATC and brainstormed on the flow of usage, the name of the pillars and the layout of the empty spaces.

4 Artefact Description: The Agile Team Canvas (ATC)

In this section, we describe the result of the three design cycles. Overall, the ATC is composed of a canvas (which includes two parts: Diagnostic and Action) and three cards (Fig. 1).

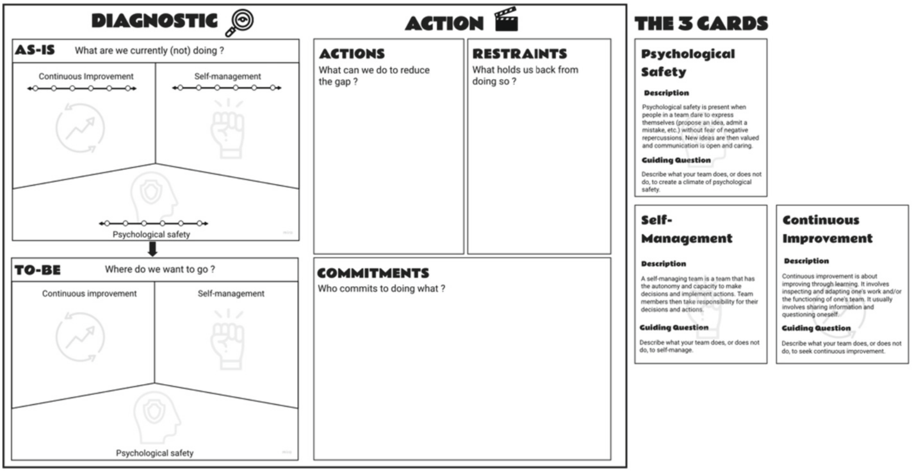

Fig. 1. The Agile Team Canvas (ATC)

Part 1: Diagnostic. The objective of this first part is to help participants create a common understanding of their current situation (as-is) and desired agile vision (to-be), thus addressing the semantic boundary problem. This creation of a common understanding and vision is necessary prior to taking action [31, 43]. In that regard, the Diagnostic includes two steps: *(1) As-is*: participants are asked to inquire on "What are we currently doing?". They must describe their current situation by identifying their current practices around the three key pillars of agile culture: psychological safety, self-management, and continuous improvement (further described in the following section). They do so by answering the set of guiding questions (written on the cards) that are specifically formulated to elicit information about the practices relating to the three key pillars. They then collectively agree on their perceived level of each pillar. This gauge will act as a benchmark along their agile journey. *(2) To-be:* participants discuss and identify what constitutes their desired agile vision. They negotiate the meaning behind the language of agile and the three pillars to create a common and shared vision (reducing the semantic boundary). They do so by answering "Where do we want to go?" Although resting on the same three pillars, each team will have its unique interpretation of what an agile culture looks like. Hence in this second step, the team must discuss and formulate a common vision of its desired to-be around the three pillars.

Part 2: Action. The second part of the ATC concentrates on reducing the gap between the as-is and to-be by finding ways to enact the vision through everyday practices. This part includes three steps: *(3) Actions:* team members answer the question: "What can we do to reduce the gap?". They are asked to come up with practices they could start or stop to enact the vision and thus, reduce the gap. According to Schein [31], it is essential for individuals to generate their own solutions, as they will be more likely to stick to them. This is important because, for there to be a lasting effect on the deeper levels of the culture (i.e., values), it is necessary for individuals to willingly adopt and internalise these new practices [31]. *(4) Restraints:* participants reflect on "What holds us back from doing so?”, thus diving deeper into the practices they identified in the previous step. Schein [31] suggests that the most effective way to produce change is to minimize the restraining forces that impede it. One of those restraining forces is the “learning anxiety”, which is what holds people back from changing. Accordingly, the participants must identify and examine the restraining forces that would hold them back from doing the actions they identified in the previous step. *(5) Commitments:* participants address the question: “Who commits to doing what?” At this point, the participants know what they must change, how they could change (action) and what might hold them back from doing so (restraints). They solidify the insights from the previous steps by formulating commitments that are time-bound, specific, actionable, and achievable. With the commitments, the participants will be actively contributing to the everyday reframing of the culture [1] and thereby, effectively walking the agile talk.

Finally, the ATC is not set in stone. Rather, it will evolve as it becomes an inherent element of the communication and visualisation of the team agility since it will be used several times. Consequently, once the workshop is finished, participants leave with a commitment and the sticky notes remain on the ATC to serve as a gauge of progress for the following time. The next time the workshop is conducted (when that is left to the will of the participants), participants begin by reviewing their commitments and assessing if they were respected or not. If a commitment was respected, participants reflect on whether it has contributed to enacting the value in the vision, thus reducing the gap. However, if the commitment was not enacted, participants must reflect on why this was the case and adapt accordingly.

4.1 Three Pillars of Agile in the Agile Team Canvas

In accordance with the design theory [2], we adopted Roschnik and Missonier [29]’s conceptual model of agile culture and refined and validated the pillars of agile culture through the three design cycles by confronting it with domain experts and agile teams. It is needless to say the three pillars mutually influence each other, are not mutually exclusive and are not meant to be comprehensive. Rather, as noted in the design theory, they are meant to be parsimonious building blocks of the canvas, thus solely representing key tenets of the concept. *Pillar 1: Psychological Safety.* Edmondson [12] defines team psychological safety as “a shared belief held by members of a team that the team is safe for interpersonal risk-taking” [12 p. 350]. According to Edmondson [12], psychological safety in a team does not stop at interpersonal trust. Rather, it goes beyond and includes respect between team members, where each feels at ease and is authentic in their interactions. Edmondson [12] additionally notes that it sustains and improves the learning scheme in a team. Psychological safety is an important pillar of agile culture because, as noted by Thorgren and Caiman [38], agile depends on collaboration and open communication. Therefore, if team members do not feel safe speaking their minds, such collaboration will not take place. *Pillar 2: Self-Management.* A self-managed team is entrusted and empowered to assume ownership of its work, make decisions, and manage its tasks without the need for regular supervision. It includes the concept of autonomy. An autonomous team is responsible for making joint-team decisions [26] and is held accountable for them. Team members share responsibility and ownership and require a common purpose and mutual trust [25]. Decisions in the team are not taken by a single person (centralised) nor are they taken individually, rather they are shared amongst the members [26]. *Pillar 3: Continuous improvement* relates to iteratively improving by finding ways to maximise successes and minimise failures by learning from them [6]. Consistently engaging in learning from successes and failures contributes to continuous improvement [21]. Learning is sustained when individuals are given the opportunity to talk and reflect on their successes but also their failures. Thus, allowing them to improve. Teams can suggest new ideas and if bad news must be presented during meetings outside the team, this should be used as a springboard for improvement.

5 Demonstration and Evaluation

Evaluation is a dominant feature in DSR [20] as it is considered a science *because* of the evaluation activities that take place to evaluate the designed artefact [41]. Hence, to ensure rigour in our evaluation process we followed the Framework for Evaluation in Design Science (FEDS) [42]. Following the FEDS, we performed formative evaluations early in the study (through the design cycles), and subsequently conducted two summative evaluations (expert interviews and confirmatory focus groups) to evaluate the resulting instantiation (Fig. 1). We evaluated the ATC in regard to its efficacy and efficiency as these criteria are amongst the ones proposed in the design theory for visual inquiry tools Avdiji et al. [2]. The efficacy of a visual inquiry tool refers to its ability to sustain and enhance the outcomes of joint inquiry, and its efficiency refers to the number of resources (e.g., time, financial, people) required to use it. We additionally selected perceived usefulness and ease of use as evaluation criteria because they have been employed and proven effective in the development of previous visual inquiry tools [e.g., 15]. To identify what data to capture (e.g., participants' behaviour, dialogues, opinions, feelings, workshop timing), how to do so (observation, moderated group discussion, artefact analysis or questionnaire), and when to do so (during or after the workshop), we used the goal-method framework for DSR workshops proposed by Thoring et al. [39].

Beginning 2023, we conducted three semi-structured **expert interviews** as the first summative evaluation. We evaluated whether, according to the interviewees and given their experience with the industry, they considered that the ATC would be useful to them in their day-to-day work (perceived usefulness). Each interview lasted approximately 60 min and was recorded and subsequently manually transcribed verbatim. We conducted the second summative evaluation by organising a confirmatory focus group [40].

In April 2023 we conducted a second summative evaluation of the ATC. We conducted a **confirmatory focus group** that lasted 150 min and included 15 participants (divided into four groups, one ATC per group) and two moderators. Having two moderators allowed us to not only efficiently divide tasks but also reduce subjective bias. One moderator was responsible for asking the questions and prompting participants and the second one was responsible for capturing the data (observation, note-taking, recording). Participants were from various organisations from industries (pharmaceutical, IT, insurance, and energy) and their participation was voluntary. The confirmatory focus group took place in two phases: (1) during the workshop: participants used the ATC in teams while we observed and (2) after the workshop: we held a group moderated discussion with the participants, asked them to fill in the questionnaire and analysed the generated artefacts (i.e., the sticky notes they had filled in and stuck to the ATC). As suggested by Thoring et al. [39], we developed a questionnaire to complete the collected insights. To mitigate potential bias and thereby encourage respondents to provide honest and accurate answers without fear of repercussions or judgment the questionnaire was anonymous. Finally, to enhance analysis accuracy, we audio and video recorded the session to revisit it if necessary.

Data Analysis. We analysed the data collected from expert interviews and confirmatory focus group by performing manual bottom-up coding and by following the recommendations of Krueger et al. [23] and concentrated on the extensiveness of the collected feedback (i.e., how many different people made a comment) as opposed to the frequency of it (i.e., how many times it was brought up). We decided to do so following their argument that a certain comment can be made 10 times, but by the same person and hence cannot serve as a measure of importance. We therefore manually extracted the most extensive feedback and observations from the notes and recordings and analysed the questionnaire answers.

5.1 Evaluation Results

Overall, the evaluation results demonstrate that the ATC meets its requirements, is perceived as being useful, easy-to-use and is efficient and effective. We hereunder present and discuss the evaluation results in relation to the evaluation criteria and provide quotes from the confirmatory focus group participants and interviews to support the discussion.

To evaluate the **perceived usefulness** of the ATC in regard to its requirements, we formulated statements related to the three requirements for the ATC (R1, R2, R3 in Table 2) and asked participants to assess them. Ranked in order of usefulness perceived by the participants, the ATC: helps collectively assess the gap between the as-is and the to-be (R2, gap): "*…good because it forces the users to do the state-of-the-art*", helps a team agree and visualise where it wants to go (reduce semantic boundary) (R3), helps decide what to put in place (R2, actions): "*the action orientation is good because it is not because they [the values] are displayed that they are there*" and helps members of a team communicate with one another (serve as boundary object) (R1): "*help to all talk about the same thing*". Data from the questionnaire also demonstrates high perceived usefulness: we for example asked if the participants would reuse it: 54% answered "yes", 46% answered "maybe", and 0% answered "no". Participants who answered "maybe" noted that they either lacked time to use it or that for the moment, it was going well in their team. In addition to the above, we asked participants to provide their contact details if they expressed interest in utilising the ATC again so we could get back to them: 9/15 participants did, meaning that more than 50% of participants wish to use the ATC with their teams. Thus, being a positive indicator of the perceived usefulness of the ATC.

To rate the perceived **ease of use** of the ATC, in the questionnaire, we asked participants to rate on a Likert scale how easy they deemed the ATC to use: 90% of the respondents found it either "easy" or "very easy to use", and the remaining 10% found it "neither easy nor difficult". During the discussion the participants commended the structure of the ATC in terms of its simplicity *"[the ATC is] simple because using post* *it forces us to have simple concepts and ideas that come to mind*", familiarity "*I think the approach is fairly standard: Current situation, target, gaps and action plan*" and general flow: *"The funnel from theoretical action to commitment is great. You give air in the actions for the brainstorm and then you narrow it down with the restraints and finish with commitments".*

Regarding the **efficacy**, we observed and took note of how people interacted with one another (verbal and non-verbal interaction) and with the ATC. We observed that the ATC played a central role in supporting the participants jointly inquire to identify the current situation (as-is), negotiate meanings to identify their desired vision of being agile (to-be) and ideate on ways to enact the vision through everyday practices. We additionally observed that participants wrote on sticky notes, and then edited them or moved them around as the understanding or meanings of the sticky notes changed.

Finally, to evaluate the **efficiency**, namely if using the ATC did not require an inappropriate amount of time or other resources, we assessed the timing, the furniture, the space, and the amount of cognitive energy required for the workshop. By cognitive energy, we refer to the participants not being overwhelmed or left drained by the workshop. Regarding the material resources, the use of the ATC only required sticky notes, pens, and a printed version of it. We conclude that the material resources required to use the ATC are acceptable. To assess the cognitive load of using the ATC, after the workshop, we asked participants how they felt using the ATC. The overall feeling was positive as participants answered that they felt "*good*", "*comfortable"*, "*at ease"*, "*interested*", or "*reassured"*.

6 Conclusion

Motivated by the cultural challenges organisations face when bringing agile across the enterprise to match the openness and fluidity brought by emerging Next Generation technology [11, 13], this study adopts an engaged scholarship approach based on design science to develop an artefact. The artefact is a visual boundary object that supports closing the chasm between the endorsement of agile and its enactment through everyday practices. By doing so, the tool contributes to the necessary fluidity required for the successful adoption of emerging technology, thus serving as a valuable contribution to practice. Furthermore, to the best of our knowledge, this is the first study that binds visual inquiry tools and the study of value enactment to address cultural challenges in scaling agile. Hence, we contribute to research not only by adding to the design knowledge [3] but also by advancing the literature on visual inquiry by establishing a connection between visual inquiry tools and actions/commitments. By doing so, this study participates in helping cross the chasm between agile endorsement and enactment.

Finally, this study does not come without its limitations, one of which pertains to the proposed agile pillars. As per the followed design theory [2], the ambition was to frame the concept of agile culture parsimoniously to ensure the affordance to the tool. Therefore, the key pillars are not meant to be prescriptive. Rather, they represent the foundations of agile culture from which a team can negotiate what it means for them and create a visual common understanding. Hence, trade-offs between comprehensiveness and simplicity have been made during the design process, and based on empirical inputs, we have proposed three. Future research could dive deeper into the three pillars and explore further dimensions that could be added to the ATC.

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Social Media Trolling: An fsQCA Approach

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Abstract. The rise of online social media has fostered increasing instances of deviant online behaviour. One of the most lethal is collective bullying i.e., trolling, which has severe impacts including suicides of victims. Yet, it remains a mystery what kind of factors lead social media users to engage in trolling. To explain social media trolling, we contextualized concepts from *deindividuation theory*. Using fuzzy-set qualitative comparative analysis technique to analyse survey data from 337 Facebook users, three configurations explaining social media trolling have been developed. The results suggest that social media affordances and deindividuation states together give rise to trolling. Our results offer theoretical and practical implications.

Keywords: Social Media · Trolling · Deindividuation · fsQCA · Configuration

1 Introduction

Cyberbullying is an aggressive, intentional, and repeated act using electronic forms of contact [1]. Among various forms of cyberbullying, including cyber-harassment and cyber-stalking, trolling – a collective form of cyberbullying – is becoming severe worldwide across social media [2]. "The atmosphere of social media has become so poisoned by incivility that trolling can rightly be said to be the new normal" [3, p. 220]. The increase of trolling has been discussed in information systems (IS) literature [4, 5].

While trolling can be planned involving insults, provocations, and threats or organised by psychopaths for fun [6], the consequences are devastating. In its more sinister forms, trolling may lead to mental health issues, suicide attempts or suicides of victims [6]. Despite the malicious consequences, "Why people do it [trolling] continues to baffle the experts" [2] and thus it is an unresolved question in IS literature. Meanwhile, a major stream of research on trolling identifies behavioural (and emotional) characteristics of trolls. Although antecedents including hedonic benefits [7, 8] or personality traits [9] may be influential in the social media trolling context, they are very generic and equally

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applicable to most types of cyberbullying [10]. With some exceptions [e.g., 11, 12], IS studies have not theoretically consider the group/crowd nature of trolling whereas context-specific variables of trolling can provide us with better theoretical and practical meanings on trolling.

Against this backdrop, this study investigates: ‘how do social media affordances and deindividuation factors drive social media trolling?’ We draw from the *deindividuation theory* to propose a model to investigate trolling. Using M-Turk platform, we have collected data from 337 Facebook users. The data have been analysed by fuzzy set qualitative comparative analysis (fsQCA) technique. Specifically, we develop three equifinal configurations where each configuration can sufficiently explain the trolling behaviour. Our study thus provides support that crowd-related theories can provide a useful lens to explain collective cyberbullying i.e., trolling. Moreover, to explain a collective delinquency in social media platforms i.e., trolling, our integrated approach is unique and plausible.

2 Background

2.1 Trolling and Its Nature

Different kinds of deviant or anti-social behaviour in social media platforms are reported; cyberbullying is one of them. With similarities, yet, “Trolling is substantively different from cyberbullying” [13, p. 1336]. *Cyberbullying* is to deliberately and repeatedly cause (or the intention to cause) harm and distress the victim where the two parties often know each other. Trolls make abusive comments against people they know and do not know alike. Although trolling can be done non-repeatedly but it has rippling effect because of doing it in a group. Trolling can sometimes be unintentional and relatively innocuous or juvenile (e.g., making fun of weight or skin colour) but frequently involves dangerous stalking and harassment [14], insults, provocations, threats [2], and inflammatory and abusive behaviour [15]. Moreover, trolling is a ‘community’ activity [11], ‘multi-party interaction’ [8] or ‘a collective form of harassment’ [12, p. 2] whereas cyberbullying can be individual.

In early age, trolling was a ‘game’ of deceiving people with false or pseudo identity to ‘frustrate’ or annoy someone with time-consuming discussions. It also referred to writing something incorrect or deceptive, “but not overtly controversial” [16]. The first reported trolling was done by a ‘hacktivist’ group – an anonymous collective group – “for their own enjoyment” [17]. Also, “trolling can be seen to be done for the community’s consensual entertainment in order” [17, p. 9]. For trolling, anonymity has been the main protection to offenders. Using fake profiles, anonymous users start unleashing the worst possible instincts: irrational hatred, racism, misogyny, homophobia, transphobia, anti-semitism, Islamophobia and the like [3]. Such anonymity affordance provoke many people to do deviant things on social media which they would not ordinarily do in the real world where their interactions are not anonymous.

Despite having distinct characteristics of trolling (than cyberbullying) including collective effort, anonymousness, and to get distinct collective pleasure, trolling literature scarcely consider them in empirical and causal settings although a few studies attempt to understand the motivations behind trolling [e.g., 18].

2.2 The Theory of Deindividuation

The *theory of deindividuation* is one of the most influential theories describing people's anti-social behaviour in crowd. The fundamental understanding of this theory is that, people often behave differently in two general kinds of situations i.e., in groups and individually. "[P]eople obtain release in groups, that is, are sometimes more free from restraints, less inhibited, and able to indulge in forms of behaviour in which, when alone, they would not indulge" [19, p. 382]. *Deindividuation theory* suggests that, under anonymity provided by being a member of a crowd, a person may experience deindividuation (e.g., loss of self-evaluations) by directing his attention towards the crowd in which he is immersed [20]. "When attention is drawn outward and away from the self, conscious deliberation of behavior is undermined" [21, p. 239]. In this process, a deindividuated individual will rely less on his own assessments but be more influenced by external cues [22].

Scholars suggest that anonymity (by being a member of a crowd) is the key of crowd behaviour, which provides an individual with protection from 'social disapproval' or 'rejection' [27]. Festinger, Pepitone [22] suggest, "under conditions where the member is not individuated in the group, there is likely to occur for the member a reduction of inner restraints against doing various things" [22, p. 382] that are not socially-acceptable. The crowd may have some certain characteristics to draw attention and making a person to feel as a part of, as well as to draw the group members' attention away from themselves and toward the group as a whole.

The other important element is *deindividuation* – "the state of inner restraint on usual behavior that is experienced by individuals in a group" [23, p. 1]. *Deindividuation theory* asserts that immersion within a crowd or group results in deindividuation [22, 24]. *Deindividuation* is an internal psychological phenomenon which refers to the absence of self-variables (e.g., self-awareness, self-evaluation) in certain situational conditions [19, p. 382]. In short, *deindividuation* is the effect of a crowd or group on the behavior of an individual. However, some studies confuse with anonymity and deindividuation and use them interchangeably. For example, Wheeler [25] defined *deindividuation* as "a feeling of anonymity, and one would expect it to exist to the extent that the individual cannot be singled out as the only person performing a behavior" (p. 190). Similarly, Ziller [20] stated that deindividuation occurs when a person becomes subjectively undifferentiated from those around him. However, we understand them as different variables and may have causal relationships.

The *deindividuation theory* has been popularly used in the past few years; naturally, a series of relationships between these variables have been tested but with mixed results. Supporting *deindividuation theory*, most researchers suggest that anonymous crowd conditions stimulate to produce a deindividuated state in people, which in turn increases the probability of uninhibited behavior performed in groups [10, 24, 26]. However, others suggested that anonymity is not a necessarily condition but the deindividuation variables resulting from crowd can also lead to anti-social behaviour. Alternatively, others [e.g., 26] suggest a direct effect of anonymity on crowd behavior, bypassing deindividuation. However, their configurational relationships are yet to be tested in IS studies in general and social media trolling context in particular.

2.3 The Conceptual Model

Our theoretical foundation is based on the argument that social media affordances (i.e., digital anonymity and dispersed collectivity) and deindividuation variables (i.e., loss of self-consciousness, diffused responsibility, and collective distinct pleasure) will have configurational effects on trolling. Prior studies [e.g., 27] suggest that a configurational approach than investigating the net effect of the variables is more meaningful when investigating cyberbullying. Mathematically, TROLL = f (digital anonymity, digital dispersed collectivity, loss of self-consciousness, diffused responsibility, collective distinct pleasure). Our research model is depicted in Fig. 1 as a Venn Diagram [28].

"Anonymity has traditionally been conceived as the inability of others to identify an individual or for others to identify one's self" [29, pp. 3039–40] within a crowd. In order to distinguish from general crowd to virtual-crowd, we call it *digital anonymity* – the extent to which the online social media users are able to confirm the true identity of another user over the Internet. *Digital anonymity* is a technological factor associated with social media [30] where immersion in a crowd makes one less-identifiable [22]. Social media platforms facilitate the misrepresentation of identity where people can use pseudo- or virtual-identities and thus offer greater anonymity [31]. "The anonymity of trolls […] provides them with their greatest weapon" [32, p. 54]. Hence, *digital anonymity* is an inherent affordance of social media and very relevant for trolling [33].

Collectivity refers to the collection of people who interact with each other without well-defined and structured norms. Collectivity can be localised and dispersed. A *localised collectivity* refers to offline gathering whereas a *dispersed collectivity* consists of people who are connected from different physical places. On digital platforms, people from dispersed locations gather in virtual spaces, develop collective communications toward an agenda, and consequently accomplish it. Couldry [34] report the "new forms of collectivity" for quicker mobilization of people in online platforms, which we call *digital dispersed collectivity* (DDC). However, DDC is neither unique to social media nor new to IS [e.g., 35]. Social media's DDC affordance has been observed for several political movements throughout the globe [13]. Numerous instances demonstrate how people from dispersed locations develop virtual crowd to commit trolling [e.g., 18] or 'paradoxically' to play 'constructive role' [e.g., 31].

Self-consciousness is the tendency to examine one's thoughts and inner feelings about self. It refers to the disposition to direct one's attention to self-related aspects [36]. On the contrary, *loss of self-consciousness* is a subjective state in which people lose their self-consciousness. It is an outcome when a person becomes aware of others' perspectives (than self's), converts himself to a social object and pays concern over the self as a social stimulus. *Loss of self-consciousness* is considered as an indispensable part of deindividuation [24].

Diffused responsibility, also known 'altered responsibility' [37], "is the degree to which a potential cyberbully believes that he or she will be held accountable for his or her abusive behaviour in social media" [10, p. 891]. Diffused responsibility is a subjective thought when a person believes that someone else than himself is responsible for his own action. In the context of social media, diffused responsibility gives a potential troll an implicit license that not him but all other social media users who participate in the trolling should be liable for the act of trolling [29]. Or, if he is accused, all other trolls should be accused too. Others justify their actions arguing that they should not be accused at all as long as they have not started the troll; they simply participated for 'harmless fun'!

Finally, studies suggest that people get distinctive entertainment by offending someone on social media [12, 14, 17]. There are two parts of collective distinct pleasure. First, trolling is a collective effort and the pleasure derived from trolling is enjoyed as a crowd. According to Dynel [8] "all trolling serves as a form of entertainment of the troll, and possibly also of others, which may be conducive to humour" (p. 373). Second, enjoyment is a major reason behind trolling. However, distinct pleasure refers to unusual 'sick enjoyment' consequent from trolling [8], which is different from 'enjoyment' that some studies have discussed [e.g., 18, 31]. In the current context, *collective distinct pleasure* may be derived from collective watching of unsympathetic, argumentative and impolite behaviour, which some people find thrilling but can be treated as voyeuristic pleasure from a bigger society's perspective.

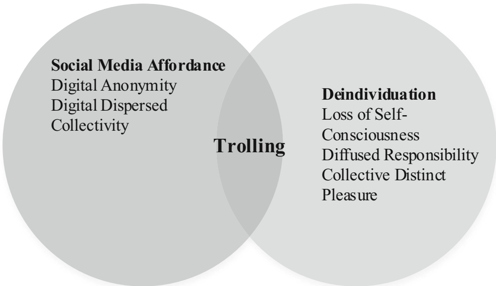

Fig. 1. The configurational research model.

3 Methodology

3.1 The Measures

In order to minimise the threat of common-method bias (CMB), we have used established scales of the variables, where possible. For example, *digital anonymity* has been measured using Harrison [38]'s scale. Measuring the variables related to the de-individuated stage, we have used scales from prior studies, and adapted them where required. For example, when measuring *loss of self-consciousness,* we have tried to capture where a person who could be a very conscious person but loses his self-consciousness when in a group. *Loss of self-consciousness* is measured with items adapted from [39] and *diffused responsibility* are based on [10]. For *collective distinct pleasure*, we adapt Heijden [40]'s *enjoyment* scale. Finally, *trolling behaviour* is measured with items from [41] and [30]. All items for the measures (except trolling) are rated on five-point Likert scales. Following [30] and [42], the scale for *trolling* used five-points (i.e., 1 = "Never" to 5 = "Very frequently"). The items have been reported in Appendix A.

3.2 Data Collection and fsQCA Procedure

For data collection, we have employed Amazon's Mechanical Turk platform [43]. The sample consists of more men (56%) than women (44%). The majority of the responders are between 23–30 years old (45%), followed by 20% between 31–40, and 18% between 41–50. In terms of education, the vast majority (45%) are university graduates while 30% possess associate degree. The fsQCA method is considered appropriate for complex configuration analyses [44]. For data analysis, we have used the fsQCA application software and have followed the guidelines of seminal papers [e.g., 45, 46, 47]. For data calibration, the latent variable scores are rescaled into fuzzy values [46].

Table 1. The graphical representation of the sufficient configurations for social media trolling.

Conditions	Configurations		
	C1	C2	C3
Digital anonymity	●		●
Digital dispersed collectivity		●	●
Loss of self-consciousness	●	●	●
Diffused responsibility	●	●	●
Collective distinct pleasure	●	●	
Raw coverage	0.687	0.660	0.664
Unique coverage	0.025	0.005	0.004
Consistency	0.906	0.900	0.903
Solution coverage	0.739		
Solution consistency	0.894		

Key: The black circles (●) indicate the presence of a condition and blank space refers to a "do not care" condition (i.e., either present or absent).

4 Data Analysis and Findings

First, we check the measurement properties of the variables. The results (partially presented in Appendix A) provide support for the measures' reliability and validity. Next, we check the necessary conditions. A *necessary condition* is a respective condition that always needs to exist to achieve the outcome of interest [45]. No variable came as necessary for trolling as they did not fulfil the criteria (i.e., consistency >0.9) [45]. Finally, we check the sufficient conditions. A *sufficient condition* refers that the outcome occurs whenever the respective condition is present [45]. All of our consistency values are greater than 0.8 and the raw coverage values are above 0.2, indicating significantly valid configurations to explain trolling. Reporting the configurations, we have used 'intermediate solutions' as they are considered as best suitable for causal analysis [47]. As presented in Table 1, the overall solution consistency (0.89) is well above the

0.75 threshold. Considering the coverage value, it can be derived that 73.9% of social media trolling can be explained with our configurations.

5 Discussion

The results show that one variable is neither necessary nor sufficient for trolling. Also, no single variable itself is sufficient for trolling; instead, the examined variables need to be combined into distinct configurations. It denotes that trolling is a complex phenomenon where multiple variables must work together, contrasting the conventional regression-based methods. In other words, trolling does not take place because of only one variable but specific combination of these variable, supporting the 'recipe principle' of *complexity theory* [53]. Furthermore, all the configurations suggest a combination of one or both social media affordances with at least two deindividuation states to predict social media trolling behaviour. Supporting the 'equifinality principle of *complexity theory*, fsQCA produces three different solutions (C1–C3) to explain social media trolling where each of the solution sufficiently predicts trolling. In general, C1 and C2 suggests that the deindividuation states can be combined with any of the social media affordances for trolling to take place. Alternatively, C3 suggests the combination of social media affordances with loss of self-consciousness and diffused responsibility. Among these three configurations, based on the raw and unique coverage, it can be said that C1 empirically is the most relevant and important solution for trolling, followed by C2 and C3.

The first and best configuration (C1) shows that trolling is a function of digital anonymity and three deindividuation states where *digital collectivity* is not important at all. This result summarises that trolling is a function of crowds' feeling of anonymity and disinhibition in cyberspace. In other words, digital anonymity stimulates crowd-related attributes to take control over personal selves and trolling take place. This configuration supports the common theme of *deindividuation theory*: the social media's anonymity affordances provoke users to be de-individuated and exercise deindividuation factors to participate on trolling and enjoy collective pleasure.

The second best configuration (C2) shows that the combination of digital collectivity and the deindividuation states is sufficient for trolling to take place, where digital anonymity is not considered as important. The plausible explanation is as follows. Once a digital crowd is formed with participants from dispersed locations, users consider themselves as a part of it; they either think that their identity is not identifiable, or they do not care if their identity is anonymous or not. The sense of group immersion can de-individuate social media users to enjoy collective pleasure from trolling [10].

Configuration 3 suggests that trolling can happen when digital anonymity, digital collectivity, loss of self-consciousness, and diffused responsibility are present, and CDP is a 'do not care' condition. This configuration suggests that getting *collective distinct pleasure* is not always a reason of trolling; trolls can troll even without getting fun when they lose their self-consciousness and experience diffused responsibility as a result of social media affordances.

5.1 Implications to Research

Several implications to research can be derived from this study. *First*, to explain social media trolling, we suggest a model with variables from *deindividuation theory* that are complemented with social media affordances. According to our model, because of the ease of forming inexplicit ad-hoc virtual groups in social media where anyone can be anonymous to others, social media users may experience deindividuation. Such deindividuation may exist as the loss of self-evaluations (e.g., consciousness) and by directing one's responsibility towards the others in the crowd in which he is immersed (i.e., diffused responsibility) to enjoy collective distinct pleasure. The findings support that crowd-related variables play important and complex configurational roles, which will shed light on our understanding of trolling phenomenon. *Second*, the concepts from *deindividuation theory* have been employed in social network studies [e.g., 48]; however, its capacity to explain trolling has yet to be fully assessed. To the best of our knowledge, although *deindividuation theory* has been formulated since long and its variables have been used in various studies discretely including in IS, a complete configurational model has never been developed and tested in IS. Our model shows how social media affordances instigate people to submerge in a crowd environment, lose their inherent self, and consequently start behaving as the crowd behaves. Thus, our second contribution is related with the formulation of *deindividuation theory* and validating the respective measures in trolling context. *Finally*, our study reiterates that trolling is a sociotechnical phenomenon [30] and suggests that trolling is a consequence of the combined effect of social media affordance and deindividuation. In our study, *digital anonymity* and DDC are considered as the social media affordances which insist deviant crowd behavior in digital platforms. Although *anonymity* has been examined specifically in social media platforms [e.g., 41], collectivity by digital means i.e., DDC has not been used in social media studies whereas it is extremely critical in digital societies [e.g., 35]. Thus, our conceptualization of the role of DDC reveals the collectivity affordance of social media as a determinant of trolling and is an important contribution to the cyberbullying literature.

5.2 Implications to Practice

Our *first* practical implication is related to understanding social media trolling. Given the proliferation of social media use in every society, social media introduce new societal and ethical problems, trolling is one that often has devastating consequences. While many studies reported users' deviant behavior through social media, these studies often fail to explain how exactly it happens [10]. Diagnosing the problem, as done in our study, is one step towards reducing trolling. *Secondly*, digital anonymity and collectivity develop a sense of diffused responsibility for being a part of a crowd and lessen self-consciousness, which leads to commit trolling. Therefore, the anonymity in social media should be controlled. Technologists and social media architects can develop solutions to identify the originator and the participants of troll and take necessary actions from their end e.g., warning, ban, deleting account. *Finally*, people commit trolling not only because they enjoy distinct enjoyment from it but also as a result of combination of other factors with it, especially either digital anonymity or digital collectivity. Therefore, digital collectivity should be managed properly; specifically, social media groups should be closely and constantly monitored by using monitoring services.

5.3 Limitations and Future Research

Despite several contributions provided by this study, it has a few limitations that can be addressed in future research. *First*, we used self-reported responses thus self-selection and/or social desirability bias could be a problem of the dataset upon. In future, log-data from users' social media account could be used to check the roles of the variables on actual trolling.

Second, trolling is a group behaviour where culture can play a role. As our data have been collected from USA (individualistic society) and India (collectivistic society), a comparative study investigating the role of different culture, if any, on trolling will be interesting. *Third*, we did not consider the surrounding variables that may affect during a crowd such as interest on the troll-subject e.g., personal disliking, revenge, racial animosity, and political belief. Future studies can offer a more comprehensive explanation of trolling by taking these surrounding conditions in consideration. *Finally*, although a majority adolescent in the age range of 14–18 years experiences trolling significantly [49], because of the ethics constraint we could not collect response from under 18 years of old. Also, in future, the robustness of the configurations can be evaluated using different thresholds for data calibration and different frequency for truth table analysis.

Appendix A

The items of the constructs and their psychomatric properties.

Digital Anonymity (CR: 0.833; AVE: 0.501)

I believe that in social media …

1. it is not easy for others to verify who truly I am. (0.716)
2. it is not easy for others to make sure if I am truly what I say I am. (0.701)
3. it is not possible to confirm other's true identities. (0.736)
4. people cannot confirm each other's true identities. (0.763)
5. I cannot be sure who I am communicating with. (0.614)

Digital Dispersed Collectivity (CR: 0.804; AVE: 0.542)

1. In social media, I can become a part of a group easily. (0.758)
2. I can interact with members from dispersed locations. (0.701)
3. The members are from various locations. (0.616)
4. We do not need to know each other in social media. (0.644)
5. In social media, we do not need to come at a place. (0.634)

Loss of Self-consciousness (CR: 0.867; AVE: 0.566)

Try to recall an incident where you participated in a trolling (if did not participated ever, you should pretend), and then answer the following questions: During that …

1. I was not worried about my performance. (0.760)

2. I was not concerned how I was presenting myself. (0.785)
3. I was not worried about what others' thinking. (0.680)
4. I completely overlooked what I was doing. (0.742)
5. I lost my self-mind/intellect. (0.789)

Diffused Responsibility (CR: 0.857; AVE: 0.501)

Try to recall an incident where you participated in a trolling:

1. All people on the group would be equally liable for trolling; not only me. (0.693)
2. It would be impossible to make me more responsible than others for my trolling. (0.715)
3. It would be impossible to blame me personally for troll I have participated in. (0.726)
4. It is okay to participate in trolling since I do not start. (0.726)
5. Someone else rather than me is responsible for troll I have participated in. (0.653)
6. The content creator, not me, can be punished for trolling, if someone has to blame. (0.727)

Collective Distinct Pleasure (CR: 0.852; AVE: 0.537)

Try to recall where you participated in a trolling incident:

1. Trolling gives us consensual enjoyment. (0.665)
2. Trolling is exciting to our group. (0.722)
3. Trolling is interesting to our group. (0.703)
4. Seeing someone suffering makes me feel good. (0.769)
5. Teasing others is fun for us as a group. (0.798)

Trolling (CR: 0.892; AVE: 0.626)

In the past three months, how often you liked/ shared/commented in posts with a **group** that …

1. targeted someone. (0.741)
2. publicly embarrassed someone. (0.842)
3. spread rumours about someone. (0.858)
4. was threatening or harassing someone. (0.844)
5. made fun of someone. (0.652)

Note: CR, composite reliability; AVE, average variance extracted; the values in parenthesis are the item loadings of respective item.

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Application of Artificial Intelligence Methods for Improvement of Strategic Decision-Making in Logistics

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Abstract. Highly evolving economic environment requires from logistics companies fast response and agile solutions. Recently development of digital technologies gives significant advantages to logistics business. Hence many optimized processes belong to operational management level. At the same time the importance of digital technologies adoption to strategic management level should not be underestimated, as it allows gaining competitive advantages alongside the supply chain. In our research we develop a conceptual framework for matching operational and strategic management decisions in order to achieve the stated strategy. The choice of the appropriate strategy is conducted with artificial intelligence tools, machine learning in particular. The present study demonstrates high efficiency of applying artificial intelligence tools both in operational management and strategic decision-making. The research is focused on transportation and inventory management as the most resource consuming and challengeable logistics operations. At the same time these processes makes the most considerable influence on the configuration of supply chains. So the article proposes a multi-level conceptual approach that includes several steps aimed on identifying key metrics for different market strategies in logistics and introduction of artificial intelligence tools to different management levels in order to contribute to decision-making promptly.

On the first step we suggest the model targeting to optimization of transportation costs via reduction of logistics cycle duration, and estimation of logistics-related assets. On the second step it is suggested to define the most appropriate market strategy by defining a set of metrics relevant for each strategy. So the proposed approach allows obtaining the most suitable market strategy for logistics companies with artificial intelligence tools. The optimization solutions suggested by the authors are tending to be practically applied and claims their high relevance in terms of digital transformation and adoption in strategic logistics management.

Keywords: Digitalization · Artificial Intelligence · Logistics · Decision-making · Strategic Management · Market Strategy · Machine Learning

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1 Introduction

Understanding the role of digital transformation in strategic management can benefit to development systems in a significant way. Loebbecke and Powell [1] in 1998 explained the role of logistics and IT as core competitive advantages. Since that the nature of IT has changed: data obtained has transformed from the source to achieve corporate goals to value adding attribute. New-generation of digital solutions, such as virtual reality, blockchain, internet of things and others bring certain benefits to traditional view of business process management. Monitoring, control, optimization, and autonomy are the examples of the value created through gathering data [2]. Information nowadays plays a crucial role in economics, politics, environment protection and other spheres by creating both tangible and intangible value. Moreover, customers are tending to appreciate the efforts of technological innovation [3], so it builds positive corporate image (intangible value). At the same time digital transformation costs a lot, and companies should carefully investigate investment and outcomes beforehand [4]. This highlights the integrated nature of modern ecosystems, where adoption and diffusion of digital technologies should be considered as multidiscipline and multidimensional tasks within the ideas of industrial information integration [5, 6].

State-of-the-art technologies contribute to the globalization of business by providing quick access to qualified labour, new markets, and partners worldwide, as well as coordinating global interaction between companies at different stages of the value chain [7]. Artificial intelligence (further AI) should be mentioned as one of the most leading next-generation digital technologies that are no longer limited to the adoption and deployment. AI is considered as a set of technological solutions at the stage of active development, and it has already been successfully used in many industries, economic sectors, and companies. AI techniques include data mining, database, machine learning (further ML), pattern recognition, and knowledge discovery. Obviously such opportunities give a basis for decision-making and strategy choice in particular. For logistic company, the strategy selection is an important task, which determines further activities. In fact, the strategy is a long-term particular direction of company's development in terms of the internal relationship system, the company's position among competitors. Thus the strategy is considered to be a set of decision-making rules applied by the company in its activities [8]. Each of the strategies selected by the company leads to different consequences. That's why the strategies shall be selected based on all the available information at the decision-making stage. According to [8], the strategy is an elusive and abstract concept; but it is the tool that can significantly benefit to the company's robustness and reliability. As a result, the strategy as a management tool serves as a critical reference point for the companies involved in various areas of activity, including logistics. One of the essential decision-making tools in various areas of activity is ML, which is becoming an increasingly popular concept and method in the modern world since its most common goal is to optimize systems by allowing one to make smarter use of products and services [9]. In the manufacturing, ML can lead to cost savings, time savings, increased quality and waste reduction by solving traveling salesman problem (TSP), vehicle routing problem (VRP), job-shop scheduling (JSC) and resource allocation problem (RAP). Some of those problems are related both to manufacturing and logistics [10]. These developments show the increasing complexity and the importance of planning on the operational and the strategic management level in organizations, as well as the interconnection between these management levels. Whereas powerful approaches were developed in solving tasks of the operative management level by using ML algorithms and weak AI [11–15], the usage of these methods and models shows their limitations in digitalization of activities in strategic management, which is reasoned in the more complex and different mind-set in solving decision situations [16]. Thus, the research problem is to increase the efficiency of logistics systems, there are limits in creating a decision-making model which ensures the purposefulness by choosing the market strategy managing time and costs-dependent activities in logistics [17, 18]. Considering the choice of applicable market strategy in logistics as a part of decision-making, it should be mentioned that not all procedural steps are possible to digitalize with present methods of AI. To continue the causal-chain and correlation understanding in the activities, and with split complex tasks into smaller steps it allows to transfer them into ML and AI solutions [19].

To meet the research gap in the topic, we have stated the following research questions:

Q1. Can AI-tools contribute to strategic decision-making in logistics?
Q2. Different types of market strategies have different indicators?
Q3. What are the limitations of applying AI tools in strategic management planning?

The questions above contains insights to strategic management design and planning, aimed on generating additional value to companies through product, process and supply chain management enhancement. The aim of the research is to develop a conceptual framework for matching operational and strategic management decisions to achieve the stated strategy and to align the strategic and operational aims on achieving logistics systems target goals with AI tools.

The remainder of this paper is organized as follows. Section 2 describes the application of AI tools for increasing the efficiency of transportation performance and inventory management in relation with company assets. There is given the conceptual basics of the proposed decision-making process. Section 3 gives a numerical example demonstrating applied value of the proposed model with ML. Here we analyze the process of assigning the appropriate market strategy for a logistics company based on a set of indicators. In Sect. 4 there are presented the results of the conducted research, given conclusion and future research directions.

2 Models and Methods

2.1 Strategic Management in Logistics: Digital Shift

The challenge of managing complex systems has been studied already for many decades. The researchers of strategic logistics management [20–22] are pointing out that the market strategy should be correlated with all management levels and be aligned with corporate vision and goals. At the same time, the creation of conceptual framework without proper support on the operation level will hardly contribute to overall system goals achievement, as the completion of value added operations is conducted at the lower management level. Evidently these processes could not be considered apart from the main trend of modern world – the penetration of informational technologies (i.e. digitalization). Digitalization plays a significant role in modern social and economic development. Cyber physical systems and state of the art solutions create significantly new way of planning and operations control. It emphasizes the importance of conceptual design and mathematical formalization of management tools for the possibility of their application in cyber physics control systems, business intelligence (BI) process, decision-making support and others. Experts [23, 24] claim the outstanding role of state-of-the-art solutions in simulation, modelling, forecasting, real-time control and optimization procedures, whereas the AI tools (ML in particular) and big data analytics provide a vast set of transport optimization tools. According to Leung et al. [25], digital footprint remains at every stage of commodity movement, through manufacturing process till final consumer delivery point. Obviously it requires a high level of integration between all participants of the logistics process under certain market strategy. Herewith, the conceptual optimization algorithms considering time completion on delivery to manufacturing area and from manufacturer to final consumer in accordance with contract sheet terms and planned performance indicators are highly relevant for enhancement of decision-making. Another dimension of freight transportation belongs to costs level decrease. The traditional approach to calculation of transportation costs based only on transportation tariffs does not look respectable, as nowadays there are much more sources of logistics costs: penalty costs, latent costs, costs of storage on delivery, costs on IT-support, green logistics-related costs and others. Experts claim, that precise performance control should rely on cloud business processes on real-time [26] that contribute to operational excellence in logistics companies. This is especially relevant to challenges arising on transport management process, where ‘costs’ performance dimension and time-related indicators are considered to be crucial. For example, considering variable ‘time delays’ and ‘on-time arrival’ may influence on the overall system performance to an extended rate [27]. To coordinate the process management of activities under consideration of key metrics it is recommended to define the overall market strategy [28], and make sure that all the system elements are following it on completing their activities on the operational level. The classical approach based on defining the concept of management process should be developed towards analyzing the possible ways of applying the AI tools for complicated logistics systems.

The research discussion starts at the point of creating a decision-support system for logistics relevant for different management levels. Baring in mind the global and risky nature of worldwide trade and supply, many tasks are solved with the help of automated planning and scheduling (such as tracking and tracing options, inventory management systems, e-transactions systems, etc.). The industry analysis has showed that many tasks of the operational management level have been already assigned to certain digital tools, resolved automatically and demonstrate high applied efficiency [29], see Table 1.

Analysis of Table 1 allows concluding that there are several efficiently applied solutions in transport-related operations, inventory management and replenishment: all these activities belong to the operational management level. This conclusion emphasizes the need to develop conceptual management model for control enhancement on strategic and operational levels both, and digitalize it with modern AI tools. At the same time the problems of choosing the strategy (which refers to the strategic management level, see Table 1) with AI tools have been also previously considered by the experts. An example of using ML as an AI methodology to choose strategy is given in the article [30] that

Table 1. Application of digital technologies to solve tasks at different management levels in logistics.

Management level	Application field	Description of tools	Innovation rate
Strategic	Decision-making support systems; Corporate vision	Database Management System (DBMS)	Rather innovative
Operational	Solving the TSP (transportation salesman problem);	Graph Neural Networks;	Regular
	VRP - vehicle routing problem; Capacitated VRP; Inventory management and replenishment	Warehouse Management System (WMS); Order fullfilment software	Regular

demonstrates the use of ML methods based on the MatLab 2018b. The most critical market strategies (in terms of business development) for the logistics companies are: Penetration strategy, Market development strategy, Product development strategy and Diversification strategy. According to Krichevsky and Serova [31] each of the strategy is characterized by the following indicators: expansion of the market share (x_1), increase in the number of purchases of goods (x_2), increase in the frequency of purchases of goods (x_3), discovering new opportunities for product use (x_4), use of new distribution channels (x_5), searching and winning new market segments (x_6), product sales in new regions (x_7), upgrading of existing products (x_8), expansion of the product range (x_9), creation of the new generation (models) of products (x_{10}), development and manufacture of a fundamentally new product (x_{11}), presence of competence for the development of new business (x_{12}); growth opportunity in the current markets with the current staff. We add two more indicators relevant for strategic management level: data accessibility and data quality (x_{14}) and sustainable development of the company (x_{15}). The indicator x_{15} is introduced to meet the challenges of ecological management of modern companies. The indicator x_{14} highlights the knowledge significance and data transparency in a company. These indicators determine the tools that influence the strategy selection process. In case of using AI as a tool for strategic management design in planning and control, the analysis and handling of any data imply model building based on the observations and its further use, for example, in classification, forecasting, etc. In ML data plays an essential role, and the learning algorithm is used to discover and get knowledge or properties from data. ML uses the theory of statistics when building mathematical models because the primary task is inference based on data sampling. The name of ML reflects the fact that the described method analyses data and independently finds the model without human intervention. This process is called learning because it resembles learning with data to find a model. Therefore, the data used in ML is learning data. ML methods are currently used in various fields, for example, in management for risk assessment, in production, development of recommendation systems and others [30–32]. So the benefits of using ML for decision-making enhancement in terms of the market strategy choice stay evident.

2.2 Application of AI Tools for Processing Costs and Time-Related Metrics in Logistics

The research question arises at the point, if there are models that allow aligning the strategic and operational aims on achieving logistics systems target goals with AI tools? Understanding the approach towards coordinating the strategic goals with operational ones in logistics companies will be beneficial from the point of stakeholders and top-managers as well. So, in order to increase the efficiency of decision-making process in logistics we propose the conceptual framework presented in Fig. 1.

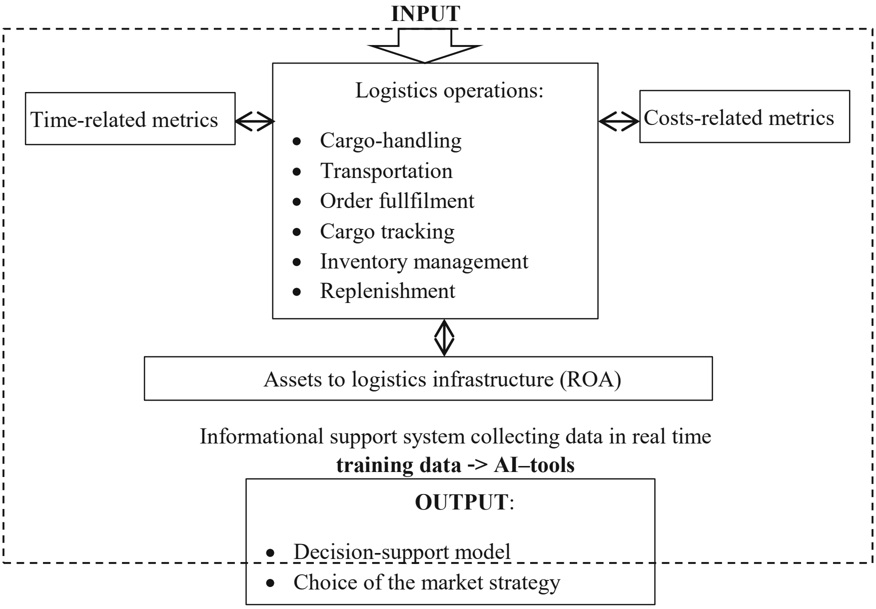

Fig. 1. Conceptual framework for strategic management of logistics operations with AI tools.

As can be seen from the Fig. 1, in order to define the market strategy based on considering diversity of logistics operations, it is important to plan, control and monitor logistics-related metrics (or performance indicators). The strategy choosing process is linked with efficiency performance indicators. The literature overview has proved that the main indicators in terms of transportation are costs, assets, service level and time [33]. As seen from Fig. 1 we transfer service level to 'costs' dimension, because thus the metric will be possible to evaluate and control, and from the other hand customer satisfaction of the service level is an empirical category targeting to long-term relationships and being important to consider. Recently many researches also focusing on sustainable development issues and human resource aspects in corporate and digital responsibility concern [34], thus it is reflected at the performance assessment system additionally or considered optionally. Anyway, the higher level of decomposition allows increasing the accuracy of control and assessment process. Herewith, on introducing such approaches to business processes many companies may face with the problem when logistics costs, including transportation, storage and others are not distinguished separately, but assigned to other generalized groups of costs. That is why another challenge of controlling systems is in finding the balance between the appropriate decomposition level being affordable for companies to deal with in terms of database design.

Transportation as a complicated logistics function consists of a set of different operations, such as cargo-loading, transportation, cargo-unloading, and others. The precise control on completing these operations from the point of on-time delivery (time windows are usually estimated by the contract sheet terms) allows to accumulate data, learn the machine and make it possible to see the deviation from the given values in real time. On this issue the equation for international multimodal conveyance considering goals of sustainable development and digital transformation proves its high academic value [35]. The proposed equations have a focus on operational management level. In order to correlate them with the strategic view of logistics management the correlation between the investment and budgeting planning is introduced. The problematic issues here are the assignment process of operational costs and assets devoted to logistics activities. We assume that logistics costs relevant for the operational level considered to be a part of net profit (see numerator), where costs of inventory and logistics infrastructure refer to assets (denominator). Thus a crucial financial indicator return on assets (ROA) might be presented in the following way:

$$\mathrm{ROA} = (\mathrm{R} - \mathrm{TLC})/(\mathrm{LK} + \mathrm{K} + \mathrm{A}) \tag{1}$$

where R – sales volume, TLC – total logistics costs, LK – logistics infrastructure assets, K – other capital assets, A – current assets.

Summarizing, the values LK, K and A shows the money value of assets (refers to strategic management level); where R, TLC are linked with the costs for using assets (which is operational management level). The Eq. (1) demonstrates its particular significance for assets-consuming logistics operations. For example, freight transportation, also known on its important role in economic growth and global market development. It has become especially evident during the last years when many countries has faced with previously unknown challenges in a way of pandemics, political obstacles and social tension. On this occasion, the traditional view of freight transportation as a part of global trade and logistics has changed. Freight logistics has become a core competitive advantage, enabling stable economic growth for certain companies, regions and countries. This point highlights the importance of applying the advanced intelligent solution able to reflect the evolving market possibilities and challenges at the same time. The suggestion of our research is based on the idea that the choice of market strategies for logistics companies involved to freight transportation activities has impact on the assets and income of the logistics company (see Eq. 1).

3 Results

In order to define the appropriate method for choosing the logistics strategy with ML it is proposed to follow the logic presented at the article [31], and complete the following steps. Firstly, define the key values for each of possible market strategies for a logistics company:

- To implement strategy 1 (penetration), high values of features x_1 - x_4, x_{14} are required.
- To implement strategy 2 (market development), high values of features x_5 -x_8, x_{14} are required.
- To implement strategy 3 (product development), high values of features x_1, x_9 - x_{11} are required.
- To implement strategy 4 (diversification), high values of features x_4, x_{12}, x_{13}, x_{15} are required.

The impact of each of the four mentioned strategies on valuable indicators of the Eq. (1), enabling to correlate strategic and operational management levels, is presented in Table 2.

Table 2. Analysis of the impact made by the market strategies on ROA estimation components.

Impact	LK	K	A	R	TLC
Strategy 1:	+	+	+	+	+
Strategy 2:	+	+	+	+	+
Strategy 3:	+	+	−	+	+
Strategy 4:	+	+	−	−	−

As seen from Table 2, strategy 1 and strategy 2 could show the impact on ROA; strategy 3 and strategy 4 have limitations of the impact on ROA.

Conducting the experiment, we assume that each feature was generated according to the uniform distribution law, based on the 10-point scale, taking into account high and low values of the parameters. There were a total of 40 options of implementation, so the observation matrix consists of 40 rows and 13 columns. In addition, random noise was added to the draw values. So this step of the analysis includes selection of features using the Feature Selection and Variable Screening module (MatLab 2018b software), which allows to rank features in order of importance. On the next step cluster analysis using the Kohonen network was carried out.

Than we use four classification methods: decision trees, discriminant analysis, support vectors, and k-nearest neighbors with the MatLab 2018b program (see Fig. 2).

And on the last step, after completion of classifier training based on the available sampling, the graph displays prediction results of the selected model (Support Vector Machine, SVM), which has higher accuracy level. Thus the most appropriate market strategy among the mentioned ones could be chosen with SVM method by using the proposed conceptual algorithms considering different management levels, as well as

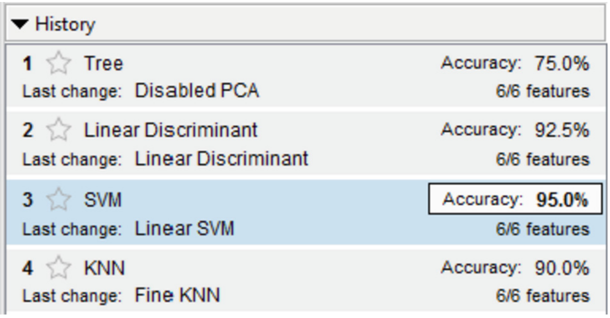

Fig. 2. Classification results obtained with Classification Learner module.

performance efficiency indicators for freight-transportation systems organized by one or several logistics companies.

In the given example we consider one aspect of strategic decision-making – the choice of the market strategy in logistics. Market strategy makes the business process management explicit, increases efficiency of communication and adoption of innovations, digital technologies in particular. But there are much more questions on strategic management level, such as allocation of manufacturing facilities, strategic partnership, 'green' initiatives and others. The suggested ML methodology can be applied to deal with other strategic tasks. To validate the proposed approach, it was taken the strategic planning activities of an industrial engineering company in machine building sector. Although for testing in the model were used data sample generated with Monte Carlo method, the applying with real data shows similar results and confirmed the approach. The implications of our study results in a deliberate choice of market strategy based on the indicators relevant for completion of core logistics activities (freight transportation and inventory management) with ML.

4 Discussion and Conclusion

The approach proposed in our article corresponds to the most challengeable issue of digital transformation – the conceptual framework designing. This is partly explained by rapid development of digital technologies in logistics, and the need for fundamental studies on conceptual basis. Despite there are many sophisticated research papers devoted to the topic, we contribute to multidimensional approach toward strategic decision-making enhancement allowing considering a freight transport activity of a logistics company in a view of three dimensions: costs, time and assets. The problem of choosing the most suitable market strategy under the proposed concept is solved with AI tools, which demonstrates the high application level of our research.

Further development of the considered issues might be focused on investment planning strategies, i.e. identifying stakeholders and their needs, define processes which support the activities and capabilities required to operate and enhance the processes and others. The present study is focused on freight transportation and inventory management, at the same time other logistics functions might be considered in the same way and analysed possible ways of choosing a market strategy. Apart from the mentioned AI tools and ML, we suggest also the following approaches to be useful for solving simultaneously the management task of combining the strategic development goals with operational targets: Quantum Decision Theory [12], two process theory [36], Multi-period optimizing [37], Continuous time multi state models [38], Markov-chains and Sensitivity model. Thus, the following research could be focused on three possible directions: consideration of other logistics functions; analysis of other approaches apart from ML to solve the described research gap; include more performance indicators to the proposed conceptual model in order to consider other relevant metrics for stakeholders, apart from the assets. In any way, it is important to adopt digital solutions on the basis of a conceptual framework.

Considering the possible diversification of the model should be rationale, and do not restrict the opportunity for its digitalization. On this issue, the approach proposed by the authors demonstrates its high application relevance for logistics companies. So the objective of the present study expressed in designing the conceptual framework validated with AI techniques has been gained with the focus on its further industrial application.

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AI and Human Relationship in the Workplace: A Literature Review and Future Research Agenda

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Abstract. The relationship between human and artificial intelligence has attracted debates and polarized views. A key area of this debate that received research attention is human and AI capability to augment each other to achieve better outcomes. While there is a growing research interest in the topic, research is currently dispersed and spread across the management disciplines making it hard for researchers to benefit from an accumulated knowledge in this domain. This study synthesises the literature and describes the current research findings in order to provide foundation for future research in this area. Based on a systematic review, we identify and discuss three emerging themes in the literature and highlight different possible challenges related to integrating AI in organisations. A future research agenda is also presented.

Keywords: Artificial Intelligence · AI · Human-AI augmentation · Human-AI collaboration · Human-AI symbiosis

1 Introduction

The first introduction of Artificial Intelligence (AI) was in 1956 by John McCarthy at a Dartmouth conference [1]. AI was introduced as "making a machine behave in ways that would be called intelligent if a human were so behaving" [2, p. 11]. AI refers to the capacity of machines to perform tasks that ordinarily require human intelligence (HI) [3] and includes a range of technology such as natural language processing, machine vision, robotics underpinned by different machine learning techniques [4]. AI emerged as a crucial part in numerous organisational sectors such as business, medicine or government [5]. The adoption of AI has become ubiquitous in business [6] thanks to the availability of big data, the advancement in computer power [7, 8] and organisation's demand to enhance their agility and quality of performance [9, 10]. According to International Data Corporation, the worldwide expenditure on AI-centric system is projected to reach 154 billion US dollar in 2023 [11]. This represents a substantial growth of 26.9% compared to the amount spent in 2022 [11]. In addition, another finding shows that the total corporate investment on AI significantly increases from 38 billion US dollar in 2019 to 100 billion

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US dollar in 2023 [12]. The McKinsey Global Survey depicts that the ratio of organisation that adopt AI escalates from 20% in 2017 to 50% in 2022 [13]. Following the findings from McKinsey's research, the total economic value of applied AI rises from 17 trillion US dollar to 26 trillion US dollar [13].

There is a heated debate on AI application in organisations and its capability to replace the need for HI and humans in most professions. This debate invited several calls for researchers to focus on examining the relationship between AI and humans in organisations. Van Veldhoven and Vanthienen [14] call for shifting the focus from solely considering AI to paying attention to the interactive relationship between humans and machines. This interaction can manifest in various forms and levels of automation and augmentation [15–20]. Automation refers to machines substitute humans in performing the tasks which traditionally conducted by humans in the workplace and process these tasks without the need of any human involvement [20]. Augmentation refers to the developing a complementary and collaborative relationship between humans and machines in order to achieve an optimal productivity for organisational tasks [21–23]. Other terms, which are used to name a human receiving the machine augmentation, are "cyborg" [24] and for a machine receiving a human support as "human-in-the-loop" [25–27].

A growing number of research has examined AI applications in different sectors and the nature, types and possibility of augmentation, however these studies scattered across management and organisation studies discipline making it difficult for researchers to conceive this domain. To better inform academia and practices on the critical issues of automation and augmentation, there is a need for consolidating the findings of previous research. This can guide future research on what is known in this area and direct research efforts to much needed areas in this domain. While there is a number of notable literature reviews on AI, they are general in nature. They take broad multidisciplinary perspectives on AI adoption [5], strategic perspective [28] or focus on particular sectors such as finance [29], marketing [30], education [31], human resource management [32], and health and medicine [33]. Therefore, this study aims to answer the following question: What are the themes on Human-AI augmentation in business that have been examined to date by researchers?

To answer the research questions, we conduct a systematic literature review, which is an organised, explicit, exhaustive and replicable process for recognising, analysing and synthesising the current research in order to pave the way for future research [34]. The study identifies main themes in the existing literature on Human-AI augmentation. In doing so, the study contributes to advancing knowledge on the domain of AI-Human augmentation. The paper is organised into seven sections. Following the introduction, section two presents the research background. Section three explains the research methodology while section four presents the research findings. Section five provides discussion and section six is future research agenda. Subsequently, the limitations and the implications of the study are discussed in section seven.

2 Research Background

2.1 The Development and Application of AI

AI is the intelligence of a machine that can mimic human doing, thinking and even feeling [35]. It has unlimited potential for improving human's life in a wide range of areas such as healthcare, education, employment, entertainment, and transportation [23, 36]. AI has the ability to take charge of several roles such as problem-solving, perception and decision-making [37, 38]. The crucial role of AI for management has been recognised since the 1950s [39, 40]. However, due to the immaturity of technology's capability during the 1960s, scholars assumed that machines could only serve the operational repetitive tasks, that prevented AI from being included in a complex tasks such as managerial activities [21]. At that time, AI was studied under computer science and operation research, while business and management research paid more attention to humans [23]. During two decades after that, AI received a little attention from management researchers [21, 41]. Today, as a consequence of the advancement of AI capabilities which shifted from processing a simple problem to more intricate one such as social presence or creativity [42, 43] in addition to the availability of big data and computing capacity, organisations turn to AI seeking the realisation of AI benefits of significant improvement of productivity and efficiency.

2.2 Adoption Human-AI Augmentation in Workplace

To date, Human-AI augmentation has pervaded into different aspects of business and management such as customer service chatbot [44, 45], sales and marketing [46], research and development (R&D) [18], human resource management (HRM) [6, 47] and logistics [48]. For example, in customer service, AI chatbot is adopted to automatically respond to customer basic requests and delegate the complex enquiries to humans [49]. Brachten, Kissmer [50] indicate that the application of chatbot can support organisation in mitigation of workload. In sale and marketing, the analytical ability of AI is utilised for analysing customers' data to forecast and create sale plans [10]. In HRM, AI-based systems are adopted for talent acquisition [51]. The topic of Human-AI augmentation continues to be surrounded by some ambiguity partially due to the different terms used to describe it [52, 53]. Scholars have employed various terms to describe the collaborative relationship of humans and machines such as Human-AI interaction [6], Human-AI partnership [54], Human-AI augmentation [21, 55], Intelligence Augmented [56], Hybrid Intelligence [57], Human-AI constellation [58].

3 Research Methodology

3.1 Literature Search

The detail of searching method and criteria are illustrated in Fig. 1. This study reviewed academic work on Human-AI augmentation in business to the early of 2023 from Web of Science (WoS) database. The protocol of this study is developed and motivated by our research question, which are foundation for choosing keyword and include, exclude criteria. WoS database is chosen as the primary source for literature as it is the largest publishers' independent publication databases [59]. To answer the research question related to augmentation, the chosen keywords are "Human AI augmentation" and its synonyms. The search strings for this review is "Human AI augmentation OR Human AI collaboration OR Human AI symbiosis OR Human AI constellation OR Human AI partnership". The boundary of this review is identified by the application of several criteria. The authors completed the search at 23rd of March, 2023. That means all the literature from 23rd of March, 2023 and earlier from WoS are taken into consideration. Initially, the search for these terms has resulted in a total of 3649 articles. The authors reduced the search results by selecting publications that are only in the English language, peer-reviewed documents and in the business and management discipline. This resulted in the identification of 69 articles. The authors proceeded to scan the title and abstract of these articles and removed 34 articles, which are irrelevant to the topic such as focusing heavily on technical aspects of AI or not paying attention to the interaction of humans and machines. The remaining papers were 35. This is followed by a full-text scanning, a paper is considered suitable if the content was accessible and it answered the research questions of this study. There were 07 papers that were excluded. Finally, the authors carried out reference backward search to enrich the review from other sources. The final result recorded 42 papers.

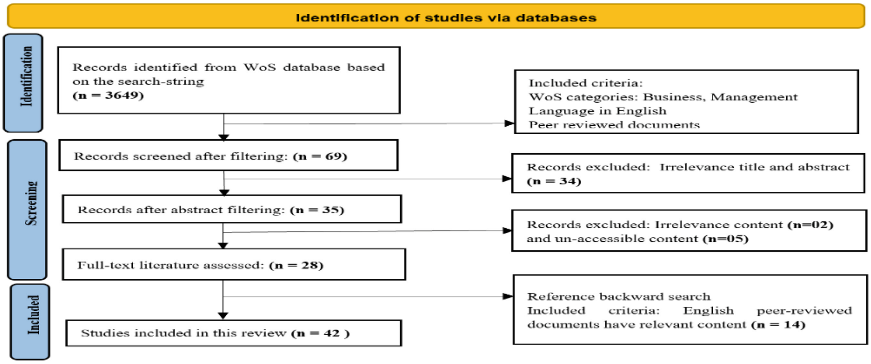

Fig. 1. Search description.

3.2 Literature Analysis

Initially, a matrix concept was developed to classify and synthesise the research findings of the selected papers [20]. The author reviewed and documented all the concepts presented in each paper. During this stage, a comparison among the papers set a foundation for the finding. To categorise the central themes and sub-themes in the literature, thematic analysis was employed [60, 61]. Thematic analysis is considered one of the most prevalent and practical methods of qualitative approach [61] that is used to identify, analyse and report patterns within data [62]. After several iterations, key themes were identified following thematic analysis guidelines [61].

4 Findings

In this section, the identified themes in the literature are discussed as follows.

4.1 Automation Versus Augmentation

The discussion of automation and augmentation has received a great deal of attention by scholars, practitioners and policy makers [63]. The primary similarity between AI automation and AI augmentation lies in their shared application of AI within organisation. While the human involvement is lacking in a pure automation [55], augmentation is the intelligent collaboration of humans and machines to accomplish given tasks [64]. AI automation can process repetitive and well-structured tasks but not the complicated ones, which augmentation can address [15–17]. Accordingly, through AI automation, organisation can enhance their productivity [21, 65] and save the labour cost. AI augmentation processes, due to their focus on assisting humans rather than replacing them [20], can result in the re-allocation of workforce within an organisation as they acknowledge that machines can support humans in some certain aspects [66]. In light of ethical concern, especially fairness consideration, studies are likely to in favour of augmentation than automation because augmentation can consider the social context [67]. Researchers disagree on how automation and augmentation come about. Some scholars consider automation and augmentation as two different stages of the existence and co-existence of humans and machines [64], where automation is considered as "low-status" while augmentation is seen as "high- status" [64]. Others argue that automation and augmentation are interdependent and permeate the entire organisation [21, 64]. Other scholars consider time and propose that at a certain time, humans are faced with the choice of either opting for automation or augmentation for a specific task [64]. However, recently few scholars argue that automation offers the basis for augmentation and enhances the core process of an organisation [64] and hence they are not detached from nor in paradoxical tension as previously argued [64].

4.2 Team Up, Job Role and Task Allocation

The traditional notion of team is the interdependent interaction of two or more individuals' action toward a common goal and each team member holds their own roles and functions [64]. Other scholars highlight that team is formed by the complementary characteristics of team members to achieve a shared goal [64]. Humans and machines can complement each other's since they differ in characteristics and strengths [46, 52]. Weber, Engert [68] reveal four distinct organisational factors necessary for AI implementation: AI Project Planning, Co-Development of AI systems, Data Management, and AI Model Lifecycle Management.

In order to absorb the advantages of AI, it is of paramount importance for organisation to properly integrate AI in their workplace. When considering an effective collaboration relationship, researchers find that factors such as knowledge-sharing [69], technical resources (data resources, technology infrastructure, and AI transparency) and non-technical resources (financial resources, business skills, culture, and so forth) play key roles [70]. Furthermore, Raftopoulos and Hamari [71] disclose four factors that play as facilitators of value creation in Human-AI augmentation are strategic leadership, human engagement, systems adaption and technology development. There are several factors that have positive impacts to the implementation of AI-based system such as system fit, organisational fit, quality of data [72] humans' trust, benefit realisation [69] and humans' control toward an AI-based system [73]. Chuang [74] suggest that to strengthen the relationship between humans and machines, organisations are encouraged to begin with establish a strong sense of belonging of humans toward machines. Researchers also proposed that the compatibility between types of AI applications and levels of human involvement need to be takes into consideration [75]. Huang and Rust [65] pay attention to characteristic of tasks for the distribution of work. Huang and Rust [46] point out that humans should be in charge of the higher complicated tasks and machines can augment humans in solving basic tasks which require lower level of intelligence, when machines are able to solve a task autonomously, it should be assigned to new tasks which involve in a higher level of intelligence requirement. By following that rule, the intelligence level of machines will be trained and enhanced continuously that facilitates humans to concentrate on the complicated tasks. Huang and Rust [65] identify four types of AI intelligence: mechanical, analytical, intuitive, and empathetic. Mechanical intelligence is used to perform systematic, repeated or rule-based tasks [65]. Analytical intelligence can self- learn from historical data, process information and think logically [65]. Intuitive intelligence is used for the high-level professionals which requires innovative problem-solving skills, such as lawyers, doctors or marketing managers [65]. Lastly, empathetic intelligence can understand and react appropriately to humans' emotion [65]. Vassilakopoulou, Haug [49] indicate six action possibilities of chatbot in customer service including: filtering – automatically response customer requestion, informing – quickly update information, monitoring – continuously detect anomalies, delegating – automatically transfer task to humans, multitasking – simultaneously solve problem and distilling – summarising information. Siemon [27] indicate that AI can play four roles in a team: connecting team member (coordinator), generating ideas and solve problems (creator), operating repetitive tasks (perfectionist) and involving in the action of "get things done" by the rapid execution of process (doer) [27].

4.3 Collaborative Intelligence in Decision-Making

According to Di Vaio, Hassan [76], AI and HI capabilities are interdependent in decision-making. AI can support humans in decision-making process in terms of two aspects: offering novel idea through the accumulations of data and determining the correlation among factors [66]. Decision making process between humans and machines based on two factors are: the nature of the independent relationship and the nature of specialisation [77]. Firstly, the independence of humans and machines refers to the way decision-making process take place, which can take one of two forms: sequential process where output of one agent serves as an input for the other or the super-additive value where value is created from jointly created output [78]. Secondly, the nature of specialisation, humans and machines can be assigned to make decisions based on their respective strengths, or they can make identical decisions [77].

As fairness is an crucial factor in decision making, scholars based on fairness difficulty level to consider the decision maker between humans and machines [79, 80].

Fairness difficulty is the combination of several fairness criteria that organisations are required to achieve. The level of fairness difficulty will be high if the high number of fairness criteria is involved in the situation [55]. In a high level of fairness difficulty situation, the most effective way to achieve fairness is humans and machines augment and supervise each other to generate a final result [55]. Humans role is directing, guiding and training machines toward a suitable conclusion if machines take the role of decision making, and machine role is supervising humans process to ensure that the results are fair if humans are the decision maker [55]. In a low level of fairness difficulty situation, if machines is the decision maker, human intervention is required only when machines behave inappropriately. In addition, humans can decide whether or not to follow machine suggestions when they are the final decision maker [55].

4.4 Organisational Reconfiguration

The implementation of Human-AI augmentation can create major transformation in the organisation. First of all, the introduction of AI creates new job opportunities and diminished other jobs [26, 81–83]. For example, US government occupational database found evidence that the emergence of AI gradually transform the economy from mechanical to thinking and towards feeling [83]. Secondly, organisational structure can experience reconfiguration when AI are integrated [17] as employees are required to modify their activities to communicate with and work alongside AI [84]. The organisation needs to allocate resources to work with algorithms in two new roles: auditing and altering [26]. Auditing role is the supervision of humans of the AI performance. Altering role is the continuous training and directing of the AI performance [26]. Maragno, Tangi [44] indicate three types of team member organisation should have in an humans and machines team are: AI solution (machines), AI trainers (humans) and managers (humans).

5 Discussion

Research on the business and management side of AI implementation and research on Human-AI augmentation in particular had increased in the past few years. Hence this paper provides timely review of research. It reveals that most studies tend to discuss the essence of Human-AI augmentation relationship. In which, the authors diffirentiate AI automation and AI augmentation by pointing out the similarities and differences between them. Automation and augmentation are demonstrated as co-existing interdependently. Interestingly, while some scholars revealed that automation is the lower level of humans and machines relationship, others suggest that organisation have to achieve augmentation before being automated by machines. Research shows that the combination of humans and machines brings the best performance for the organisation when compared to work done solely by machines or humans for both white [64, 85, 86] and blue-collar workers [48]. While some studies focus on the interaction between internal actors of Human-AI relationship, others discuss the impact of this relationship on task, work and organisation. Scholars from reviewed studies agree that the intervention of Human-AI augmentation can yield several benefits to different types of tasks such as quality control, productivity enhancement or strengthen the sustainability. Yet, it still contains negative impacts for organisation. It is undeniable that the adoption of AI improves the decision-making process of organisation. In which, the fairness concern received a great deal of attention from scholars.

6 Future Research Agenda

Based on the literature review findings, we offer key avenues for future research. First, there is a lack of research on user interface design of AI-based system. Future studies are encouraged to conduct experimental research to examine the design of user's interfaces in other aspects such as the challenges when designing an AI-based system. Second, future scholars can explore the user's reaction toward AI across different job positions, types of job, humans'cognitive styles, different forms of AI. Third, it is importance to investigate the leadership style for a human-machine team, identify potential risk associated with managing this team, understand how the roles of managers change and how to effectively manage this new form of organisation. Fourth, future research should delve into the impact of Human-AI augmentation in organisation in other aspects. The interactive effects and conflicts might raise between possible challenges (e.g., interal resistance, employees' fear of job loss, etc) and drivers (e.g., employee's training, facilitate conditions for collaboration,etc) of Human-AI collaboration relationship, the interaction between technical and social aspects within an organisation and how AI impact organisational management are important areas for exploration. Furthermore, researchers also can explore how organisational structure and capabilities impact Human-AI augmentation relationship and AI adoption in organisation. Fifth, while our findings present several factors regarding to an effective collaboration in a human-machine teamwork, further empirical research is needed to examine how these factors vary across different business and management sectors. These factors can be humans' insight such as demographic, gender, family composition, educational background. Lastly, future researchers should consider the Human-AI augmentation relationship in a macro-level perspective. This could involve examining the influence of this relationship to social interactions in the marketplace or identifying the dimensions that organisation can consider when deciding whether to adopt AI automation or AI augmentation in their workplace.

7 Limitations and Implications for Research and Practice

Undeniably, we encountered some limitations when conducting this research. Firstly, we used several keywords within search string to search for the related papers with our topics, that might prevent our work from gathering papers which emerged outside from our keywords in search string. To mitigate the bias related to term selection, we searched for main keywords and its closest synonyms, which were recommend from other author to boarden the search result. In addition, we also enrich our findings by implemeting reference backward search to gather related papers from other sources. Secondly, we also limited our search in English content only, publications in other languages were not considered in our research. Thirdly, we also encountered some difficulties in term of accessing the literature content, which we have to remove from our reviewed papers list. For any papers, which cannot be accessed from WoS, we searched for its availability from other sources such as google search, google scholars search, sciencedirect or elsevier database. Lastly, the literature review was limited to publications in the business and management disciplines. We are aware of that the review could be more valuable if papers from other disciplines are included. However, we limited our search for business and management only due to the high number of search results.

Through our study, scholars from any other disciplines can gain a comprehensive understanding of AI performance as a team member in business context. In addition, this review also highlights the gap in term of Human-AI augmentation research area. That creates several research opportunities for scholars who are interested in exploring AI in business context. Furthermore, the study provides practitioners and policymakers a general guidance on AI and the change in the business organisations. The results and findings exhibit several critical rules that organisational member are recommended to follow to fully utlise the benefits from machines, which facilitates business to attain performance enhancements and competitive advantages in the market. Additionally, the study provides organisation and understanding of the factors that necessary to achieve an effective Human-AI augmentation. We hope that the synthesis of literature provided in this study support knowledge accumulation and provides a base for future research on Human-AI augmentation.

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General IT Adoption

A Low-Cost Air Quality Monitoring IoT System Using Node MCU: A Novel Approach

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Abstract. Air pollution is currently the world's most dangerous threat to the environment and public health and has a detrimental effect on the ecosystem, climate and human health. Several factors contribute to air pollution, including industrial production of harmful gases, automobile emissions, a rise in the number of hazardous chemicals and particulate matter. Quick decision-making calls for the analysis of information from real-time air quality monitoring are required. This work presents a cost-effective, scalable and flexible Internet of Things (IoT)-based air quality monitoring system developed using a novel approach. The proposed system employs IoT technology to track various vital parameters, such as particulate matter, carbon monoxide, ozone, temperature and humidity, in real-time. Data are sent to the ThingSpeak cloud platform, thereby enabling users to access and analyse the information remotely. The values of particulate matter in the clean surrounding and that in polluted surrounding were two times that of national ambient air quality standards. However, the values of carbon monoxide and ozone were within the permissible limits. The cost effectiveness and user-friendly nature of this system makes it well suited for use in diverse geographic locations, thus enabling prompt decision making in addressing environmental issues.

Keywords: Internet of Things · Cloud Computing · Particulate Matter · Ozone · Carbon Monoxide

1 Introduction

Air pollution is caused by the emission of hazardous compounds, particulate matter and biological molecules into the Earth's atmosphere [1]. Most of the countries in the world consider carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), lead (Pb) and particulate matter (PM) as the major contributors for air pollution [2]. SO_2 and NO_2 are released during the combustion of fossil fuels and smelting of metals and are also present in automobile exhaust emissions. In the presence of sunlight, NO_2 reacts with unburnt hydrocarbons to form O_3, which has detrimental health impacts [3]. O_3 is known to cause more severe damage to plants than other pollutants [4]. CO is emitted because of the incomplete combustion of carbonaceous

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compounds. Compared with oxygen, CO has a stronger affinity for haemoglobin [5]. Therefore, CO absorbed into the bloodstream through the lungs binds to haemoglobin to generate carboxyhaemoglobin (COHb). However, COHb cannot carry oxygen to the body's tissues and organs. This inability leads to oxygen shortage, which can be lethal. PM of $< 10\ \mu m$ (PM10) and $< 2.5\ \mu m$ (PM2.5) are formed in the atmosphere as a result of complex reactions involving chemical pollutants, such as oxides of sulphur and nitrogen. These are emitted from automobiles and industrial activities, whereas some particles are emitted directly from sources such as construction and quarrying sites, unpaved roads and fields [6]. Therefore, these six pollutants are the major sources for air pollution and pose an immense threat to the natural environment and human health.

Long-term exposure to polluted air causes or exacerbates several diseases and conditions, including respiratory diseases, such as asthma, pneumonia, bronchitis and lung cancer, as well as cardiovascular diseases, such as myocardial infarction and blood clotting [7].

According to the World Health Organization (WHO), up to 4.2 million people die each year from air pollution [8]. Furthermore, air pollution harms wildlife, disrupts plant growth and damages crops [9]. Also, the pollutants accumulate in the food chain, affecting predators and the overall ecosystem [10]. Ground-level ozone can damage plants by entering through their stomata (leaf pores), thereby leading to reduced photosynthesis, stunted growth and lower crop yields [11]. Moreover, oxides of sulphur and nitrogen can contribute to acid rain, which can affect plants, trees, soil quality, buildings and infrastructure [12].

Most nations use centrally located stations that cover a certain diameter in a geographical area for manual air quality monitoring [13]. Despite the fact that these monitoring stations enable precise and comprehensive measurements of air pollution, the system is expensive and laborious and requires conditioned storage, which demands substantial maintenance and regular on-site calibrations [14]. Hence, industries are looking for solutions that would provide efficient and accurate air quality monitoring systems. In this regard, Sam et al. [15] proposed a real-time air quality monitoring system based on internet of things (IoT). Two microcontrollers were used, namely, Arduino Uno for obtaining values from MQ-135 and MQ-7 sensors and ESP8266 for transferring data to ThingSpeak. This reduced the overall efficiency and increased the expenses. Moreover, this system only monitored CO levels and the air quality index (AQI) was calculated based only on one sensor, owing to which the accuracy was low. Similarly, other researchers [16, 17] have created their own air quality monitoring systems using the Raspberry Pi, Arduino and cloud platforms to monitor the environment interfaced with wireless sensor network. However, further research is needed to enhance the features, portability, affordability and accuracy.

Therefore, this work was focused on providing a highly accurate and low-cost air quality monitoring system using Node MCU. Node MCU ESP8266 is a 32-bit microcontroller operating at a frequency of 80 MHz. The controller offers built-in Wi-Fi support, which makes it easy to connect to the internet. Furthermore, MQ-sensors (MQ-131 and MQ-7), a DHT-11 sensor and a dust sensor are integrated into ESP8266 via an MCP-3008 microchip. Finally, data collected from different sensors are transferred to the ThingSpeak website, which is a public cloud infrastructure for quickly storing and retrieving real-time data. Hence, the proposed method is an IoT-based air quality monitoring system that provides a user-friendly interface to deliver real-time data.

2 Methodology

The system is implemented using low-cost sensors and a microcontroller. The list of components that have been used are listed on Table 1. WiFi-enabled ESP8266 is utilized as it is affordable and aids in the monitoring of air quality in real-time. The proposed air quality monitoring system is illustrated in Fig. 1 and comprises an MCP-3008 chip, an optical dust sensor, a DHT-11 sensor and MQ-7 and MQ-131 gas sensors.

Table 1. Components used for air quality monitoring

Name
1. NodeMCU-ESP8266
2. MQ7 gas sensor
3. MQ131 gas sensor
4. DHT-11 Sensor
5. 220 µF capacitor
6. 150 Ω resistor
7. Adapter 5V
8. GP2YP1010AU0F Dust Sensor
9. MCP-3008 chip

The controller has the capability to provide the required voltage range of 3–5V for all employed sensors. The digital output from the DHT-11 sensor is connected to the digital pin of the microcontroller. It has a thermistor for measuring the temperature and a capacitive element for measuring the humidity. It measures the current temperature in degree Celsius and relative humidity in percentage. Next, the MQ-7 sensor detects 20–2000 ppm of CO in the air. It is coated with a sensitive tin dioxide (SnO_2) layer, which has a low conductivity for clean air. The conductivity of the sensor increases as the concentration of the targeted gas increases. The MQ-131 sensor has a low detection range (10–1000 ppb) for ozone and other gases owing to which it is expensive compared with other sensors used in the system. It is coated with a sensitive tungsten trioxide (WO_3) layer and has low conductivity in clean air. However, the conductivity of the sensor decreases with the increase in the concentration of ozone and vice versa. An optical dust sensor with a detection range of 0–400 $\mu g/m^3$ is used to measure the concentration of PM2.5. It works on the principle of pulse light from an infrared LED, for which a resistor and a capacitor are needed. Infrared light is scattered by particles that enter the detecting area and then passes through a lens and a slit before being picked up by a photodiode. The detected particle concentration determines the analogue voltage output. The sensors

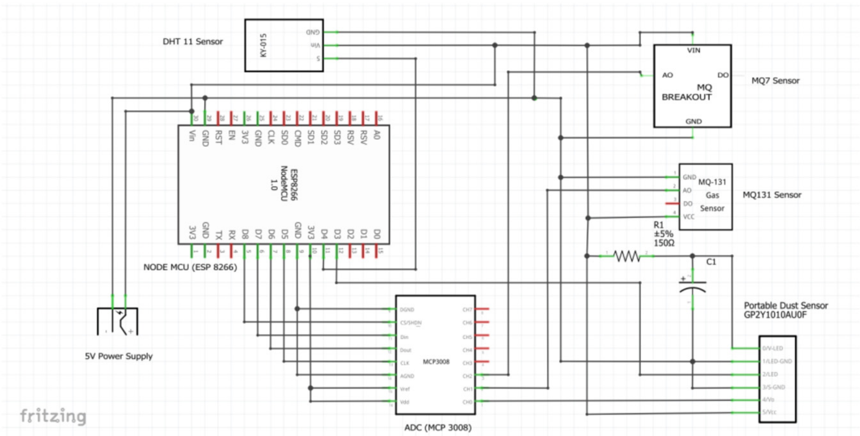

Fig. 1. Circuit Diagram

Table 2. Pin description of MCP-3008

Name	Functions
V_{DD}	2.7 to 5.5 V Power Supply
DGND, AGND	Digital & Analog Ground
$CH_{0–7}$	Analog Input Pins
CLK	Serial Clock
D_{IN}	Serial Data In
D_{OUT}	Serial Data Out
$\overline{CS}$/ SHDN	Chip Select/Shutdown Input
V_{REF}	Reference Voltage Input

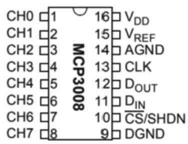

Fig. 2. MCP-2008 microchip

discussed above provide output in the form of analogue voltages, which are converted to the recognised concentration type (μg/m^3) using mathematical equations.

As ESP8266 has only one analogue pin, a microchip (MCP-3008) is attached to it. Eight ADC channels are available on MCP-3008. It connects ESP8266 to the MQ sensors and dust sensor. MCP-3008 chip schematic is shown in Fig. 2. The pin functions of ADC chip are described in Table 2.

The output data from the sensors are displayed on the ThingSpeak website. Therefore, the device is integrated into an IoT platform that enables remote monitoring of air quality as well as stores the data collected from sensors in the cloud. ThingSpeak ultimately extracts and analyses the various results to determine the condition of the environment. The graphical depiction of environmental parameters by ThingSpeak allows a basic understanding of the environmental condition in that area.

The basic block diagram of the model is provided in Fig. 3. It mainly comprises four important modules, namely, the data acquisition module, air quality monitoring module, cloud-based data storing and monitoring module and analysis module.

The AQI is a method for expressing the status of the air quality in an understandable manner. As the AQI increases, so does the risk to public health. It is designed to increase public involvement and awareness in initiatives to improve air quality.

A sub-index, which is a linear function of concentration, is calculated based on the computed concentrations of a pollutant. It consolidates complex air quality data pertaining to numerous pollutants into a single number or index value. The AQI as a whole is determined based on the worst sub-index.

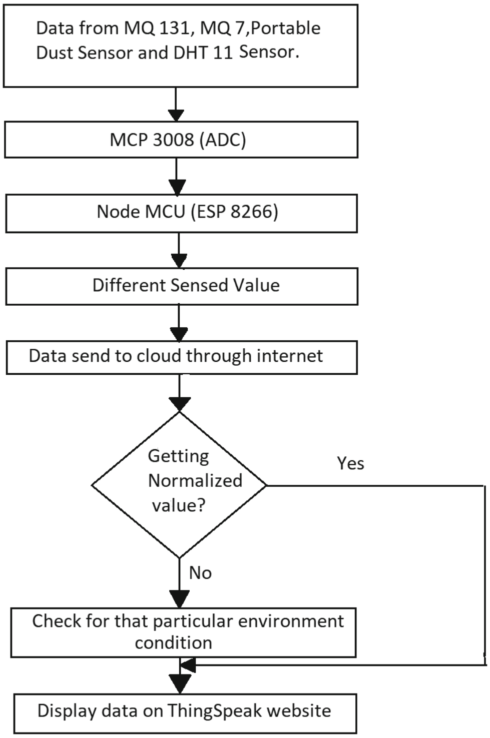

Fig. 3. Flow chart of the proposed system

Only if data are available for at least three pollutants, one of which must be either PM2.5 or PM10, the overall AQI can be calculated. Otherwise, the data are deemed insufficient. The sub-index values (γ) of CO, O_3, PM2.5 are calculated using the below given equations:

$$\gamma_{O3} = \begin{cases} \alpha_{O3} & \alpha_{O3} \leq 100 \\ (\alpha_{O3} - 100) * 25/17 + 100 & 100 < \alpha_{O3} \leq 168 \\ (\alpha_{O3} - 168) * 5/2 + 200 & 168 < \alpha_{O3} \leq 208 \\ (\alpha_{O3} - 208) * 100/539 + 300 & 208 < \alpha_{O3} \leq 748 \\ (\alpha_{O3} - 400) * 100/539 + 400 & \alpha_{O3} > 748 \end{cases} \tag{1}$$

$$\gamma_{PM2.5} = \begin{cases} \alpha_{PM2.5} * 5/3 & \alpha_{PM2.5} \leq 30 \\ (\alpha_{PM2.5} - 30) * 5/3 + 50 & 30 < \alpha_{PM2.5} \leq 60 \\ (\alpha_{PM2.5} - 60) * 10/3 + 100 & 60 < \alpha_{PM2.5} \leq 90 \\ (\alpha_{PM2.5} - 90) * 10/3 + 200 & 90 < \alpha_{PM2.5} \leq 120 \\ (\alpha_{PM2.5} - 120) * 10/13 + 300 & 120 < \alpha_{PM2.5} \leq 250 \\ (\alpha_{PM2.5} - 250) * 10/13 + 400 & \alpha_{PM2.5} > 250 \end{cases} \tag{2}$$

$$\gamma_{CO} = \begin{cases} \alpha_{CO} * 50 & \alpha_{CO} \leq 1 \\ \alpha_{CO} & 1 < \alpha_{CO} \leq 2 \\ (\alpha_{CO} - 2) * 25/2 + 100 & 2 < \alpha_{CO} \leq 10 \\ (\alpha_{CO} - 10) * 100/7 + 200 & 10 < \alpha_{CO} \leq 17 \\ (\alpha_{CO} - 17) * 100/17 + 300 & 17 < \alpha_{CO} \leq 34 \\ (\alpha_{CO} - 34) * 100/17 + 400 & \alpha_{CO} > 34 \end{cases} \tag{3}$$

$$AQI = max\,\{\gamma_{PM2.5}, \gamma_{CO}, \gamma_{O3}\} \tag{4}$$

where, $\alpha_{PM2.5}$, α_{O3}, is the concentration of PM2.5 & O_3 in μg/m^3 and α_{CO} is the concentration of CO in mg/m^3. The equations used are standard and were derived from the Central Pollution Control Board [18].

3 Results and Discussion

The implemented system has a considerable chance of improving the living standards in polluted areas owing to its adaptability and employability. Furthermore, for monitoring purposes, the system is simple to set up and implement in any location, and the overall cost of the setup is approximately ₹4000 only.

The system was tested by placing the device in various locations to measure the current air quality. The experiment was performed in two different locations: clean surrounding (place A) and polluted surrounding (place B). To check and validate the suggested system, 24-h data were collected at a frequency of two values per minute and sent to ThingSpeak, and the data was exported. Graphs were plotted based on the values against time to verify and validate the proposed system.

The low levels of CO at night could be attributed to the reduced human activity and the natural processes that happen during this time, which lead to decreased CO emissions and enhanced removal of the gas from the atmosphere. Figure 4 shows the variation of CO versus time through MQ7 sensor at different places in real time environment. Average concentration of CO in place A was 447 μg/m^3 while for place B was 774 μg/m^3. The concentration in Place B was found to be 73.1% more than that of place A. Values were within the standard limit (2000 μg/m^3).

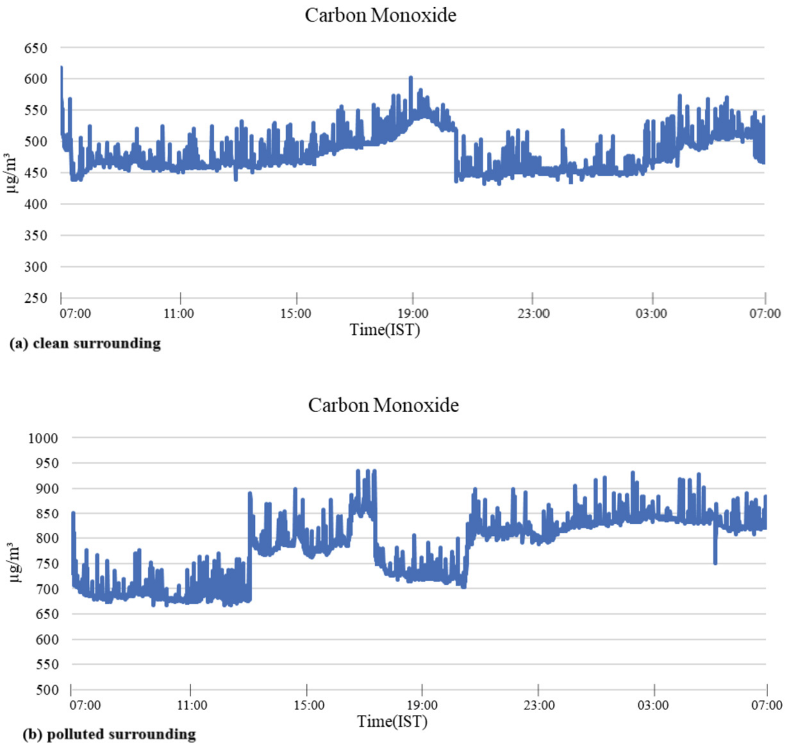

Fig. 4. CO graph comparison based on real-time monitoring of air quality at different locations.

Hazardous ozone in our troposphere is produced by chemical reactions that require sunlight. O_3 levels are low at night because of reduced photochemical processes for ozone synthesis or destruction. High temperature increases the rate of O_3 generation, and stagnant weather causes ozone accumulation. Figure 5 shows the variation of O_3 versus time through MQ131 sensor at different places in real time environment. Average concentration of ozone in place A was 32 $\mu g/m^3$ while for place B was 55 $\mu g/m^3$. It was determined that place B had a concentration that was 71.8% higher than place A. Values were within the standard limit (100 $\mu g/m^3$).

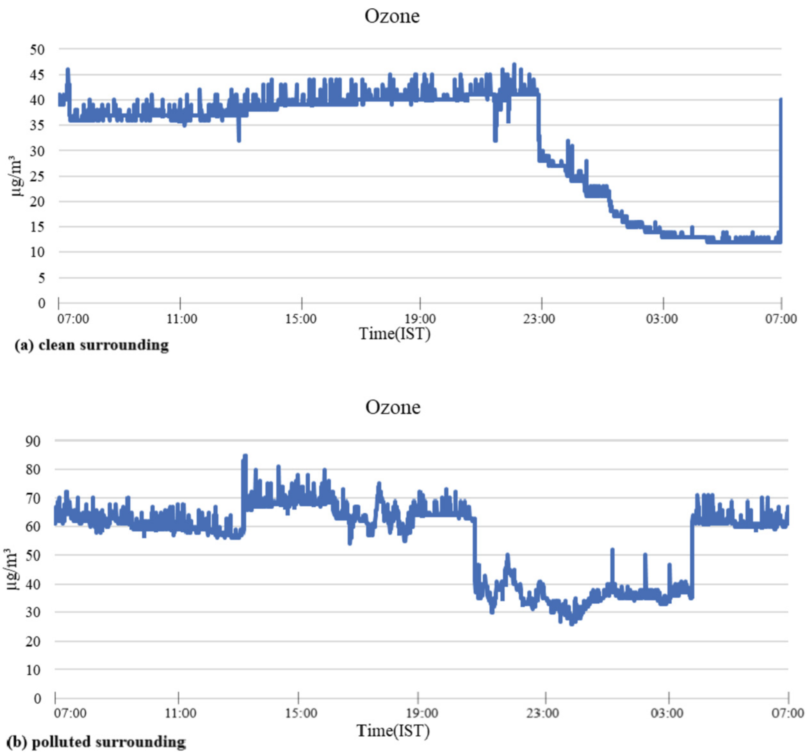

Fig. 5. O_3 graph comparison based on real-time monitoring of air quality at different locations.

The majority of particles are formed in the atmosphere as a result of complex reactions involving chemical pollutants such as oxides of sulphur and nitrogen, which are emitted from automobiles and industrial activities. On the contrary, some particles are emitted directly from sources such as construction and quarrying sites, unpaved roads and fields. Figure 6 shows the variation of PM2.5 versus time through optical dust sensor at different places in real time environment. Average concentration of PM2.5 for both places was found to be 32 $\mu g/m^3$. Almost, 2 times more than that of standard limits (15 $\mu g/m^3$) set by WHO. The several hikes in graph can be explained by environmental parameters such as temperature, humidity & wind speed.

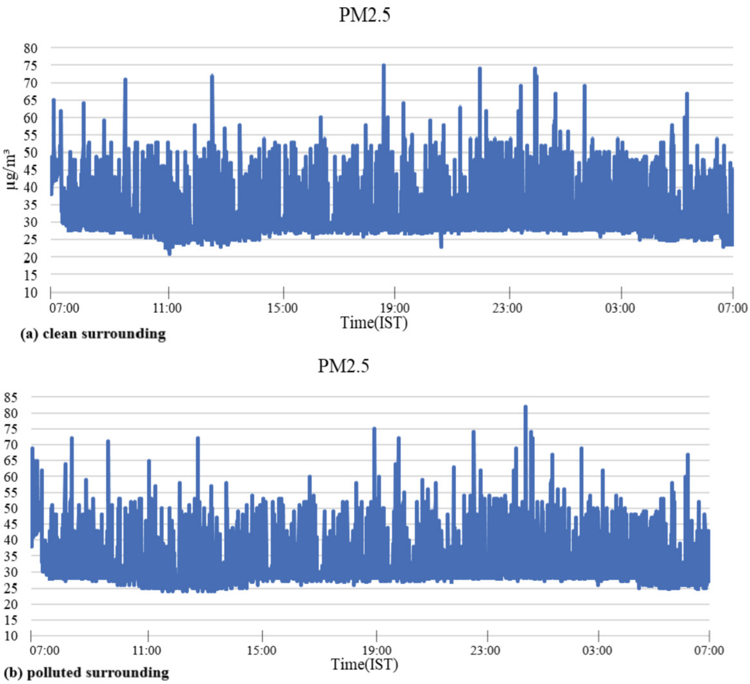

Fig. 6. PM2.5 graph comparison based on real-time monitoring of air quality at different locations.

AQI for both the places was calculated using the sub-index values. Using Eqs. (1), (2), (3) and (4),

Sub-Index	Clean Surrounding	Polluted Surrounding
$\gamma_{PM2.5}$	52	52
γ_{CO}	29	39
γ_{O3}	32	58

For place A, the AQI was calculated and value was found to be 52 and for place B, value of AQI was 58.

The experimental results demonstrated that the proposed system is highly responsive and capable of instantly detecting the types and concentrations of air pollutants.

4 Conclusion

The development of low-cost smart sensors, embedded systems and IoT in the recent years has inspired other researchers to perform in-depth studies in the field of air quality monitoring. In this research, we have proposed a cost-effective IoT-based air quality monitoring system to track various air pollutants. Additionally, the proposed system has been installed at two sites as part of this work to track variables related to temperature, humidity, ozone, PM2.5 and CO. As an air quality monitoring system, the ThingSpeak platform can aid in the analysis of cloud data on environmental conditions. It helps citizens learn about the pollution in their area by uploading information on the webpage in a way that is easy to understand. The developed system is more affordable than the standard air pollution systems in the market. However, this system monitors only a few parameters; hence, it can be upgraded to include more parameters, especially those that are related to industrial activities, which are a major source of air pollution. Moreover, because of the high-power consumption of this system, switching to solar power will make it more environment friendly.

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“We Do What Everyone Else is Doing” – Investigating the Herding Behavior of Mobile Payment Users

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Abstract. As the technologically advanced unified payment interface (UPI), enabling cross-bank mobile payment transactions, was launched in India, mobile payment's popularity in the country grew multi-fold. However, contrary to what mobile payment usage literature suggests about technology features driving usage, we posit that common users often lack the understanding of the detailed technical features and are predominantly driven by what everyone else does – i.e., the herding behavior. Motivated by this, we examine the types of herding – rational and irrational. We develop a research model comprising multi-dimensional scales to capture herding behaviors that impact mobile payment continuance usage. We validated the herding-focused research model using the survey responses from 507 users. The study contributes to the field significantly by adding elements from herding behavior theory to the literature on mobile payment usage, which is of significant value owing to the networked nature of the technology. The results show that there is a balancing influence of rational and irrational herding on continuance usage, which has implications for practice for controlling for certain herding factors to promote technology's popularity.

Keywords: Rational herding · Irrational herding · Self-herding · Mobile payment

1 Introduction

With technological innovations and advancements, the popularity of mobile payments has also been growing rapidly in developing countries like Kenya and India, promising financial inclusion and socioeconomic development (Ngugi and Pelowski 2010). A sudden spike of 8.7 billion mobile payment transactions was reported in March 2023 in India after the introduction of the Unified Payment Interface (UPI) by National Payments and Settlement of India (NPCI) in 2016, which enables cross-bank transactions (Shahid, 2022) (Kashyap, 2023). Despite all of its advantages, UPI-based mobile payment applications are still significantly behind in terms of per capita digital transactions

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in India compared to developing nations like China, Argentina, Mexico, and Saudi Arabia, where the adoption of digital payments is much higher (Kumar et al. 2022). To maintain the driving forces of the development of UPI-based mobile payment applications, promising monumental financial inclusion, it has become important to understand what is driving the users in masses to use UPI-based mobile payments? Are they truly driven by technology-focused factors (Pal et al. 2021) or simply because 'everyone else is doing it' since users are human beings, and they possess inherent instincts such as imitation and mimicry (Devenow and Welch 1996). Herding is a phenomenon where people follow the crowd and do what others do. In this process, people may also compromise on their own beliefs or ignore their personal information, which may suggest that they should act differently (Banerjee, 1992). Therefore, in this study, we examine how the herding behavior of users drives mobile payment usage [Research question].

Based on basic adoption models and theories, mobile payment application literature has extensively studied how customers adopt and continue using these services (Shankar and Datta 2018). The investigation of the herd behavior traits that influence users to adopt mobile payment services is understudied. Hence, it is crucial to understand the side of the herding behavior of users while adopting and continuing their intention to use mobile payment applications. The concept of herding is met in various fields, from neurology and zoology to sociology, psychology, economics, and finance (Spyrou, 2013), and cannot be neglected in the context of technology usage, where users often observe similar individuals and decide to imitate, eventually moving in herds (Walden and Browne 2009). Herding in the context of technology adoption can be defined "as the phenomenon that the person follows others when adopting a technology, even when his/her private information suggests doing something else." (Sun, 2013). Further, herding behavior can be rational or irrational, which we observe in the study (Bikchandani and Sharma 2000). When people act rationally, their actions are consistent with known facts from other's behavior, whereas irrational actions may be inconsistent with or unsupported by known facts and may be driven by emotions and beliefs (Bikchandani and Sharma 2000; Devenow and Welch 1996). Motivated by this phenomenon, we investigate the contrasting impacts of both rational and irrational herding on the user's usage and continuance intention of mobile payment applications, along with the effect of self-herding where past decisions influence future actions (Ariely and Norton 2008). We have developed multiple -dimensions to capture rational herding and irrational herding. We additionally enrich the continuance intention variable with three dimensions using the recency-frequency-monetary amount (RFM) framework (Chen et al. 2009). These theories and multi-dimensional measures for predicting continuance intention in our research model are important contributions to the field of mobile payment applications, which previously relied on widely used technological theories and used continuance intention as the model's dependent variable. (Pal et al. 2021). The model is validated using 507 responses from the users of mobile payment applications. The results highlight the balancing effect of both rational and irrational herding and, the significant role of continuance intention and self-herding for predicting the present usage behavior. The following part of the paper discusses the literature, theory, research model, and results, followed by the implications of the findings, before concluding the paper.

2 Literature

This study contributes within the broader domain of mobile payment adoption/usage. The focus of study in this area has shifted to the consumer as mobile payments have gained popularity worldwide (Dahlberg et al. 2015; Pal et al. 2021; Thakur and Srivastava 2014). The existing literature in the field of mobile payment applications has heavily investigated how customers adopt and, continue to use such types of services based on general technology adoption models and theories, including the technology acceptance model (TAM) (Shankar and Datta 2018; Bailey et al. 2017; Yang et al. 2023), and the unified theory of acceptance and acceptance of technology (UTAUT) (AI- Saedi et al. 2010; Patil et al. 2020; Wei et al. 2021). These studies primarily focus on factors, such as perceived usefulness and perceived ease of use, performance, effort expectancy, and facilitating conditions, etc. Studies on user adoption based on behavioral characteristics such as herd behavior when adopting any mobile payment application are under-researched. However, herd behavior has resulted in influencing an individual's behavior in the field of technology such as internet wealth management (Kang et al. 2022). In the same vein, it is vital to focus separately on natural behaviors such as imitation and mimicry tendencies, which are together referred to as herd behavior (Devenow and Welch 1996). In the context of a developing country like India, where technological advancements are still underway, it is important to analyze the adoption of mobile payment applications through the lens of herding behavior. This analysis seeks to determine whether users embrace these applications based on their inherent benefits or primarily due to the influence of observing others using them. By doing so, we can obtain a thorough comprehension of the factors driving the adoption of these applications.

3 Theoretical Background

The primary focus of the study is on herding behavior-based adoption factors that keep users utilizing mobile payment applications. The model developed by Heshan Sun (Sun, 2013) suggests that individuals follow others while adopting a technology, even when their own information suggests to do something else. Herding involves both the observation of other people's behavior and the use of one's own personal information. Keeping the elements of understanding of the theory developed by (Sun, 2013), along with we have distinguished between two types of herd behavior that are primarily displayed by human beings - (1) rational herd behavior and, (2) irrational herd behavior (Raafat et al. 2009). The five dimensions of rational herding include network externality direct (NED), network externality indirect (NEI), representative heuristics (RPH), anchoring and adjustment heuristics (AAH), and information cascades (IC). The three dimensions of irrational herding include fashion and fads (FF), social influence (SI), and stress and panic (SI). All these different dimensions were developed using (Abdin et al. 2017; Ahmad et al. 2021; Kang et al. 2022) and, irrational herding (Chua et al. 2021; Yang and Lin 2019; Lins and Aquino 2020; Mouakket, 2015; Venkatesh et al. 2012) from various field studies such as financial markets, mobile adoption, panic buying, and internet wealth management. These dimensions are critical for the model development as they provide the basis to capture users herding behavior perspectives required for mobile payment applications. The effect of herding behavior among investors in the context of stock markets has been used, to investigate whether or not individuals acting in a manner similar to a herd contributes to an excessive amount of volatility in the markets (Bikchandani and Sharma 2000; Spyrou, 2014). We advance this to get a thorough understanding that herd behavior leads to identifying the continuance intention of the users for utilizing these applications, as discussed in depth below.

4 Model Development

We included herd behavior theory as our primary theory in this study, the theory of interpersonal behavior (TIB) (Triandis, 1979) was also incorporated, we developed the research model depicted in Fig. 1, by adapting ideas and research on many dimensions of rational herding, irrational herding, and continuous intention. The research model balances multi-dimensional second-order formative constructs, rational and irrational herding on continuance intention, which affects mobile payment application present usage. Self-efficacy and self-herding influence continuance intention and present usage, respectively. This section discusses the study model for mobile payment application customers' current usage behavior.

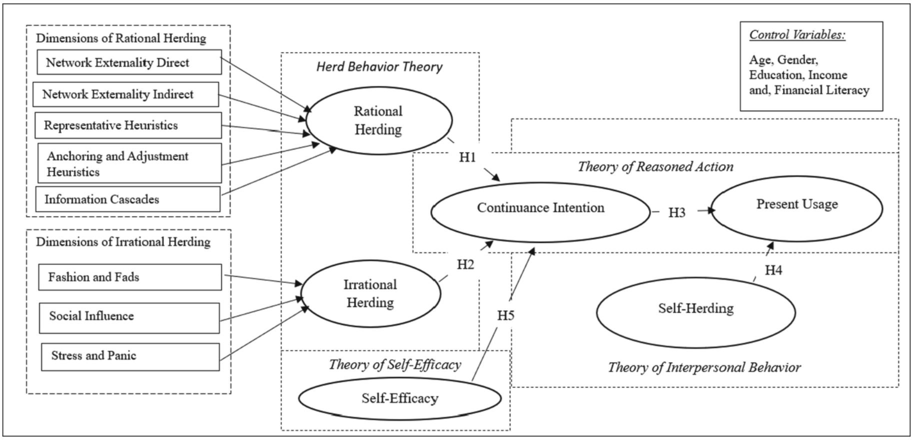

Fig. 1. Research Model

4.1 Rational Herding

Rational herding was primarily studied mainly in the field of financial economics (Devenow and Welch 1996), and financial markets (Spyrou, 2013). However, it has not been studied as an individual factor in the field of mobile payment literatures. The logical assessment of the benefits offered with the technology is captured by this form of herding. The multi-dimensions developed are discussed below:

Network Externalities Direct (NED) and Network Externalities Indirect (NEI)
At present network externalities have been widely used in the study of e-commerce (Cen and Li 2020; Lu and Lin 2012), software applications (Li et al. 2018), financial services (Gong et al. 2019; Yen and Wu 2016), internet wealth management (Kang et al. 2022), and other fields. If the value of a product or a service increase with an increase in the number of users, then the product or service is said to benefit from network externalities. Network externalities can be classified into direct externality (NED) and indirect externality (NED) (Lu et al. 2015). Direct network externalities are related to the number of users in the network; as the user size increases, the value of the product or a service increase (Zhang et al. 2017). In the context of adoption and continued use of mobile payment applications, direct network externalities imply that the users will retain using the applications because they feel that the application has a vast user base and may be useful for them too. Indirect network externalities may imply that complementary services of the applications such as recharge and paying bills, insurance, booking tickets, wealth management services, etc. make the application seems useful and is attracting a large user base. These two forms of network externalities can help mobile payment apps with a large user base attract new users. Thus, we assume consumers rationally weigh direct and indirect externalities while adopting a mobile payment app.

Representative Heuristics (RPH) and Anchoring and Adjustment Heuristics (AAH)
Human beings have been found to have certain patterns of response for taking decisions for their tasks (Tune, 1964). As decision makers, human often take some mental shortcuts, also called heuristics, to simplify the tasks while making estimates efficiently (Kahneman et al. 1982; Rasheed et al. 2018). It has been demonstrated that heuristics affect entrepreneurs' ability to make decisions (Ahmad et al. 2021), capital market investors (Fisher and Statman 2000; Novianggie and Asandimitra, 2019; Cao et al. 2021) and also has been explored in the area of cryptocurrency markets (Gurdgiev and O'Loughlin 2020). We have typically taken two types of heuristics, namely representative heuristics and anchoring and adjustment heuristics. Representativeness heuristics, occurs when people tend to have over-reliance on other people and make the same decisions (Goyal et al. 2023). Investors relying on this type of heuristics tend to be knowledgeable and make more apt decisions which are based on facts and information's (Grether, 1980; Chen et al. 2007). For instance, in the context of technological adoption, assuming that someone with a good qualification is using a specific mobile payment application means that it must be very useful and popular and they should also use it. Anchoring and adjustment heuristics occur when an individual sets an "anchor" by referring to the decisions or actions of others and users, then adjusts that information until an acceptable value is reached over time is known as "adjustment." (Goyal et al. 2023). Therefore, users while deciding to initially start using a specific mobile payment application because other people are using it might act as an "anchor" and end up using another application after gathering relevant information about it is "adjustment." As a result, we believe that each user's intention to adopt and use mobile payment applications in the future depends

on these two different heuristics. Together, they can help to fully capture the heuristics dimensions for the adoption and use of mobile payment applications.

Information Cascades

Information cascades is the most general explanation of herding introduced by (Bikhchandani et al. 1992). An information cascade is a situation in which people tend to make rational decisions based on the observation of others by discounting their own information. According to informational economists, informational cascades could cause herd behavior (Li X., 2004). The concept of information cascades suggests that, the individuals gain useful information from observing previous individual's decisions, to the point where they optimally and rationally disregard their own private information entirely (Devenow and Welch 1996). In the context of technology adoption, an information cascade may occur when people disregard their own private information about the mobile payment application they are using because they see that other people's views are different and start blindly following the same views. Information cascades. It is when an information cascade occurs. Accordingly, we propose evaluating whether consumers rationally overlook their private information and herd when adopting mobile payment applications.

Consequently, we propose that user's rational herding behavior can contribute to a positive influence on their continuance intention for using mobile payment applications.

H1: Rational herding will positively impact continuance intention to use mobile payment applications.

4.2 Irrational Herding

Irrational herding, refers to the behavior that is motivated by irrational thoughts, feelings, or sentiments (Bikchandani and Sharma 2000). Instead of assessing to use the technology, users are diverted through beliefs, sentiments, and emotions towards the decision to adopt any technology; after a while, it may cause discontinuation of that technology when it fails to align with the needs and preferences of the users at that point of time. The three dimensions of irrational herding are described below:

Fashion and Fads

There is many prior research that applied fashion motivations for adopting various mobile communications and social service media (Yang and Lin 2019). Fashion and fads refer to trends or popular styles that attracts significant attention and popularity within a specific time period. In simple terms, it is when people adopt goods or services which are considered fashionable or trendy. Fashion motives as motivating factor for adoption of technology has been found in studies on college going students and elderly users, and it could be one of the reasons for users to adoption of mobile payment applications (Yang and Lin 2019). These fashion and fads result in a rapid increase in adoption rate of the trendy technology, but then it may decline just as quickly as any other new trends emerges. It has become important to differentiate between fashion-driven adoption, which is influenced by temporary trends, and adoption based on actual intention to continue use of a technology for a long-term value for that technology. Accordingly, for evaluating this we also proposed to understand whether fashion and fads could determine irrational herding for the adoption and continue intention to use of mobile payment applications.

Social Influence

Social influence as a separate factor have been studies heavily in the field of mobile payments applications (Yang et al. 2012). Although TAM2 (Venkatesh and Davis 2000) and UTAUT (Venkatesh et al. 2003) incorporate the concept of social influence, by primarily assessing it that align with organizational objectives. Social influence refers to the degree to which an individual perceives that other people important to them (e.g.- family and friends) believe he or she should use the new system or a technology (Venkatesh et al. 2003). It also includes the way someone changes their actions to fit in the social environment. Social influence plays a significant role in the adoption of technology. It refers to the impact of family, friends, and other important individuals on a technology user's decision to accept and use it. We also hypothesized that social influence, which arises from an individual's attitudes and emotions, can contribute to irrational herding and the continuation intention of mobile payment systems.

Stress and Panic

When stress levels increase among people, they tend to panic, and they tend to think that others take better decisions in such situations. Thus, people when faced with a stressful situation behave similarly to others (Parker and Prechter 2005). This situation can increase the herd behavior among the individual. It has been widely examined in the field of financial markets. A study conducted with 4000 corporate earnings by the company analysts and found that, the greater the difficulties in forecasting the earnings per share, which leads to a source of stress, the herding behavior among the analysts increases (Olsen, 1996; Prechter, 2001). The phenomenon of panic buying, triggered by a perceived scarcity during the COVID-19 pandemic, has been observed in the field of marketing as well (Chua et al. 2021; Lins and Aquino 2020). Accordingly, we feel that in stressful situations such as demonetization and the pandemic, people imitated others and adopted mobile payment applications without necessarily possessing information on the applications. This could be tested by our proposed current research model.

Thus, we hypothesize:

H2: Irrational herding will negatively impact continuance intentions to use mobile payment applications.

4.3 Continuance Intention and Self-Herding to Present Usage

Next, we assessed present usage. Since usage models are mostly focused on intention, mobile payment application literature lacks focus on present usage (e.g., (Kim et al. 2010)). Even in broader IS literature, intention is used to understand usage in most cases. As (Bhattacherjee et al. 2008) pointed out that there is a need for a deviation from intended use, as a proxy for actual usage, and developed a frequency-based actual usage measure. Thus, we extend our model to evaluate the present usage behavior based on the theory of interpersonal behavior (TIB) by (Triandis, 1979). TIB states that continuance intention and habit determine present usage. In this paper, we examined habit as a factor of self-herding, which is one's desire to repeat prior actions that bring them some level of satisfaction and they continue to do it (Ariely and Norton 2008). Additionally, Intention has also been identified as the predictor of actual usage in the theory of reasoned action (TRA) by (Fishbein, 1979), frequently have been implemented in both IS and mobile-payment literatures (e.g., Kim et al. 2010; Shin D. H., 2009; Thakur, 2013). Moreover, in the field of mobile payment applications literatures have very limited studies measuring actual or present usage. Also, there are very low number of empirical investigated models with habit as an independent variable (Pal et al. 2020). We suggested that together, continuance intention and self-herding predicts the present usage of users to use mobile payment applications.

H3: Continuance intention to use mobile payment applications will have a positive impact on present usage.
H4: Self-herding will positively impact the present usage of mobile payment applications.

4.4 Self-Efficacy to Continuance Intention

Self-efficacy refers to the individual's perception of their own ability to effectively perform IT-related tasks, such as conducting transactions, with ease (Marakas et al. 1998; Zhou et al. 2016). Due to the daily burden of multiple tasks, individuals tend to rely on their self-efficacy, which influences their behavior and motivates them to use the system (Bandura et al. 1999). Past mobile payment literatures that have examined the impact of self-efficacy on intention to use, has reported mixed results (Shin D.-H., 2010; Luo et al. 2010). Limited studies have examined the importance of self-efficacy as a predictor for intention to use (Pal et al. 2020). Therefore, we posit,

H5: Self-Efficacy will positively impact the continuance intention to use mobile payment applications.

5 Research Methodology

The developed research model on multi-dimensional factors of rational and irrational herding behaviors of mobile payment users was validated using survey data through both offline and online modes. To test and analyse the results of the survey we have used PLS-SEM (partial least square structural equation modelling) with Smart PLS (v. 4.0.9.5). Below is an explanation of the detailed procedure for the research methodology.

5.1 Instrument Design and Data Collection

The survey was designed using instruments from prior literatures and modified as necessary to fit the specific requirements of the present study. To identify the inattentive participants, an attention check question was included as a means of filtering them out easily (Peer et al. 2014; Pal et al. 2020). The survey was developed in the Qualtrics survey design tool.

In order to maximize the number of individuals using UPI-based mobile payment apps, a snowball sampling technique was employed for data collection. We have collected 267 number of responses through offline mode and 474 number of responses through online mode. The data collection process started from 30th of May, 2023, and the last response was received on 25th of June, 2023 including both the modes. During this duration, we collected total number of 741 responses. A total of 507 samples were analyzed after the removal of incomplete, inattentive, and insincere responses. The demographics characteristics sample like age, gender, education, and income serve as the control variables for our study. We included an additional control with the construct, financial literacy, to know how much they feel confident while making their financial investments and planning, and their understanding about their financial decisions (Kang et al. 2022).

5.2 Data Analysis and Results

We tested the model using the sample data (n = 507) using SmartPLS software. As demanded by our model, it can handle both reflective and formative constructs (Ringle et al. 2015). Given that the sample size was small and the data distribution was non-normal, the PLS algorithm proved to be appropriate for conducting the analysis (Hair et al. 2011). In our analysis, we conducted tests for the measurement validity of the instrument, followed by the hypotheses testing, as a part of the structural model analysis, as a sequentially given below (guidelines by (Hair et al. 2019)).

The Measurement Model

The reliability and validity of the reflective constructs of our research model were validated using the composite reliability (CR) score (above 0.7), the Cronbach's alpha (CA) value (above 0.7), and the average extracted variance (AVE) scores (above 0.5), which were above the satisfactory level. The convergent validity was established using the construct's cross-loadings scores, which were higher than 0.7 or above 0.6, which are acceptable values for high and medium, respectively (Hair et al. 2019). The discriminant validity of the constructs was validated using two techniques, first the Fronell-Larcker criterion which evaluates the discriminant validity by comparing the square root of each construct's AVE scores, with the correlations with other latent variables. According to this criterion, the square root of AVE should be greater than the correlations with other latent variables (Fronell and Larcker 1981; Hair et al. 2019), and it was satisfied for our model, second the Heterotrait-Monotrait (HTMT) ratio of correlation (values less than 0.85) (Hair et al. 2019).The common method bias (CMB) test was carried out using a marker variable, we selected "attitude towards the color red" (red attitude), which is theoretically unrelated to the other scales to be an ideal marker variable for CMB (Simmering et al. 2015). For this process, we treated the marker variable as the dependent variable while keeping all other variables in the model as independent variables. By analyzing the VIF scores, we observed that they remained below the threshold limit of 3.3, indicating the absence of common method bias in our results (Knock, 2015).

Structural Model

All five research model hypotheses (H1, H2, H3, H4, and H5) were significant. The results of the hypotheses testing indicates that the second-order formative construct – rational herding – has a significant impact on continuance intention in H1. In support of H2, the second-order formative construct – irrational herding was found to have a negative impact on continuance intention. The significance level of rational herding (p value- 0.001***) is marginally higher than the significance level of irrational herding (p value- 0.01**). The positive impact of continuance intention to use on present usage also was found to be supported (p value- 0.001***). Continuance intention and self-herding was found to be as strong predictors of the present usage (p value- 0.01**), significantly supporting H3 and H4. H5 for the positive impact of self-efficacy on continuance intention also was found to be supported (p value- 0.001***). The R2 values for continuance intention as the dependent variable is 0.163 and for present usage is 0.282. Figure 2 below presents the model with the results shows the path coefficients with respective significance for the hypotheses (See Table 1). The implications of the results are discussed in the next section.

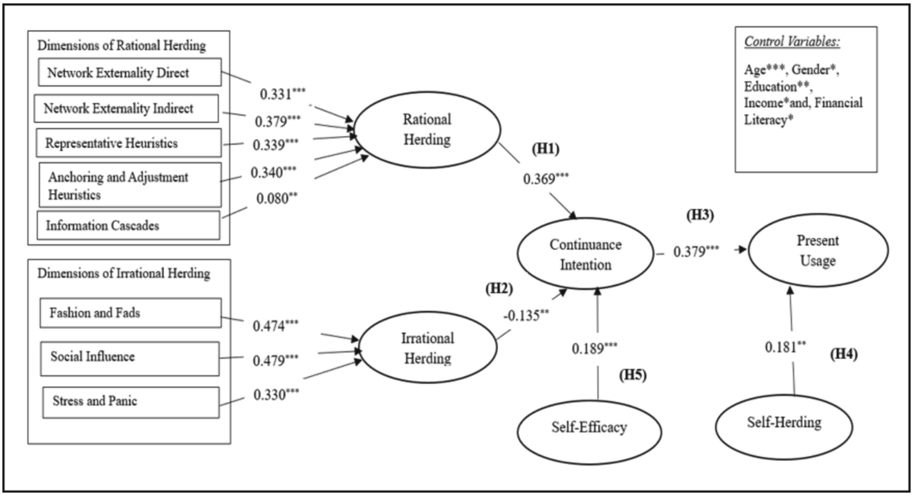

Fig. 2. Results of Research Model (Significance level: *p < 0.05, **p < 0.01, ***p < 0.001)

Note: Results include (a) relationship of the dimensions with the second-order constructs, rational herding and irrational herding, (b) Structural model- path coefficients and significance.

Table 1. Results for path coefficients and significance

Hypothesis	Relationship	Path coefficients	T-statistics	Significance Level
H1	Rational Herding - Continuance Intention	0.369	5.650	Significant ($p < 0.001)^{***}$
H2	Irrational Herding - Continuance Intention	−0.135	2.624	Significant ($p < 0.01)^{**}$
H3	Continuance Intention - Present Usage	0.379	5.904	Significant ($p < 0.001)^{***}$
H4	Self-Herding - Present Usage	0.181	3.087	Significant ($p < 0.01)^{**}$
H5	Self- Efficacy - Continuance Intention	0.189	3.866	Significant ($p < 0.001)^{***}$

6 Discussions Based on the Findings

The results of the model show interesting findings, as discussed below.

Our study found both rational and irrational herding influence users' decisions to continue using mobile payment applications. These factors counterbalance each other. The larger influence of rational herding shows that users are more likely to base their application usage decisions on facts and information. Information cascade has a somewhat lower significance level than other measures of rational herding, indicating that users do not frequently neglect their own personal information to the extent where they logically follow others. Instead, they combined other information related to applications such as its user base, benefits such as immediate transfer of funds to friends/family, self-transfer to your own account, hassle-free transfer of funds without entering bank details every time, and accessing complimentary services (e.g., payment of insurance premium, rent, mobile bills, etc.), the reputation of the parent company in the business and its other services, and the results showed that most of the mobile payment applications users don't utilize them only in uncertain circumstances or to stay trendy. Based on the results findings, we can also state that young population age between 18–34 years are also taking rational decisions as our sample tends to be 88.75% dominated by this age groups. Continuance intention plays a vital role because it directly impacts a user's present usage of mobile payment applications. When customers have a positive tendency to continue use their mobile payment apps, it influences their present usage. They are more likely to use the application regularly, making transactions and exploring its features. In this present study we reconfirmed the significance of continuance intention in influencing the present usage. Furthermore, emphasized the importance of capturing present usage separately, as behavioral intention alone is insufficient for understanding for usage behavior accurately (Bhattacherjee et al. 2008).

Further, our findings suggest that self-herding impact present usage of the mobile payment applications. Self-herding makes decision-making easier because people stick with what they know rather than collecting information of other new options. Self-herding is habitual. According based on the findings results findings we can state that, the current users have developed a habit of using their mobile payment application in the past, and they are more likely to continue using it in the present. They have become familiar and comfortable with their application which leads them to self-herd their own behavior of relying on their previous usage patterns without consideration of any other alternatives. As mobile payments have received mass adoption across the country and the stores rapidly adopting the mobile payment apps, self-herding behaviors of users to use UPI apps for payments every time they visit a store is obvious. During the year 2022–2023, India has contributed to approximately 75% of the total transaction volume in the retail segment. Furthermore, it is projected to be 90% by the year 2026–2027 (Dixit, 2023). It is also to be correct to state that users of mobile payment applications more self -herding their behavior of using UPI-based mobile payment applications as their primary mode of payments. The result of self-herding influencing present usage is a significant contribution to the mobile payment literature.

In this study, the impact of self-efficacy on the continuance intention of UPI-based mobile payment applications is supported. Self-efficacy can make users of mobile payment applications feel like they have to effort less. They believe that they have the necessary skills and knowledge to navigate the application, make transactions by their own, and if any issue arises, they can handle it without any external help. When users, feel confident in their usage of UPI-based mobile payment application, they are more likely to have positive intention for its continued usage. Therefore, the findings of this study have also added to the literature in terms of the importance of self-efficacy as a significant predictor to continuance intention.

7 Implications

Theoretically, the contribution of this paper is threefold. One, the herding behavior and its multi-dimensions have not been developed in the field of mobile payment literature. Two, self-herding emerging as one of the most influential predictors of present usage. Three, with most of the mobile payment literatures using "continuance intention" as the final dependent variable, the present usage dependent variable in this present study depicts the vital role of actual behavior measures. This paper, measured the continuance intention under the umbrella of the recency-frequency-monetary value (RFM) framework, which was earlier is very limitedly explored (Pal et al. 2021). Additionally, the combination of the seminal theories of herd behavior (Banerjee 1992; Ariely and Norton 2008; Sun 2013), and theory of interpersonal behavior (Triandis 1979), provides a thorough understating of the various aspects in the model.

Analyzing herding behavior in the context of mobile payment adoption can also prove advantageous for application providers. By understanding whether users adopt these applications based on their own evaluation of the benefits or simply due to the influence of emerging trends or others, providers can tailor their strategies accordingly. The research findings indicate that information cascades have a lower significance, suggesting that users make more logical assessments when deciding to adopt mobile payment applications, relying on their own gathered information. This implies that users are primarily motivated by the benefits offered by the applications rather than blindly following trends.

The study's insights reveal that the dimensions of irrational herding have minimal influence on users' adoption and continuance intentions towards these applications. Therefore, providers should concentrate on maintaining the convenience, security, and efficiency of their applications to attract users who make rational decisions based on these factors. By emphasizing these aspects in their marketing and communication efforts, providers can effectively attract to users' rational decision-making processes and promote greater adoption and continued usage of their mobile payment applications.

8 Conclusion

In this paper, we have presented a comprehensive multi-dimensional model that elaborates into mainly two distinct aspects of herding behavior exhibited by the users i.e., rational herding and irrational herding to continuance intention and its significant influence on present usage. Although irrational herding has a negatively affects user's intentions to continue using the apps, rational herding serves as a counterbalancing factor, encouraging individuals to make rational decisions to use these apps. Further, this study has also presented self-herding as a significant influence to the present usage of the apps. The study has provided various important practical and theoretical implications.

This study's limitation can be addressed in future research. First, our study sampled mobile payment application in India. Since developed economies are more technologically equipped and user's financial decisions vary, herding behavior may affect them differently. Thus, a cross- country investigation would provide additional insight into user's herding-based decisions. Another limitation is that, the survey was conducted circulating the survey through emails, social media handles, which could not have reached less tech-savvy consumers. Conducting the survey through offline mode would provide reach the rural sections of India. Such barriers have received less attention in the past in the field of mobile payment applications literature.

Note- The comprehensive survey instruments and detailed results are accessible upon request.

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Modeling the Barriers in Adoption of Neo Banks in India

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Abstract. Wave of innovative technology is fast replacing the traditional financial services by new innovative financial services provided by Neo Banks. Despite that, Indian consumers are not embracing Neo Banks at the expected rate. Using Neo Bank, people can transact easily, make fund transfer, opening of new bank account etc. 24/7 spread over the year etc. However, its effective adoption is a bottleneck because of inherent and unknown barriers. However, some attempts on the identification of these barriers have been carried out; the literature lacks a thorough investigation into the relationship and interdependencies among them. We have identified ten possible barriers via literate review and in consultation with the experts. These barriers have been analyzed using Fuzzy DEMATEL method based on the expert's responses. Moreover, the analysis demonstrates Digital Inclusion barrier is the prominent one out of total barriers. Since it will affect the other barriers of Neo Banks adoption but it would not be affected by any other barriers it has a lesser threshold value. Hence, Digital Inclusion barrier is considered as most significant barrier which must be overcome for ensuring the effective adoption of Neo Bank.

Keywords: DEMATEL · Adoption · Barriers · Neo Bank · FinTech

1 Introduction

With the rise of Industry 4.0 enabled technology i.e. 5G, Big Data, AI, and Blockchain, the wave of digitalization has swept the world and the world has entered the era of digital economy. This encourages the emergence of innovation that impacts the consumer behavior, pushing them towards a society that relies heavily on smart mobile devices [46]. This phenomenon has been immensely triggered by COVID-19 pandemic, has highlighted several interests central to the economic foundations of Neo Bank, such as shifting towards cashless, reducing the waste of depletable resources like papers and pens; addressing the climate changes, designing the low carbon strategies and creating new business and comprehensive behavior that support social sustainability [19]. The growth of technology in recent years and the increased use of digital platforms have boosted the financial customers towards the internet based financial services [20].

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The growing penetration rate of internet in India is 34.4% of population, which represents 23.8% of internet users in Asia, also subsidized the interest of financial customers towards internet enabled financial services [36]. This has laid the foundation for Neo Bank, allowing access to the fund kept in bank and associated services using mobile devices. These novel technologies, along with their widespread adoption, have altered the role of banks but also have laid the foundation for the inception of nuclear payment service network by third parties, known as Neo Bank [8]. Neo Bank is a technological innovation in the finance sector that provides non-cash payment features for buying and selling goods, paying bills, buying credit, transferring funds and to carry out other types of transactions along with novel financial services [49]. Unlike the Neo Bank, e-banking model of traditional banks is limited to fund transfer and lower handling fee, paying bills etc. [22, 27]. Neo Bank is capable to provide all type of financial services virtually along with the novel financial services [46].

This digital shift has revolutionized the consumer behavior and commercial exchanges to avail all types of services at their finger tips where Neo Banks is positioned at a considerable position [26]. The leading Neo Bank in India i.e. State Bank of India's YONO had around 54 million active users as of year 2022 which is the highest in the Indian Neo Bank Market [42]. Moreover, India is the second largest country in the world where 191 million adult lacks the financial service followed by Pakistan in the year 2017 [41]. This amount of active users against the total populations is very minimal therefore unbanked people represent a great opportunity for Neo Banks and challenge for the traditional banks [19]. Traditional banks are undergoing directly or indirectly towards a digital transformation to stay resilient. Such digital transformation of banking services contributes towards reduction in operating cost, reduce customers' efforts to visit to branch physically and enhance the customers' satisfaction by offering the financial services 24/7 spread over 365 days in a year [52]. Various digital payment methods have gradually replaced the cash, leading to both advantages and disadvantages for bank customers. Sweden could be the first country in the world that completely abandons cash [10].

The aspirations and interests of banking customers in relation to service are expanding as technology evolves and they are now keen to execute the financial transactions similar to operating the social networking. However, Academic research has highlighted accessibility issues related to technology embedded financial services. Human computer interaction have explored haptic ATM interfaces for visually impaired users and augmented paper cheques for old adults [26]. Baklouti and Boukamcha (2023) in their study explored the barriers to the adoption of Internet banking service. Apart from this safety and security of the internet based banking has also been found crucial while deciding upon the intention to use internet banking [45]. Tran et al., (2019) presented that traditional, financial, performance; privacy and value barrier have impact on adoption of internet banking services. Various studies have represented the various relevant barriers. Hence, the relationship among the barriers needs to be ascertained to provide the guidance for the academicians and practitioners. This enables the banking service providers to overcome such barriers to effectively increase the adoption of Neo Bank in India. Hence, following research questions are framed:

RQ1: What are the barriers in adoption of Neo Banks?

RQ2: What is the cause and effect relationship among the barriers identified?
RQ3: How can the complex interrelationships existing among the identified barriers be uncovered?

This study is the first to conduct a detailed analysis of Neo Bank adoption barriers and the existence of relationship among them, providing a clear understanding of pertaining barriers and the most potential solutions to subsidize the research scholars, academicians and practitioners in the area of Neo Banks. Specifically, the identification of barriers of adoption can provide a basic insight which leads to the possible solutions for adoption of Neo Banks successfully and effectively. The remainder of this paper is organized as follows: Sect. 2 highlights the current pace of research on Neo Banks and also identifies the barriers to the adoption of Neo Banks; Sect. 3 introduces the research method adopted in the study, Sect. 4 depicts the step by step process that makes up the Fuzzy DEMATEL methodology to adopt Neo Banks; Sect. 5 represents the findings of the study and discusses their implication and finally Sect. 6 explores the conclusion and limitations of the study.

2 Literature Review

Prior studies encourage exploring and analyzing the practical barriers in the field of internet banking. Considering the rapid growth of digitization and advancements in information technology, it is necessary for Neo Banks to identify the barriers to gain competitive edge in their field. However, many barriers or challenges have to be identified and addressed immediately in phased manner. Accordingly 10 (ten) prominent barriers are identified and discussed in this section.

2.1 Value Barrier (B1)

The value barrier is defined as the value delivered by the innovation compared to its performance to price ratio [34]. It stems the consumers from a mismatch with pre-existing values with regard to the weighing the cost of adoption and innovation against the intervention benefits [1]. Access of price over the performance of an innovative service discourages the consumer to adopt new service. In case of Neo Banks, if the benefit offered does not exceed the value, the consumers will not attract to adopt it [25]. Hence, in order to posses low value barriers, the innovation i.e. Neo Banks must deliver greater value to its users in exchange of their efforts in learning and adoption. Previous study represents the impact of value barriers on mobile payment adoption [13]. Further, Rombe (2021) in his study state the negative impact of value barriers e-mobile banking adoption.

2.2 Usage Barrier (B2)

The Usage Barrier is defined as the disruptions caused by an innovation that changes the established consumption patterns [34]. The most common functional barrier is the usage barrier which arises when innovation is not compatible with existing practices and requires changes in consumers' routine. In case of Neo Bank, the apparent complexity in use of service may lead to usage barrier. Moreover, if an innovative service brings more complexities rather than convenience, then people might reject that service [25]. Prior study presents the positive impact of usage barrier on usage of digital contact tracing apps [30]. Another study represented the negative impact of safe barrier on adoption of digital marketing [2].

2.3 Risk Barrier (B3)

The Risk Barrier is referred to as the amount of risk involved in the innovation. Risk is more of a consumer perception than an innovation's feature [34]. The risk barrier represents the uncertainty involved with an innovation. Risk is considered as the representation of human perception as compare to a characteristic of an innovative service [25]. In case of Neo Bank, risk barrier is perceived as uncertainty and unexpected financial losses in using it. Moreover, the adoption of Neo Banks is also influenced by the degree of risk involved. Likewise, other study reflects that risk barrier negative impact the customer intention to use mobile payment solutions (Kaur et al., 2020) and internet banking adoption [4].

2.4 Tradition Barriers (B4)

The Tradition Barrier refers to the barriers arising out of traditions, norms and some sort of behavior that contravene societal norms [34]. Individuals get used to a particular tradition and prefer to retain, once they start practicing and follow it for a long time. Tradition barriers arise when people deviate from an established tradition by an innovation [25]. In case of Neo Banks, tradition barrier arises when people move away from traditional banks towards the Neo Banks, offering only internet enabled novel financial services to match the growing financial service needs of the customers. Prior study represents the negative impact of tradition barrier on mobile wallet adoption [23]. Another study represented the negative impact of tradition barrier on adoption of digital marketing [2].

2.5 Image Barrier (B5)

The Image barrier is referred to as the consumers' impressions of innovation about how complicated or easy it is embrace. Each innovation provokes a range of reactions from individuals [34]. Image barrier refers to a negative perception of any innovation arising from stereotype thinking of users. People may have an unfavorable imprinted image on their minds about the origin, efficacy, or functionality of an innovation, producing a barrier to adoption. In case of Neo Banks, the perception of how difficult or easy it is to adopt the innovation can generate an image barrier [25]. Prior study on mobile payments adoption represents the negative impact of image barrier on consumers [13].

2.6 Privacy Barrier (B6)

When the expected users are worried about the information privacy, they may develop resistance [23]. People are very much concerned about their privacy while using technology enabled financial services which make the new technology or innovation unfavorable initially [17]. While using the innovative financial services a customer expects to keep private the information such as credit information, payment history, bank account authentication information, social security number etc. [32]. Neo Bank stores the personal and financial information of the users, and if the users perceive privacy issue while sharing the information, may result into reluctance of Neo Bank adoption.

2.7 Visibility Barrier (B7)

Visibility is defined as the individuals' beliefs concerning to the extent to which their possession of innovation or innovative technology is noticed by others. On the basis, it may be concluded that visibility focuses on physical nature of technology [35]. Gani et al., (2023) defines visibility as the degree of accurate and timely information that is available and accessible to the consumers. Effective integration and communication contribute positively towards achieving visibility. Delay in providing the information may cause in reluctance towards the adoption of innovative technology. In case of Neo Bank, non physical nature of technology and non-providing the information of the financial transaction executed by the customer might arises the reluctance towards the Neo Banks adoption. Prior study demonstrated the importance of visibility towards the adoption of social media in Ghana [3].

2.8 Digital Inclusion Barrier (B8)

Digital inclusion follows some clear economic and social contour, and people with lower levels of income, employment and education are significantly less digitally included. It is clearly said that a person's economic, social, cultural and personal resources create a digital engagement [40]. Digital inclusion can be defined as "whether a person can access, afford, and have the digital ability to connect and use online technologies effectively" [11]. ICT have also considered as a major contributor towards the adoption of innovative technology. In case of Neo Banks, lack of digital inclusion among the consumer may act as reluctance towards the effective adoption of Neo Banks. Prior study recognizes the fundamental role of ICTs and internet access to the adoption of innovative technologies [32].

2.9 Social Barrier (B9)

Social norms (SN) are central to our social life. SNs refer to an individual's beliefs about how to behave in social situations [14]. Social norms may be enforced, either by people whose interests are affected when norms violations occur, or by other parties who are unaffected by norms violations but are in position to take action against the violators [15]. If the people around the proposed user are inactive and consider negatively the innovation, it enables proposed user also to be inactive [38]. In case of Neo Banks, the absence of usage of Neo Banks by the people around the proposed consumer impacts negatively the adoption of Neo Banks. Previous study indicates that social interaction is important in financial behavior because they seek assistance from neighbors to overcome difficulties associated with daily living [50].

2.10 Trust Barrier (B10)

Trust is an individual's perception of the security of innovative services. Trust is considered as prominent factor because of the sophistication and variety of online interactions [51]. Trust is multi faceted and energetic-idea of thoughts, emotions, feeling, or behavior that may occur when consumer recognize that they can rely upon the providers for acting in their best interest once they have given up their direct control. If the consumer recognizes that the providers will not be able to act in their interest they might develop reluctance towards the novel service adoption [18]. In case of Neo bank, absence of trust may stand as reluctance towards its adoption. Silva (2023) in his study presented the value of trust towards the adoption of Chatbot services. Moreover, Cahaya et al., (2023) in his study stated the impact on trust on customers' e-loyalty towards online baking.

3 Research Methodology

In this study, fuzzy decision making trial and evaluation laboratory (Fuzzy DEMATEL) is used to find the exact relationship among the various barriers. A summary flow diagram of the proposed approach is shown in Fig. 1**.**

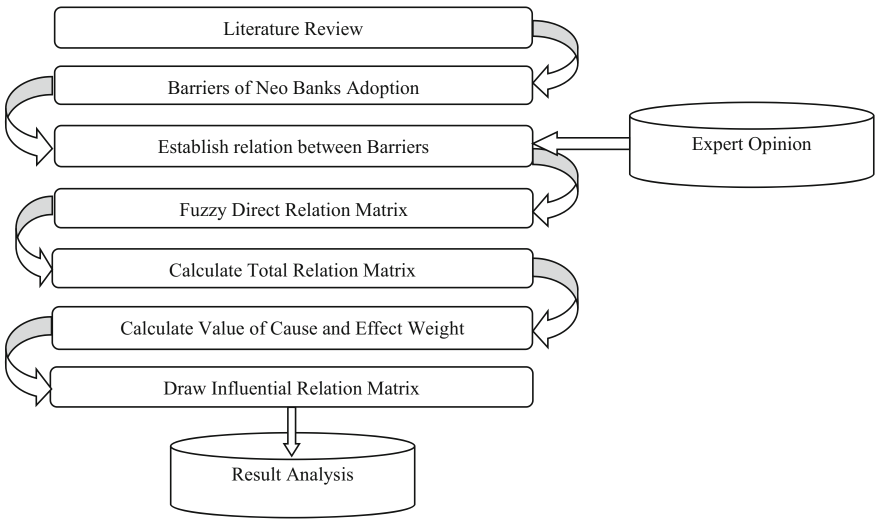

Fig. 1. Flow Diagram of Proposed Research

3.1 Fuzzy Set Theory

The concept of Fuzzy was proposed by Zadeh (1965). He introduced the concept of fuzzy set theory and the concept of membership function. A membership function defines the degree of truth in logic. The membership function in fuzzy logic plays a vital role in selecting the best alternatives out of the feasible ones [21]. However, the information derived from fuzzy set theory may be probabilistic, uncertain or even ambiguous in nature. Various experts and decision makers declare their opinions about the importance and preferences among the criteria based on their acquaintance and experiences. They tend to express their opinion by verbal values, which as a human centered operation, certainly include uncertainty. Hence, in order to handle the inherent uncertainty and ambiguity in experts' fuzzy variable can be used to assert decision makers' preferences [33].

3.2 Dematel

Problems with sophisticated decision making processes such as barriers to the effective adoption of Neo Banks may include various system criterions directly or indirectly. Here DEMATEL can map the direct and indirect relationship and interactions among barriers into a comprehensible structure model of the system in this study based on the type of criterion. As an approach it differentiates the factors into cause and effect and visualizes the structure of the causal relations and interactions among them using graphs and matrices [21, 33]. The DEMATEL method was originally proposed by the Battelle Memorial Institute Geneva Research Centre in the year 1970. It is a systematic analysis method that makes full use of an expert's experience and knowledge. This method is based on graph theory and matrix tools and is often used to solve complex social problems containing elements with uncertain relationships [47]. One of the critical success factors of DEMATEL is that it can work very well with the small sample size. DEMATEL is used to understand the relationship among the factors and analyze how they influence each other [21, 29]. This method of ranking had been used previously in many domains such as Supply chain Management [48], E-waste management [37], Health Care service assessment [43], Construction Industry [24] and Electric Vehicle Market [9].

3.3 Fuzzy DEMATEL

There are many approaches which can be used to identify the significant factors for a specific system under consideration, such as the technique for order preference by similarity to an ideal solution (TOPSIS), the analytical hierarchy process (AHP) and structural equation modeling (SEM). Whereas AHP and SEM cannot be used to identify the interrelationships among factors. Under the given conditions and existing models DEMATEL approach is found significant. Because it covers all the possible interdependence relations between the attributes to improve decision making. After analyzing the limitations, it can be concluded that Fuzzy DEMATEL is the appropriate technique to explore the barriers to Neo Banks adoption [16, 29].

3.4 The Steps Involved in Fuzzy DEMATEL Method is Presented Here:

Step 1: Establish the barriers from literature reviews and industry's expert's opinion.
Step 2: Consult with the experts and make a linguistic matrix.
Step 3: Pair-wise comparison will be converted into corresponding triangular fuzzy numbers as per Table 1.

Table 1. Linguistic scale and fuzzy triangular numbers

Scale (linguistic)	Fuzzy Number
(NI) No Influence	(0.00, 0.00, 0.25)
(VL)Very Low Influence	(0.00, 0.25, 0.50)
(LI) Low Influence	(0.25, 0.50, 0.75)
(HI) High Influence	(0.50, 0.75, 1.00)
(VH) Very High Influence	(0.75, 1.00, 1.00)

Step 4: Calculate the average fuzzy direct relationship matrix.
Step 5: Calculate the normalized fuzzy direct relationship matrix.

To identify the model of the relations among the n criteria, an n × n matrix is first generated. The influence of the element in each row exerted on the element in each column of this matrix can be represented a fuzzy number. If multiple experts' opinions are used, all experts must complete the matrix. Arithmetic mean of all of the experts' opinions is used to generate the direct relation matrix z.

$$\begin{aligned} Z &= \left(z_{ij1}, z_{ij2}, z_{ij3}\right) \text{ and} \\ X &= Z/a \end{aligned} \tag{1}$$

$$z = \begin{bmatrix} 0 & \cdots & \tilde{Z}_{n1} \\ \vdots & \ddots & \vdots \\ \tilde{Z}_{1n} & \cdots & 0 \end{bmatrix} \tag{2}$$

After that normalized fuzzy direct relationship matrix can be obtained using the formula:

$$\tilde{x}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r}\right) \tag{3}$$

where $r = \left\{\sum_{j=1}^{n} u_{ij}, \sum_{i=1}^{n} u_{ij}\right\} i, j \in \{1, 2, 3, \ldots, n\}$

Step 6: Calculate the total influence fuzzy relationship matrix.

The fuzzy total relationship matrix can be calculated by using the formula:

$$\tilde{T} = (\tilde{x}^1 \oplus \tilde{x}^2 \oplus \cdots \oplus \tilde{x}^k) \tag{4}$$

If each element of the fuzzy total-relation matrix is expressed as $\tilde{t}_{ij} = (l^{"}_{ij}, m^{"}_{ij}, u^{"}_{ij})$, it can be calculated as follows:

$$[m^{"}_{ij}] = x_m \times (I - x_m)^{-1} \tag{5}$$

$$[l^{"}_{ij}] = x_l \times (I - x_l)^{-1} \tag{6}$$

$$[u^{"}_{ij}] = x_u \times (I - x_u)^{-1} \tag{7}$$

More precisely**,** the normalized matrix the inverse is first calculated, and then it is subtracted from the matrix I, and finally the normalized matrix is multiplied by the resulting matrix. The following table shows the fuzzy direct-relation matrix.

Step 7: Calculate the sum of column and row of total influence fuzzy relationship matrix. Further, calculate the "Prominence" values by adding row and column (R + C) and "Relation" by subtracting the column from row (R-C). These are also known as causal and influence criteria respectively.

Step 8: Converting the values of row and column in crisp values.

Here, values of row and column are transformed into crisp value by using the CFCS technique (converting fuzzy numbers into crisp values). This method was introduced by Opricovic and Tzeng (2004). Following are the steps involved in exercising CFCS [5]:

Step I- Normalization of fuzzy numbers:

$$l^n_{ij} = \frac{\left(l^t_{ij} - l^t_{ij}\right)}{\Delta^{max}_{min}} \tag{8}$$

$$m^n_{ij} = \frac{(m^t_{ij} - minl^t_{ij})}{\Delta^{max}_{min}} \tag{9}$$

$$u^n_{ij} = \frac{(u^t_{ij} - minl^t_{ij})}{\Delta^{max}_{min}} \tag{10}$$

So that

$$\Delta^{max}_{min} = u^t_{ij} - l^t_{ij}$$

Step II- Calculating the upper and lower bounds of normalized values:

$$l^s_{ij} = \frac{m^n_{ij}}{(1 + m^n_{ij} - l^n_{ij})} \tag{11}$$

$$u^s_{ij} = \frac{u^n_{ij}}{(1 + u^n_{ij} - l^n_{ij})} \tag{12}$$

The output of the CFCS algorithm is crisp values.

Step III- Calculate the total normalized crisp values.

Calculating total normalized crisp values:

$$x_{ij} = \frac{[l_{ij}^{s}\left(1 - l_{ij}^{s}\right) + u_{ij}^{s} \times u_{ij}^{s}]}{[1 - l_{ij}^{s} + u_{ij}^{s}]} \tag{13}$$

Step IV: Calculate the final crisp values.

Step 9: At last, draw the causal diagram between the "Prominence" (R + C) values and "Relation" (R-C) values. Relation values will give the cause and effect information among the barriers; on the other hand Prominence value will give the information regarding the importance of criteria. The positive value of "Relation" i.e. (R-C) refers to the cause set and the negative value of (R-C) refers the effect set.

4 Data Collection and Analysis

This section discusses the proposed Fuzzy DEMATEL approach in detail which is used in this study to analyze the relationship among the barriers to Neo Banks adoption. Moreover, the procedures used for data collection and data analysis process are as follows:

4.1 Data Collection

Generally, participants are more willing to share their experiences and opinions about a specific event or services in an interactive atmosphere. Therefore, we contacted experts serving in the finance industry, especially in the banking industry and the academicians who are actively engaged in research on customers' intention/perception towards internet enabled financial services. The selection criterion was that the experts should have good practical expertise in the banking sector and/or specialized in the research related to internet enabled financial services. We shortlisted 16 experts from various department and institutions to ensure multi-dimensional information access to improve the reliability of the data. Overall, 10 experts agreed to participate and their background information is presented in Table 2. These experts evaluated the influence of every barrier on the remaining ones on a scale of 0–4 ranging from "No Influence" to "Very High Influence". We have used the Fuzzy DEMATEL questionnaire to collect their responses.

4.2 Fuzzy DEMATEL Analysis

On the basis of the data collected from experts on a linguistic scale, corresponding triangular fuzzy numbers have been converted and further average fuzzy direct relationship matrix has been framed and represented in Table 3.

After that, the normalized fuzzy direct relationship matrix has been formed using the Eq. 1 to 3 and has been presented in Table 4. Total influence fuzzy relationship matrix has been formed using the Eqs. 4, 5, 6 and 7, and of total influence fuzzy relationship matrix has been converted into a crisp total relation matrix by using CFCS as the steps discussed in step I t IV and Eqs. 8, 9, 10, 11, 12 and 13 and presented in Table 5.

Table 2. Experts' Profile

Characteristics	Category	Amount
Gender	Male	6
	Female	4
Highest Qualification	Bachelor	3
	Master	5
	Ph. D	2
Working Experience	5–10	4
	10–15	3
	15 & above	3
Job Position	Management Positions	5
	Technical Positions	3
	Management & Technical Positions	2
Job Title	Intermediate	6
	Senior	4

Further, values of row and columns along with the sum of total influences fuzzy relationship are calculated to get the "Prominence" value (Ri + Cj) and "Relation" value (Ri - Cj). This is represented in Table 6. In order to analyze the interdependence among the barriers in adoption of Neo Banks, a prominence relationship is draw which shows the pair-wise interrelationships among the barriers in adoption of Neo Banks. In the relationship matrix, we have represented the relationships with more than the threshold value of 0.564. Threshold value is the sum total of arithmetic mean and standard deviation of the total relationship matrix. The prominence relationship map has been drawn and presented in Fig. 2. In this figure, barriers can be grouped as per the following categories:

1. R + C higher and R – C positive:
2. R + C higher and R – C negative:
3. R + C Smaller and R – C positive:
4. R + C Smaller and R – C negative:

In Prominence relationship map the horizontal vector (D + R) represents the degree of importance among the barrier in adoption of Neo Banks. In other words, (D + R) indicates both factor i's impact on the whole system and other system factors' impact on the factor. In terms of degree of importance, B2 is ranked in first place and B10, B9, B1, B3, B6, B5, B4, B7 and B8, are ranked in the next places. In this study, B3, B5, B8, B9 are considered to be as a causal variable, B1, B2, B4, B6, B7, B10 are regarded as an effect.

The vertical vector (D-R) represents the degree of a barrier's influence on system. In general, the positive value of D-R represents a causal variable, and the negative value of D-R represents an effect. In terms of degree of importance, B2 is ranked in first place and B10, B9, B1, B3, B6, B5, B4, B7 and B8, are ranked in the next places. Therefore, in this study, B3, B5, B8, B9 are considered to be as a causal variable, B1, B2, B4, B6, B7, B10 are regarded as an effect.

Table 3. Average Fuzzy Direct Relationship Matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	0.000 0.000 0.000	0.750 1.000 1.000	0.600 0.850 1.000	0.525 0.775 0.850	0.500 0.750 1.000	0.750 1.000 1.000	0.325 0.575 0.825	0.100 0.350 0.600	0.500 0.750 1.000	0.575 0.825 1.000
B2	0.500 0.750 1.000	0.000 0.000 0.000	0.250 0.500 0.750	0.750 1.000 1.000	0.725 0.975 1.000	0.750 1.000 1.000	0.500 0.750 0.975	0.375 0.625 0.875	0.750 1.000 1.000	0.550 0.800 0.900
B3	0.725 0.975 1.000	0.700 0.950 1.000	0.000 0.000 0.000	0.500 0.750 1.000	0.500 0.750 1.000	0.750 1.000 1.000	0.500 0.750 1.000	0.350 0.600 0.800	0.500 0.750 1.000	0.750 1.000 1.000
B4	0.425 0.675 0.900	0.500 0.750 1.000	0.500 0.750 1.000	0.000 0.000 0.000	0.500 0.750 1.000	0.750 1.000 1.000	0.250 0.500 0.750	0.300 0.550 0.800	0.325 0.575 0.825	0.750 1.000 1.000
B5	0.500 0.750 1.000	0.650 0.900 1.000	0.500 0.750 1.000	0.500 0.750 1.000	0.000 0.000 0.000	0.250 0.500 0.750	0.500 0.750 1.000	0.500 0.750 1.000	0.300 0.550 0.800	0.750 1.000 1.000
B6	0.500 0.750 1.000	0.500 0.750 1.000	0.375 0.625 0.850	0.500 0.750 1.000	0.475 0.725 0.975	0.000 0.000 0.000	0.500 0.750 1.000	0.650 0.900 1.000	0.650 0.900 1.000	0.375 0.625 0.850
B7	0.500 0.750 1.000	0.525 0.775 0.975	0.750 1.000 1.000	0.525 0.775 1.000	0.300 0.550 0.700	0.250 0.500 0.750	0.000 0.000 0.000	0.250 0.500 0.750	0.725 0.975 1.000	0.500 0.750 0.875
B8	0.750 1.000 1.000	0.525 0.775 1.000	0.300 0.550 0.775	0.500 0.750 1.000	0.225 0.475 0.650	0.250 0.500 0.750	0.500 0.750 1.000	0.000 0.000 0.000	0.500 0.750 1.000	0.750 1.000 1.000
B9	0.750 1.000 1.000	0.500 0.750 1.000	0.725 0.975 1.000	0.300 0.550 0.800	0.500 0.750 1.000	0.500 0.750 1.000	0.750 1.000 1.000	0.500 0.750 1.000	0.000 0.000 0.000	0.750 1.000 1.000
B10	0.600 0.850 0.925	0.750 1.000 1.000	0.400 0.650 0.900	0.300 0.550 0.775	0.500 0.750 1.000	0.750 1.000 1.000	0.500 0.750 1.000	0.500 0.750 1.000	0.500 0.750 1.000	0.000 0.000 0.000

Table 4. Normalized Fuzzy Direct Relationship Matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	0.000 0.000 0.000	0.084 0.111 0.111	0.067 0.095 0.111	0.058 0.086 0.095	0.056 0.084 0.111	0.084 0.111 0.111	0.036 0.064 0.092	0.011 0.039 0.06	0.056 0.084 0.111	0.064 0.092 0.111
B2	0.056 0.084 0.111	0.000 0.000 0.000	0.028 0.056 0.084	0.084 0.111 0.111	0.081 0.109 0.111	0.084 0.111 0.111	0.056 0.084 0.109	0.042 0.070 0.097	0.084 0.111 0.111	0.061 0.089 0.100
B3	0.081 0.109 0.111	0.078 0.106 0.111	0.000 0.000 0.000	0.056 0.084 0.11	0.056 0.084 0.111	0.084 0.111 0.111	0.056 0.084 0.111	0.039 0.067 0.089	0.056 0.084 0.111	0.084 0.111 0.111
B4	0.047 0.075 0.100	0.056 0.084 0.111	0.056 0.084 0.111	0.000 0.000 0.000	0.056 0.084 0.111	0.084 0.111 0.111	0.028 0.056 0.084	0.033 0.061 0.089	0.036 0.064 0.092	0.084 0.111 0.111
B5	0.056 0.084 0.111	0.072 0.100 0.111	0.056 0.084 0.111	0.056 0.084 0.111	0.000 0.000 0.000	0.028 0.056 0.084	0.056 0.084 0.111	0.056 0.084 0.111	0.033 0.061 0.089	0.084 0.111 0.111
B6	0.056 0.084 0.111	0.056 0.084 0.111	0.042 0.070 0.095	0.056 0.084 0.111	0.053 0.081 0.109	0.000 0.000 0.000	0.056 0.084 0.111	0.072 0.100 0.111	0.072 0.100 0.111	0.042 0.070 0.095
B7	0.056 0.084 0.111	0.058 0.086 0.109	0.084 0.111 0.111	0.058 0.086 0.111	0.033 0.061 0.078	0.028 0.056 0.084	0.000 0.000 0.000	0.028 0.056 0.084	0.081 0.109 0.111	0.056 0.084 0.097
B8	0.084 0.111 0.111	0.058 0.086 0.111	0.033 0.061 0.086	0.056 0.084 0.111	0.025 0.053 0.072	0.028 0.056 0.084	0.056 0.084 0.111	0.000 0.000 0.000	0.056 0.084 0.111	0.084 0.111 0.111
B9	0.084 0.111 0.111	0.056 0.084 0.111	0.081 0.109 0.111	0.033 0.061 0.089	0.056 0.084 0.111	0.056 0.084 0.111	0.084 0.111 0.111	0.056 0.084 0.111	0.000 0.000 0.000	0.084 0.111 0.111
B10	0.067 0.095 0.103	0.084 0.111 0.111	0.045 0.072 0.100	0.033 0.061 0.086	0.056 0.084 0.111	0.084 0.111 0.111	0.056 0.084 0.111	0.056 0.084 0.111	0.056 0.084 0.111	0.000 0.000 0.000

Table 5. Total Influence Relationship Matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	0.514	0.618	0.557	0.555	0.551	0.589	0.541	0.477	0.572	0.6
B2	0.607	0.543	0.545	0.59	0.583	0.605	0.573	0.517	0.608	0.617
B3	0.636	0.646	0.504	0.583	0.578	0.618	0.585	0.524	0.601	0.644
B4	0.571	0.589	0.54	0.469	0.541	0.579	0.524	0.487	0.546	0.603

(*continued*)

Table 5. (*continued*)

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B5	0.589	0.611	0.55	0.555	0.475	0.547	0.557	0.512	0.554	0.614
B6	0.595	0.604	0.544	0.56	0.552	0.498	0.562	0.529	0.588	0.589
B7	0.575	0.586	0.557	0.542	0.517	0.534	0.467	0.476	0.575	0.579
B8	0.594	0.587	0.519	0.541	0.511	0.534	0.543	0.424	0.558	0.6
B9	0.639	0.631	0.596	0.565	0.577	0.598	0.604	0.537	0.527	0.645
B10	0.608	0.63	0.552	0.548	0.561	0.599	0.568	0.523	0.584	0.533

Note: Values above the threshold value are shown in italic (Threshold Value is 0.564)

Table 6. Total Influence Relationship matrix by considering the threshold values

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	0	0.618	0	0	0	0.589	0	0	0.572	0.6
B2	0.607	0	0	0.59	0.583	0.605	0.573	0	0.608	0.617
B3	0.636	0.646	0	0.583	0.578	0.618	0.585	0	0.601	0.644
B4	0.571	0.589	0	0	0	0.579	0	0	0	0.603
B5	0.589	0.611	0	0	0	0	0	0	0	0.614
B6	0.595	0.604	0	0	0	0	0	0	0.588	0.589
B7	0.575	0.586	0	0	0	0	0	0	0.575	0.579
B8	0.594	0.587	0	0	0	0	0	0	0	0.6
B9	0.639	0.631	0.596	0.565	0.577	0.598	0.604	0	0	0.645
B10	0.608	0.63	0	0	0	0.599	0.568	0	0.584	0

Table 7. Prominence and Relation Values

	R	D	D + R	Rank	D – R	Group
B1	5.928	5.573	11.501	4	-0.355	Effect
B2	6.046	5.788	11.835	1	-0.258	Effect
B3	5.463	5.918	11.382	5	0.455	Cause
B4	5.507	5.448	10.954	8	-0.059	Effect
B5	5.446	5.564	11.01	7	0.118	Cause

(*continued*)

Table 7. (*continued*)

	R	D	D + R	Rank	D – R	Group
B6	5.7	5.622	11.322	6	-0.079	Effect
B7	5.524	5.409	10.932	9	-0.115	Effect
B8	5.006	5.413	10.419	10	0.407	Cause
B9	5.713	5.919	11.632	3	0.206	Cause
B10	6.025	5.704	11.729	2	-0.321	Effect

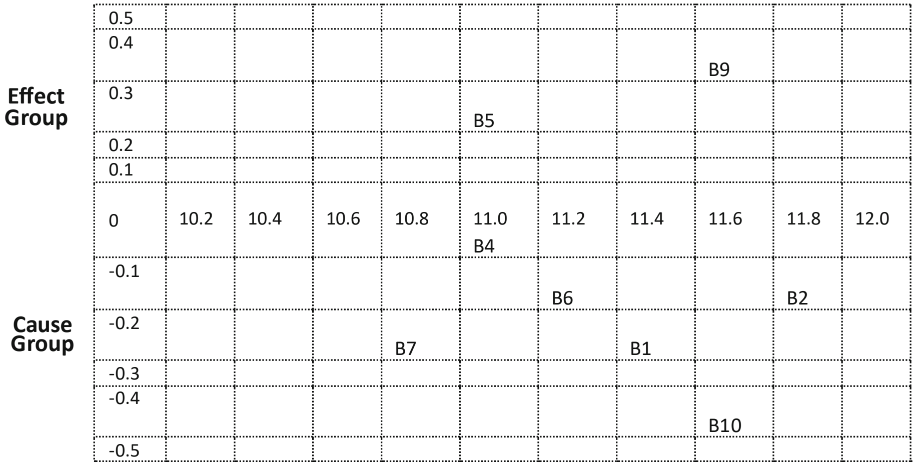

Fig. 2. Prominence Relationship Map

5 Results and Discussion

In this study, we have implemented Fuzzy DEMATEL analysis where the barriers and the interrelationship among the barriers are determined by applying the threshold value which is 0.564. The threshold value is computed by sum of the means and standard deviation of total relationship matrix [5]. Precisely, Table 6 represents that barrier B8 (Digital Inclusion Barrier)will affect the other barriers of Neo Banks adoption but it would not be affected by any other barriers because barrier B8 has a lesser threshold value. Hence B8 (Digital Inclusion Barrier) is considered as an independent barrier and not be affected by any other barrier. In Fuzzy DEMATEL analysis, the highest value of R + C indicates the highest relationship among other barriers in Neo Banks adoption. Further, Table 7, represents, B1 (Value Barrier), B2 (Usage Barrier), B9 (Social Barrier), B10 (Trust Barrier) holds the top four highest values of R + C. it means that they have strong relationship with other barriers.

From the prior literature, it is inferred that Neo Banks have advantages for banks and customers, as it provides more convenient and faster banking services. Additionally, it fulfills some tasks of physical wallet, such as holding personal information, facilitating cash and credit payment and storing temporary tokens such as: vouchers, transportation, tickets etc. Neo Banks are providing more financial and psychological benefits than traditional banks such as free transfer to other banks, no initial account fees, high interest deposit, free withdrawals from ATM, no minimum balance required, facility of cash tag, online KYC, 24/7 access to all financial service and many more. Despite, the numerous facilities provided by Neo Banks, customers are still lagging behind in adoption of Neo Banks. The primary reasons behind the phenomenon are the Usage Barrier (B2). In case of Neo Banks, all the transactions are performed by the consumer him/her self that involves the specific procedure to be followed may feel the customer reluctance towards the adoption of Neo Banks. Hence, it is crucial for the consumers to be aware and attain experience in operating the Neo Banks operation to make success the adoption of Neo Banks. In field of technological innovation, Trust is considered as an important factor which makes feel the consumer confident that their vulnerabilities will not be exploited in a risky online situation. Apart from this, the people around the consumer also affect on the consumer. If the people around the consumers are already the users of Neo Banks, makes positive impact on the consumers to adopt the Neo Banks. Customers while deciding upon the adoption of innovative service, review the value to be received against the cost or efforts incurred while choosing the Neo Bank.

The expectation of risk involved in innovative service also affect the decision the customers' decision. Neo Bank collect and store all the personal and financial information of the consumers and keep the information secret to make feel the consumer secure. The organization associated with service provider develops confidence in adoption for Ex: Association of State Bank of India with YONO develop reliable image. Every innovative technology obstructs the existing tradition but make the life of consumer comfortable. Electronically provided financial services with digitally included consumers make the appropriate environment for the effective adoption of Neo Banks. This research outcome can provide impetus to innovative technology providers and policy makers to come together and develop standards and guidelines in the light of challenges being faced by customers. Though digitalization of financial service is a positive change in the era of industry 4.0 will make the lives of consumers convenient and comfortable. In case of Indian Neo Banks, the consumers of traditional banks are understanding and considering the Neo Bank services but immediate adoption is being reluctant by some barriers. The outcomes of this study provide a roadmap to the early adopters and those who are willing to adopt in near future.

6 Conclusion and Future Scope

Industry 4.0 technologies have changed the shape of many industries in India, including the finance sector also. With the blend of these technologies, banks are offering novel financial services along with the traditional services electronically to make the lives comfortable and make accessible the services to the unbanked people. Therefore, for the purpose of optimization of consumers' lives and banking the unbanked people, it is essential to adopt innovative technologies in finance industry. Above discussed barriers need to be considered for effective adoption of Neo Banks. We have identified ten possible barriers from thorough literature and from discussion with finance industry officials.

After that the analysis explains in detail relationship between the barriers via cause and effect relationship. Findings of this study will assist the officials of the Neo Banks as well as traditional to emphasize the critical bottlenecks to stay effective and resilient in finance industry. The implementation and evaluation could be done in phased manner such as organizing the awareness campaign/program for digital inclusion, providing Neo Banks information at traditional bank's branches etc. Finally, for the purpose of effective adoption of Neo Banks, the provider must know the critical barriers which need to be addressed first and valuate accordingly.

This exploratory study was carried in the context of NCR (National Capital Region) region in India. To get better mapping of the barriers in adoption of Neo Banks, a study can be done by referring to other prominent cities across different states in India. Since the data has been taken from small number of experts, use of MCDM method for statistical decision making purpose is justified. Moreover, it is taken from more experts' inputs to get more appropriate population assessment and by using other data analysis methods like SEM (Structural Equation Modeling) or other multivariate analysis techniques so that statistical inferences can also be drawn. However, this study offers a clear picture of the barriers in effective adoption of Neo Banks in finance industry.

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Barriers to Smart Home Technologies in India

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Abstract. Smart home technologies (SHT) are critical for effectively managing homes in a digital society. However, SHTs face challenges related to their limited use in developing country contexts. This study investigates the factors that act as barriers to SHT adoption among individuals in Bengaluru, India. The roles of perceived risk, performance and after-sale service, and demographics in using smart home technologies (SHT). This study used the data from the primary survey of 133 respondents. The collected data were analyzed using regression analysis. The results supported five of the proposed hypotheses, namely, perceived performance risk, perceived financial risk, perceived psychological risk, and technological uncertainty, which influence the Behavioral intention to adopt SHT. However, service intangibility is influenced by performance risk. Income and age influence the psychological risk and adoption of SHT. The study identifies the barriers to SHT adoption. The supportive environment for SHT needs to be strengthened to reduce the associated risks.

Keywords: Smart Home Technologies (SHT) · Service intangibility · Technological uncertainty · Technology adoption model · UTAUT

1 Introduction

The expansion of digital space has transformed society. India is transforming its cities into smart cities by changing various services and conceptualizing smart cities to deliver public goods [1]. Information and Communication Technologies (ICTs) provide solutions to transform traditional functions. ICTs are changing the structures of homes to smart homes. A smart home (SH) is a setup where appliances and devices can be remotely controlled by smart devices like a mobile phone or laptop connected to the internet. Smart home technologies (SHT) offer various advantages, allowing the user to remotely control security, humidity, lighting, and home theatre, which improves access to better services and convenience [2, 3].

However, there are challenges to SHT adoption, such as privacy concerns, cost factors, performance concerns, and security [3, 4]. Most of the research on SH took place

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in the developed countries, which also reflects that smart home adoptions are still segmented into specific groups [5]. This study aims to explore the barriers to SHT adoption in India. This study investigates the following research questions:

RQ-1: What factors influence the adoption of SHT in India?
RQ-2: To determine the users' perception of using smart home products.
RQ-3: What are the risk factors which influence SHT usage in India?

The significance of technology adoption [6] UTAUT [7] model for technology usage which also guides this study. This study contributes to the smart home literature in developing country contexts by investigating the individual perceptions and barriers to SH use.

This is the paper outline: Section one introduces the study and summarizes the research background. Section two reviews the literature on smart home services and ecosystems and presents a conceptual model. The third section is methodology and section four present the findings and analyses. Section five discusses the findings, theoretical and practical implications, limitations, and future research. The last section concludes the paper.

2 Theoretical Framework and Hypothesis Development

2.1 Smart Homes Services

With the growth in digital technologies like the Internet of Things (IoT), smart homes have become more accessible and affordable to consumers. SHTs can be controlled using smart devices like smartphones, and some SHTs can even learn your usage patterns and regulate performance. The adoption of smart home technology has variability between various groups of users. These groups have experiential behavior based on interaction with smart home technology [2]. Smart home services adoption is oriented to ease of use, perceived benefits, and compatibility. The experiential factor is vital in usage [8]. The research tries to find smart home barriers to adoption. Hong et al. (2020) [9] researched the barriers to smart home adoption using the resistance theory and perceived risk model by examining the relationship between perceived risk and resistance to smart home services between two groups of users. The financial, performance, privacy, and psychological risks are related to adopting smart home usage [9, 10].

SHTs include smart lighting, smart security, smart speakers, smart appliances (refrigerators, washing machines, and air conditioners), smart plugs, and smart thermostats. Primary research on e-commerce platforms shows that many brands are operating in the SHT market in India. To investigate the barriers to SHT adoption, this research adopted the variable from TPB and UTAUT.

2.2 Conceptual Framework

The Unified Theory of Acceptance and Use of Technology helps to understand and predict the acceptance and adoption of information technology (IT) in various contexts. It integrates elements from the Technology Acceptance Model (TAM), the Theory of

Planned Behavior (TPB), the Innovation Diffusion Theory (IDT), and the Social Cognitive Theory (SCT). It has four key constructs that influence technology acceptance: Performance Expectancy (PE), where individuals perceive that using the technology will help them perform tasks more efficiently. Effort Expectancy, in this individual perceived ease of use of the technology. Social influence- individual influence by external factors and opinions [6, 7]. The elements of the Theory of Planned Behavior also influence the use of technology, including subjective norms (social pressure and support), perceived behavioral control, and attitude towards behaviors [11]. Technology use is influenced by the environment, like facilitating conditions, which reflects the resources and support available for using the technology. UTAUT has three moderating variables: gender, age, and experience. The UTAUT model has been used in e-commerce, mobile applications, and healthcare technology [7, 12].

Perceived Performance Risk. Consumers are unsure of how well smart home services or devices will operate, referred to as performance risk. This includes issues about smart homes failing to function as intended or marketed and their quality falling short of customer expectations [7, 12].

Hypothesis 1: H0- Perceived performance risk is not positively related to resistance to smart homes.

H1-Perceived performance risk is positively related to resistance to smart homes.

Performance Financial Risk. The likelihood that a product or service will not be worth the money spent on it or that a less expensive substitute will become available is known as financial risk. According to many consumer surveys on smart homes, the cost of a smart home device or service is the most significant barrier to customer adoption [7, 12].

Hypothesis 2: H0- Perceived financial risk is not positively related to resistance to smart homes.

H1-Perceived financial risk is positively associated with resistance to smart homes.

Perceived Privacy Risk. Consumers are concerned about possibly misusing their data without their consent or sharing their private information with third parties. The issue of privacy is a fundamental concern for all high-tech products and services, and it is a significant concern for technology acceptance [7, 12]. Smart homes collect information about the individual usage of various services and behavioural patterns.

Hypothesis 3: H0-Perceived privacy risk is not positively related to resistance to smart homes.

H1-Perceived privacy risk is positively related to resistance to smart homes.

Perceived Psychological Risk. Perceived psychological risk is the possibility that smart homes will negatively impact consumers' mental health or self-perception [7, 12]. Consumers may be concerned about losing control over their homes and everyday household routines.

Hypothesis 4: H0-Perceived psychological risk is not positively related to resistance to smart homes.

H1- Perceived psychological risk is positively related to resistance to smart homes.

Technology Uncertainty (TU). Technological uncertainty refers to technology performance due to limited information and experience [13]. The future interactions of technology and the environment have limited clarity about the outcomes. The lack of a precise model based on data and unpredictability about the relevancy of the data contribute to TU.

Hypothesis 5a: H0-Technological uncertainty is not positively related to perceived performance risk.

H1- Technological uncertainty is positively related to perceived performance risk.

Hypothesis 5b: H0-Technological uncertainty is not positively related to perceived financial risk.

H1-Technological uncertainty is positively related to perceived financial risk.

Hypothesis 5c: H0- Technological uncertainty is not positively related to perceived psychological risk.

H1-Technological uncertainty is positively related to perceived psychological risk.

Hypothesis 5d: H0- Technological uncertainty is not positively related to perceived privacy risk.

H1- Technological uncertainty is positively related to perceived privacy risk.

Service Intangibility. Service intangibility is associated with the outcome of service use. Smart home services are new and supported by technology, and consumers are unfamiliar with smart home services. Consumers' understanding of smart home concepts or performance attributes is limited [14].

Hypothesis 6a: H0- Service Intangibility is not positively related to perceived performance risk.

H1- Service Intangibility is positively related to perceived performance risk.

Hypothesis 6b: H0- Service Intangibility is not positively related to perceived finance risk.

H1- Service Intangibility is positively related to perceived finance risk.

Hypothesis 6c: H0- Service Intangibility is not positively related to perceived psychological risk.

H1- Service Intangibility is positively related to perceived psychological risk.

Hypothesis 6d: H0- Service Intangibility is not positively related to perceived privacy risk.

H1- Service Intangibility is positively related to perceived privacy risk.

Apart from the other factors, a few categorical variables positively influence Resistance, Psychological risk, and adoption of SHT.

Hypothesis 7: H0 = Family income has no positive influence on Resistance

H1 = Family income has a positive influence on resistance

Hypothesis 8: H0 = Age has no positive influence on psychological risk

H1 = Age has a positive influence on psychological risk

Hypothesis 9: H0 = Age has no significant influence on the adaption of smart homes

H1 = Age has a significant influence on the adaption of smart homes

Hypothesis 10: H0 = Income has no positive influence on the adaption of smart homes
H1 = Income has a positive influence on the adaption of smart homes

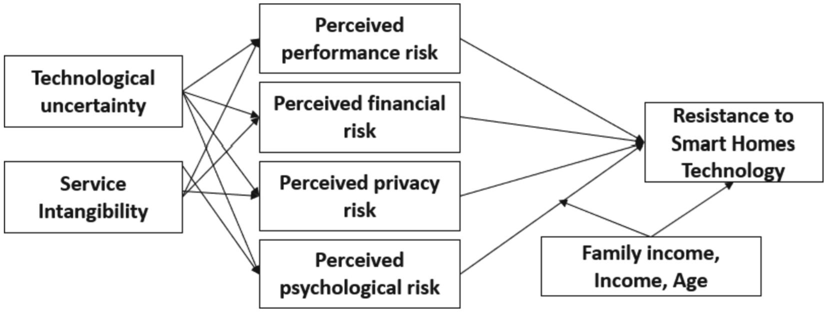

Fig. 1. Research Framework for resistance to SHT

Figure 1 shows the independent risk factors: perceived performance, financial, privacy, psychological risk and resistance, technological uncertainty, and service intangibility are the dependent factors. Explore the barriers of SHT using the relationship between dependent and independent factors.

3 Research Design

3.1 Methodology

To answer the research questions, this research adopted a quantitative study based on the primary data source and data collected through a survey tool. A five-point Likert scale structured questionnaire was designed to measure each of the variables from the existing literature [6, 7, 15]. The questionnaire has adopted variables of Perceived performance risk, Perceived finance risk, Perceived privacy risk, Perceived psychological risk, Technology uncertainty, Service Intangibility and dependent variable Resistance of smart homes [6, 7, 12], for details of constructs and items please refer to Appendix. The survey data was collected online and offline from Bangaluru, India, from January to March 2022. After removing the incomplete survey, this study used 133 responses. The data analysis is based on regression, exploratory factor analysis, ANOVA and chi-square [16] using the SPSS Statistics 25 tool. A few statistical conversions were done using Microsoft Excel 2019 software. The demographic details of respondents are provided in Table 1.

Table 1. Demographics of the respondents

Demographic details		(%)
Gender- 133 (100%)	Male	(62.40%)
	Female	(36.80%)
	I prefer not to say	(0.80%)
Age	18–26 years	(69.20%)
	27–34 years	(18.80%)
	35–50 years	(7.5%)
	More than 50 Years	(4.5%)
Family Income (Per annum in Indian Rupees) – 133 (100%)	Less than 200000	(12.8%)
	200001–500000	(13.50%)
	500001–800000	(15.80%)
	800001–1200000	(30.8%)
	Greater than 1200000	(27.10%)
Residence type	Single owned house	(63.9%)
	Apartment	(21.8%)
	More than one house (Family house)	(6.8%)
	Other	(7.5%)

4 Findings

4.1 Data Analysis

Instrument Reliability

Cronbach's Alpha measures sample consistency. The test result must be between 0.7 and 0.95 to pass. In the current research, Cronbach's Alpha test value is 0.932, which is between 0.7 and 0.95, proving that the obtained data is consistent and credible for further investigation. For details, refer to Table 2.

Table 2. Statistics for reliability

Reliability Statistics		**Kaiser-Meyer-Olkin Measure and Bartlett's Test**		
Cronbach's Alpha	0.932	KMO Measure of Sampling Adequacy.		0.895
N of Items	19	Bartlett's Test of Sphericity	Approx. Chi-Square	1843.753
			df	171
			Sig.	0.000

KMO and Bartlett's test value is 0.895, which is greater than 0.6, demonstrating that the acquired data is adequate for further investigation. In this study, the significant value is 0.000*, which is less than 0.05, proving that the sample is significant and supports the research (Table 3).

We presented the constructs of resistance to SH usage and its loading in Table and factors scree plot shown in Fig. 2.

Table 3. Loadings of constructs for resistance to Smart Home Usage

Construct	Item	Loading
Perceived psychological risk (PPsR)	PPsR1	.668
	PPsR2	.772
Perceived privacy risk (PPrR)	PPrR1	.865
	PPrR2	.860
	PPrR3	.859
Perceived performance risk (PPR)	PPR1	.795
	PPR2	.768
	PPR3	.714
Perceived financial risk (PFR)	PFR1	.736
	PFR2	.862
	PFR3	.789
Service intangibility (SI.)	SI1	.887
	SI2	.875
Technological uncertainty (TU.)	TU1	.829
	TU2	.716
	TU3	.854
Resistance (RES)	RES1	.736
	RES2	.675
	RES3	.851

Note: PPsR = perceived psychological risk, PPrR = perceived privacy risk, PPR = perceived performance risk, PFR = perceived financial risk, SI = service intangibility, TU = technological uncertainty, and RES = resistance

Model Analysis

This section presents the analysis of models for each hypothesis.

Hypothesis 1, 2 (H1, H2):

Resistance to SHT = 0.046 (Const) + 0.487 PPR + 0.396 PFR

H1: P-value is 0.000, therefore fails to accept the null hypothesis. H2: P-value is 0.000; therefore, it fails to accept the null hypothesis. This model statistics are R =

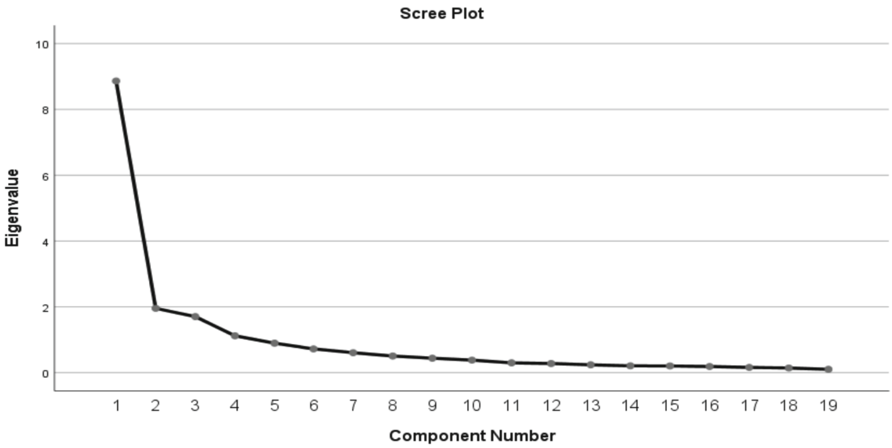

Fig. 2. Scree Plot to identify the factors.

0.663, $R^2 = 0.440$, Adjusted $R^2 = 0.431$, SE (standard error) = 0.84786. ANOVA: Sum of squares = 73.354 (df-degree of freedom) = 2, ms-mean square = 36.677), Residual = 93.452 (df = 130, ms = 0.719), F = 51.021, Sig = 0.000. The results indicate that the perceived performance risk and perceived financial risk influence the adoption of smart homes.

Hypothesis 3,4 (H3, H4):
Resistance to SHT = 0.242(Const) + 0.721 PPsR + 0.138 PPrR

H3: P-value is 0.000, which is less than 0.05; therefore, fails to accept the null hypothesis. H4: P-value is 0.026, which is less than 0.05; therefore, fail to accept the null hypothesis. The model is significant with R = 0.812, $R^2 = 0.659$, Adjusted $R^2 = 0.653$, S.E = 0.66185. ANOVA statistics are Sum of squares = 109.860 (df = 2, ms = 54.930), Residual = 56.945(df = 130, ms = 0.438), F = 125.4, Sig = 0.000. The regression analysis shows that PPsR, PPrR affect the adoption of smart homes.

Hypothesis 5 (H5a, H5b, H5c, H5d): Model of Technological Uncertainty (TU):

TU = 1.491(Const) + 0.226 PPR − 0.255 PFR + 0.312 PPsR + 0.287 PPrR)

P values are less than 0.05 (H5a = 0.015, H5b = 0.007, H5c = 0.05, H5d = 0.000) and therefore fail to accept the null hypothesis. The model statistics are R = 0.665, R2 = 0.442, Adjusted R2 = 0.425, S.E = 0.67099; Sum of squares = 45.656 (df = 4, ms = 11.414), Residual = 57.629 (df = 128, ms = 0.450), F = 25.351, Sig = 0.000. Technological uncertainty is influenced by PPR, PFR, PPsR, and PPrR.

Hypothesis 6: Model of Service Intangibility (SI),

SI = 1.911 (Const) + 0.535 PPR- 0.276 PFR + 0.89 PPsR + 0.156 PPrR.

Hypothesis 6: H6a: P-value is 0.000, which is less than 0.05, we fail to accept the null hypothesis; H6b: P-value is 0.070, which is not less than 0.05, we accept the null hypothesis; therefore, the model is not significant.

H6c: P-value is 0.426, which is not less than 0.05, we accept the null hypothesis; therefore, the model is not significant; H6d: P-value is 0192, which is not less than 0.05, we accept the null hypothesis; therefore, the model is not significant. Model statistics: R = 0.453, R^2 = 0.206, Adjusted R^2 = 0.181, S.E = 1.09279; ANOVA statistics: Sum of squares = 39.564 (df = 4, ms = 9.891), Residual = 152.857 (df = 128, ms = 1.194), F = 8.282, Sig = 0.000.

Hypothesis 7: ANOVA Statistics- Between Groups: Sum of Squares-44.075, df-12, ms = 3.673, F-value = 2.215, Sig = .015. Within Groups:Sum of Squares-198.948, df = 120, ms = 1.658 and total:Sum of square = 243.023, df = 132. Since the P-value is 0.000, which is less than 0.05, we fail to accept the null hypothesis.

Hypothesis 8: ANOVA statistics- Between Groups: Sum of Squares = 12.991, df = 8, ms = 1.624, F-value = 2.644Sig = .010. Within Groups,the Sum of Squares = 76.167, df = 124, ms = .614 and the total sum of square = 89.158. df = 132. Since the P-value is 0.000, which is less than 0.05, we fail to accept the null hypothesis.

Hypothesis 9: Age significantly influences smart home adoption with the following statistics: Pearson Chi-Square- 9.520, df = 3, sig = .023; Likelihood Ratio = 7.097, df = 3, sig = .069; Linear-by-Linear Association = 4.854, df = 1, sig = .028 (two sided). Since the P-value is 0.000, which is less than 0.05, we fail to accept the null hypothesis,

Hypothesis 10: Model statistics: Chi-Square Tests: Pearson Chi-Square17.981, df = 4, sig .001 (two-sided); Likelihood Ratio- Value = 16.743, df = 4, sig = .002; Linear-by-Linear Association = 4.852, df = 1, sig = .028. Since the P-value is 0.000, which is less than 0.05, we fail to accept the null hypothesis. Demographics are related to resistance and adoption. Family Income influences the resistance. Age and Income positively influence the adoption of SHT and are associated with PPsR.

5 Discussion

Our study investigated the barriers to SHT use that influence the adoption of SHT. The results show that users' intents were best explained by their expectations of effort, performance, social impact, perceived risk, and SHT ecosystem. The significant values of the hypothesis supported are PPR, PFR, PPR, PPsR, TU, SI and demographics relations with resistance to SH. Table 4 shows that PPR, PFR, PPrR, and PPsR influence the resistance. Technology uncertainty is positively associated with perceived performance, privacy, psychological, and financial risks, supporting H5a, H5b, H5c, and H5d [9, 10]. Technology unpredictability and service intangibility are antecedents of smart home resistance threats. SHTs are technology-intensive products; thus, buyers will associate risk with them if uncertain about their technology. PFR influences resistance differently from past studies [9].

Service intangibility affects only perceived performance risk, which differs from the past study but has no other risks. In contrast, research shows that PPR, PFR, and PPrR are insignificant resistors and PPsR is significant [21]. Users who do not understand smart home services may worry about their performance, cost, and lifestyle changes.

Table 4. Results of Hypothesis Testing.

Hypothesis	P-Value	Remark
H1 Perceived performance risk → Resistance to SH	0.000	Accept
H2 Perceived financial risk → Resistance to SH	0.000	Accept
H3 Perceived privacy risk → Resistance to SH	0.026	Accept
H4 Perceived psychological risk → Resistance to SH	0.000	Accept
H5a Technological uncertainty → Perceived performance risk	0.015	Accept
H5b Technological uncertainty → Perceived financial risk	0.007	Accept
H5c Technological uncertainty → Perceived psychological risk	0.000	Accept
H5d Technological uncertainty → Perceived privacy risk	0.000	Accept
H6a Service Intangibility → Perceived performance risk	0.000	Accept
H6b Service Intangibility → Perceived finance risk	0.070	Reject
H6c Service Intangibility → Perceived psychological risk	0.426	Reject
H6d Service Intangibility → Perceived privacy risk	0.192	Reject
H7 Family income → Resistance to SH	0.015	Accept
H8 Age → Psychological risk	0.010	Accept
H9 Age → Adoption of SH	0.023	Accept
H10 Income → Adoption of SH	0.001	Accept

In this study, the role of the risk factors in technology adoption and resistors act as critical [5, 9, 17]. Demographics such as Age and Income affect resistance and adoption of smart home services. These findings further confirm the existing literature [8, 9, 17].

Implications

We are discussing this research study's theoretical and practical implications regarding barriers to SHT usage.

Theoretical Implications. To identify the barriers to SHT pre and post-usage, we have used multiple theoretical lenses from TPB [11], TAM [6], and UTAUT [6, 7]. The research findings enrich the understanding of the barriers to SHT usage.

Practical Implications. Smart home technologies are associated with multiple sectors and stakeholders, and SHT can impact the economy of India. The integration of the SHT can benefit the citizens to manage their houses and explore new emerging SHT technologies. This research highlights the critical focus area to enhance the adoption of SHT. This study analyses the PPsR, PPrR, PPR, PFR, SI, and TU and their contribution to RES to SH usage.

Limitations and Future Research Scope. This research is confined to the barriers associated with using smart home technology-enabled products in India and having limited data to study India's smart home technology ecosystem. Future researchers can explore the implications of SHT interactions with human and non-human actors.

6 Conclusion

This study aimed to investigate the barriers which influence SHT adoption in the Indian home using a quantitative survey gathered from individuals from Bengaluru City, India. TAM, TPB, and UTUAT frameworks' ten constructs were adapted to investigate the barriers to SHT use by focusing on understanding the individuals' behavioral intention to use SHT. A quantitative model for resistance to the use of smart home technology developed using a structural equation modelling technique was adopted to test the effect between the dependent variable of resistance to the following independent variables: PPR, PFR, PPR, PPsR, TU, SI and demographics relations with resistance to SHT. The study shows the barriers to SHT adoption. The result showed that out of ten hypotheses and with subparts equals sixteen hypotheses, thirteen of which supported the non-adoption of SHT.

Appendix A

See Table 5.

Table 5. Constructs and Items

Construct	Item	Measurement question	Source
Perceived psychological risk (PPsR)	PPsR1	A smart home will not fit in with my lifestyle	[6, 7, 9, 12]
	PPsR2	A smart home will make me lose control of my home and become indifferent or lazy at home	
Perceived privacy risk (PPrR)	PPrR1	Personal information could be intercepted or accessed if I use smart home products and services	[6, 7, 9, 12]
	PPrR2	If I use smart home products and services, the chance of losing control over my private information is high	
	PPrR3	If I use smart home products and services, private information could be misused, inappropriately shared, or sold	
Perceived performance risk (PPR)	PPR1	I feel that the performance of smart home services and products may not match their advertised level	[6, 7, 9, 12]
	PPR2	It is uncertain whether smart homes will operate as satisfactorily as expected	

(*continued*)

Table 5. (*continued*)

Construct	Item	Measurement question	Source
	PPR3	I am concerned that the smart home would not provide the level of benefits that I would expect	
Perceived financial risk (PFR)	PFR1	I am concerned that I would not get my money's worth from a smart home	[6, 7, 9, 12]
	PFR2	I am concerned that repairing and maintaining a smart home would cost a lot	
	PFR3	I am concerned that it would cost a lot to purchase and install smart home products	
Service intangibility (SI.)	SI1	I feel that it is difficult to understand how smart homes work	[6, 7, 9, 12]
	SI2	I feel that it is difficult to explain the features and functions of smart homes to others	
Technological uncertainty (TU.)	TU1	I think that the wireless network of smart homes is unstable	[6, 7, 9, 12]
	TU2	I feel that the security of smart homes is questionable	
	TU3	I think that the technologies related to smart homes are undeveloped	
Resistance (RES)	RES1	I am reluctant to use smart home products and services	[6, 7, 9, 12]
	RES2	My current state is better than using smart home products and services	
	RES3	I will feel uneasy if I use smart home products and services	

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Agritech Startups and Inclusion of Small-Scale Producers: Evidence from High-Value Chains in Karnataka, India

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Abstract. Sustainability of agriculture in several countries is frequently associated with inclusion and income of its small-scale producers. Linking farmers directly with consumers is considered as one way to overcome the income problem and in the past decade, India has witnessed a rise of agritech startups, especially those that aim to address this issue. Through a qualitative study in Bangalore Urban district of Karnataka, India and its neighbouring districts, we argue that agritech startup led high-value chains are inclusive for only selected small-scale producers and this is dependent on factors such as the firms' business model, area of operations, crops cultivated by farmers, agricultural practices employed by them etc. Both agritech startups and farmers pursue their own goals that are often in conflict with each other and it is these goal incongruences that lead to exclusion of large share of small-scale producers from such value chains.

Keywords: agritech · farmer inclusion · value chain

1 Introduction

Agriculture and allied sectors are essential for human survival [1] and are instrumental in achieving several of the United Nations' Sustainable Development Goals (SDGs). One of the targets associated with SDG2 that aims to achieve zero hunger is doubling income of small-scale food producers[1] [4] This is of utmost importance to India where farmers with marginal and small sized landholdings[2] form around eighty six percent of the total number of operational landholdings in the country [5]. Within the group, it is the income of producers of horticultural crops such as fruits and vegetables that needs greater

[1] The United Nations, broadly defines small-scale food producers as those falling in the bottom 40 percent of the cumulative distribution of land size, livestock heads and total on farm revenues (all calculated at national levels). However, it also states that this definition would only be used for computing and monitoring SDGs and when framing national level policies, individual country-specific definition would be considered [2, 3].

[2] In India, a farmer is classified as marginal if he/she possesses less than 1.000 hectare of land, small if he/she possesses between 1.000 and 2.000 hectares of land [5].

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consideration, because unlike cereals, there is no centralized procurement and guaranteed Minimum Support Price (MSP) for fruits and vegetables, which leaves its producers vulnerable to frequent price fluctuations [6]. Frequent incidents of farmers dumping their produce on roads [7, 8], committing suicides [9] and permanently migrating to urban areas [10] are a few unwanted consequences of these variations in prices.

One of the reasons for low income among small and marginal farmers is the unorganized[3] and informal[4] nature of agricultural value chains in the country, characterized by multiple middlemen who, in most cases, are stated as not adding much value to the end product [11, 12]. Studies have proved that participation in agricultural value chains that are more organized, formal and either directly connect farmers with end-consumers or reduce the number of intermediaries between the two are more remunerative for farmers [11, 13, 14]. Hence, policy makers in India have been laying great emphasis on development of such organized value chains [15, 16].

In the recent decades, India has been witnessing social transformation in the form of rapid urbanization, changing lifestyles, dietary patterns etc., and this has led to a greater demand for food that is fresh and safe, especially high-value foods[5] such as fruits, vegetables and milk [18, 19]. Interestingly, owing to factors such as support from government [20], the rise of the internet [21], increased digital penetration, affordability of hardware [22] etc., the past decade has also seen the remarkable rise of agritech startups in India, and several of them seek to cater to the shifting dietary needs of the nation's urban population. They procure fresh produce such as fruits, vegetables and milk from farmers in peri-urban areas and supply them to consumers or businesses in Tier1 and Tier2 cities [21].

Peri-urban areas, while being significant sources of fresh horticultural produce to the growing urban populace [23] are also in a state of transition [24]. They are inhabited by a large number of heterogeneous social groups such as small farmers, entrepreneurs, middle-class workers with "*different and often competing interests, practices and perceptions*" [25, p. 137], and are continuously getting transformed and put to non-agricultural uses [26].

Considering this background, and given that any attempt to transform agricultural value chains should be in coherence with the SDG2 which aims to reduce inequality among populations [4], it is critical that agritech startups led value chains are inclusive for all types of farmers, irrespective of the size of their landholding or gender. Scholars state that while it is acknowledged that the entry of private players can prove to be beneficial for farmers and customers alike, it is a research area that is often less explored [27]. Lack of studies on procurement processes of agritech startups providing market linkages and inclusion of small and marginal farmers in these processes is a proof to this. It is this gap that we address through this study conducted in Bangalore Urban

[3] Lack of market driven production that results in gluts.

[4] Lack of formal agreements between buyers and sellers such as contracts that specify details such as quantity, quality and price.

[5] High-value agricultural or agro-food products are defined as "*non-bulk agricultural commodities that either require special handling, such as fresh fruits and vegetables, or are processed in one or more post-harvest stages, such as specialty coffee and honey, prior to reaching the end market*" [17, p. 8].

district and its neighbouring districts of Kolar, Chikkaballapura, Tumakuru, Ramanagar and Bengaluru Rural. The objectives of this research are three-fold –

1) What are the procurement processes followed by agritech startups that provide market linkages to farmers of fruits and vegetables in peri-urban areas?
2) Are the procurement processes (determined in first research objective) inclusive of small and marginal farmers of in peri-urban areas?
3) What are the factors that influence inclusion of small and marginal farmers in these procurement processes (determined in first research objective)?

The findings of this study contribute to the broad literature that discuss operations of agritech startups and will prove to be useful for policymakers when formulating policies that promote setting up of agritech startups or inclusion of farmers with small and marginal sized landholdings.

In the next section, we discuss literature on agritech startups in India. Then, we discuss nature of fruits and vegetables value chains and theoretical framework best suited to analyze them and follow it up with a description of our research methodology. Finally, we deliberate on our findings in two parts – one which describes the procurement processes of agritech startup driven fruit and vegetable value chains and two, which narrates the viewpoints of the startups and farmers about these procurement processes. Finally, we present our analysis and conclude the paper.

2 Agritech Startups in India

Agritech startups are said to be instrumental in the diffusion of innovations across a value chain, especially in taking them to underserved segments such as rural farmers with low-income [21]. Today, with over 2000 agritech startups, India is considered a hub for agritech startups and the number is expected to hit 10000 by the end of the current decade. It is estimated that between 2011 and 2021, agritech startups in India have raised investments of over US$ 1.5 billion, showcasing growth to the rate of 14 times [28].

They typically provide innovative ICT based services that facilitate one or more core activities of agricultural value chains, for a range of agricultural and horticultural crops, livestock and dairy. A few broad categories of innovative ICT based services that agritech startups in India provide are market linkages, supply of inputs, extension and advisory, mechanization of production and harvesting activities, financial and insurance services etc. Among all the broad categories of startups, majority of them provide market linkages to farmers [29, 30] and it is also the category that attracts most investment [31].

Firms providing market linkages focus on linking farmers with consumers either directly or via other downstream actors such as retailers (B2C or B2B). Most of them provide mobile-based platforms through which consumers can purchase the commodities/produce that the firms directly procure from farmers. This business model is also called farm-to-fork model and the startups obtain a share of the price that the consumer pays for the produce [32].

Studies indicate that agritech startups in India are still in a nascent stage and are struggling to find the right balance between scalability and sustainability. Some issues they face are with respect to financing and investment, clarity on data privacy and IPR, attracting talented personnel, market reforms, infrastructure in rural areas, mentoring, expertise in agricultural domain, winning trust of farmers and creating awareness among them about technological innovations [21, 30, 33, 34].

As mentioned earlier, at present, there are no studies on procurement processes of agritech startups. Existing studies on participation of small-scale producers in value chains that directly link farmers with supermarket chains or institutions in urban areas state that it introduces an organized system of procurement and streamlines supply in line with market demand [35, 36]. The entry of private players, who bring with them resources and investment, is also said to provide ample opportunities to make value chains more traceable and thus improve quality of produce [13]. However, small-scale producers who are hard-pressed to find resources find it challenging to meet the private players ever-changing requirements with respect to quality and quantity [13, 17, 37, 38].

3 Theoretical Framework

A typical fruits and vegetables value chain in India (given in Fig. 1), consists of several actors – input suppliers, farmer producers, farmer collectives, local markets, processors, exporters, regulated markets, wholesalers, retailers, consumers (businesses or end-consumers) etc. The presence of multiple actors and separations between them with respect to ownership, value, space, information and time [39] result in problems such as inability to meet food security needs of the populations, lower farmer income, deterioration in food quality and higher food loss/wastage [13, 35, 40–43]. These challenges are further proliferated in the case of fruits and vegetables value chains, because of their innate features such as seasonality, bulkiness, perishability etc. that vary between crops and geographies [11, 35, 37, 42].

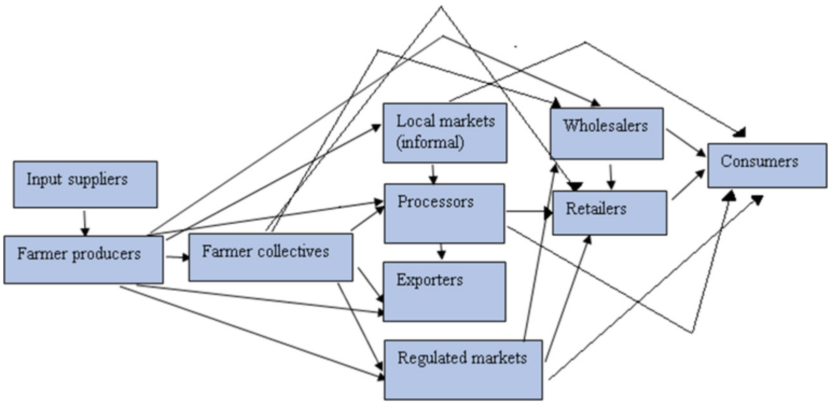

Fig. 1. Typical fruits and vegetables value chains in India. **Source** - Authors

A possible framework to investigate agricultural value chains is the complexity lens which is stated to be useful in understanding perennial problems. Complex adaptive systems, also called multi-agent systems comprise of multiple agents who represent systems as diverse as humans, organizations or even molecules. They all "*try to achieve some personal goal or value by acting upon their environment – which also includes other agents*" [44, p. 11], and in pursuit of these personal goals, they tend to ignore the long-term effects of their actions. Since goals of agents within a complex system are often in conflict with each other, each action from an agent could trigger a reaction from other agents in the system. Series of such action-reaction interactions that happen within a complex system make it difficult to predict the final outcome of the system and this represents its non-linear behaviour. Taking a holistic and pluralistic view to understand the social processes that make up these complex systems can help us better understand their behaviour [44].

Here, we employ the complexity lens to analyse viewpoints of agritech startups and farmers and thus discern how the interactions between the two and external influences on these interactions facilitate/hinder participation of small and marginal farmers in the procurement processes of agritech startup firms.

4 Research Methodology

The fieldwork for this study was conducted in the state (province) of Karnataka, India. The districts chosen for the study were Bengaluru Urban where most agritech startups have their corporate offices and its neighbouring five districts, namely Kolar, Chikkaballapura, Tumakuru, Ramanagar and Bengaluru Rural, from where the agritech startups source fruits and vegetables[6].

Fieldwork for this study was carried out by the first author between April-June 2023. Since the objective of the study was to understand the procurement processes of agritech startups and factors that influence inclusion of small and marginal farmers in these processes, we employed qualitative research methods which are considered best suited to study organizational and social processes and stakeholders' perspectives about them [45]. Data collection methods employed included field observations and semi-structured interviews carried out at collection centres and distribution centres of agritech startups and via telephonic mode. Informed oral consent of participants was obtained prior to interviews. Interviews were conducted in the local language Kannada and typically lasted between 15–45 min. Wherever permission was given, photos of field sites were taken and audio recording of interviews made. A field journal was maintained by the first author, to note observations made at sites.

Participants for the study (count, detailed profiles and their pseudo names given in Table 1) were recruited through a mix of purposive and snowball sampling methods.

– Agritech startups employees –

First, we made a list of agritech startups which provide market linkages – i.e., connect farmers in the selected peri-urban areas with institutions/consumers (B2B and B2C) in Bangalore Urban district. Then, we tried to contact employees working in these firms (email ids/phone numbers obtained from LinkedIn or company websites) either directly or through the contacts of the first author. Out of the five that the first

[6] This also includes tender coconuts, because in most online delivery platforms it is categorized under fruits.

author tried to contact, only three responded. Once a contact in a given firm was established, other participants employed in the firm were recruited through snowball sampling.

The sample includes agritech firms that differ in the business models they employ (B2B vs B2C/procurement alone vs procurement +extension services) and the selected employees – sales managers, operations lead and sourcing leads handle various operations of the firms such as sales and procurement at collection centres and distribution centres that are spread across different geographies (located in districts selected for this study). Hence, it is expected that this sample is representative and thus provides insights into procurement processes of agritech startups (and also considers variations that occur between business models and geographies).

– Farmers –

Farmers selling to agritech startups in our sample were those present at the field sites and their contacts. Farmers not selling to agritech startups in the sample were contacted through farmer collectives in the area. Both samples include small and marginal farmers. Since the sample is inclusive of farmers of all types – those selling to agritech startups, not selling to agritech startups, with small and marginal, and large sized landholdings, from different geographies, it is expected that the sample is sufficient enough to provide information on inclusion of small and marginal farmers in the procurement processes of agritech startups.

Data was collected till data saturation was obtained.

Table 1. Detailed profile of participants and their pseudo names

Participant	Count	Pseudo names
Agritech startups	**B2B firms -2** *Sales manager – 3* *Operations lead – 1* *Sourcing lead – 4*	Firm A, Firm B
	B2C firms – 1 *Sourcing Manager - 1*	Firm C
Farmers	**Farmers selling to agritech startups – 14** *Farmers with landholding size <2 acres – 2* *Farmers with landholding size - 2-4 acres- 4* *Farmers with landholding size - 4-10 acres– 6* *Farmers with landholding size - >10 acres- 2* **Farmers not selling to agritech startups – 6** *Farmers with landholding size <2 acres – 2* *Farmers with landholding size – 2-4 acres – 3* *Farmers with landholding size - >4 acres– 1*	

Participants were informed that they were free to withdraw from interviews at any point of the study. However, there was no such incident. Participants, especially from agritech startups, however, were not willing to disclose the exact number of small and marginal farmers they procure from or their pricing strategies.

The first author carried out transcription of interviews and data analysis in parallel with data collection, and wherever gaps were found, participants were contacted again for clarification. By reading interview transcripts, and field notes in conjunction with existing literature, we arrived at the final themes of this paper.

5 Findings and Analysis

5.1 Operations of Agritech Startup Led Value Chains

Steps elaborated in this section (and picturized in Fig. 2) explain the generic processes involved in agritech startup led value chains of fruits and vegetables (as observed in case of our sample firms). All of them aim to deliver the collected produce to their destinations (businesses in case of B2B or end-consumers in case of B2C), within 16–24 hours of harvest.

- **Step 1**: Customers and businesses enter their demand for the next day (crop and quantity needed) on the apps provided by the agritech startups. Operations team consolidate demand from different sales locations and communicate individual demands to each collection centre. Sourcing lead at collection centre contact farmers in their list (who grow the required crop and are ready to harvest the next day) and communicate the required crop, quantity and possible price.
- **Step 2:** Farmers who agree to pre-stated quantities and price, harvest their produce and either bring it to the collection centre or sell it to the firm at their farm gate. Quality check (sorting and grading of the produce is done at the collection centre/farm gate) by the firm's staff. Farmer receives an SMS with details such as quantity sold, quality and agreed price. Firms have different pricing strategies that take into consideration supply, demand, historical prices, average prices at different markets, price paid by their competitors etc. and the prices are calculated using machine learning and market intelligence software.
- **Step 3:** In case of the B2B firms, the sorted and graded produce is collected in crates (with RFID chips) or plastic sacks (in case of commodities that have higher shelf life such as potatoes, onions etc.) and tagged with the concerned farmer details. This helps in tracing the produce at later stages. The B2C firm cleans the produce, packs it into smaller units and places them on crates. Filled crates are stacked one over another and placed on a dolly. At scheduled times of the day, the crates are loaded on to ventilated trucks for next warehouse destinations. Highly perishable commodities such as greens in case of B2C firms are sent in containers with cold gel. Any shortfall in order fulfilment is reported to the operations team.
- **Step 4:** At the next warehouse destination, the shortage in order fulfilment is purchased from local regulated markets. Crates that arrive from collection centre and produce procured from local markets are regraded, if necessary (only in case of B2B firms), fork lifted and finally segregated based on their destinations. At scheduled times of the day, the crates/packs are shipped to final destinations. B2B firms bring back crates (with/without rejections in case of quality deterioration).

All operations and logistics decisions such as number of trucks required, routing paths for delivery are made on the basis of results of optimization algorithms. Payments are cashless and made to bank accounts of the beneficiaries. Internal activities of the organizations are coordinated through ERP software.

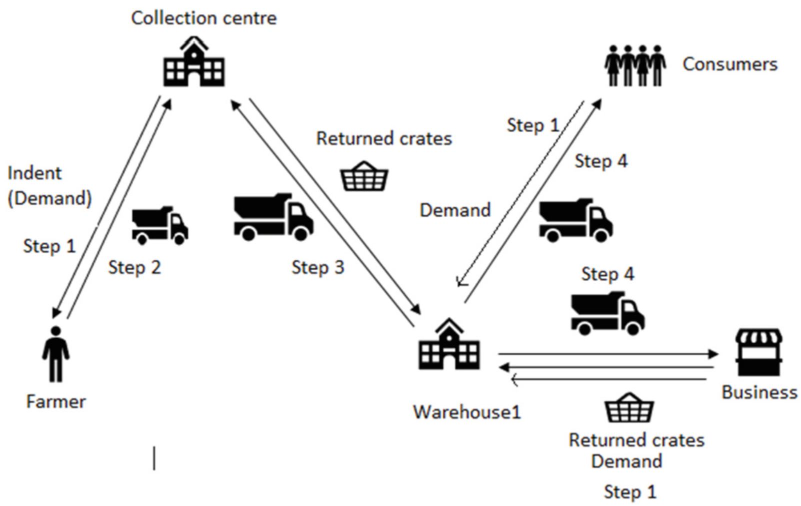

Fig. 2. Operations agritech startups providing market linkages. Source – Authors

5.2 Stakeholders' Worldviews

Agritech Startups' Worldview

Competitive Market
Sales Managers at Firm A and Firm B stated that there is fierce competition in the B2B segment. One of them said – "*There is lot of competition. Apart from five major agritech companies, there are also several small private aggregators trying to capture the B2B segment. Hence, there is no guarantee about buyers. Today, they may buy from us and tomorrow they may not. If not from one among us, they can directly purchase from the mandis too.*"

All the three firms stated that since the market is very competitive, it is very important for them to deliver the agreed quantity on time, maintain quality, and also have a prompt customer service system in place.

Quantity Issues
Operations Lead at Firm B and Sales Manager at Firm A said that some farmers default or deliver later than expected time and this makes it difficult for them to fulfil their orders. All three firms stated that in cases of supply shortage, they procure from local mandis. Sales Manager at Firm A said – *"Working with small and marginal farmers is risky for the company, especially because of their tendency to default. Today, we have built our own contacts in the local markets, and they help us complete our order shortages."* Another Sales Manager at the same firm said – *"Over the years, we have realized that we cannot completely do away with middlemen. In one of the Tier 1 cities where we operate, on an average, between 15–20 percentage of supply is procured from local markets."*

Quality Matters
All three firms mentioned that there is quality deterioration that happens as the produce moves from point of procurement to point of sale, as a result of which they get lot of

returns/complaints from their customers. Both the B2B firms (Firm A and Firm B) do not procure greens (which is highly perishable) directly from farmers and instead purchase it from local markets and then supply it to their consumers.

Firm A uses its traceability feature (RFID in crates associated with farmer details) to penalise farmers in cases of quality deterioration. Sourcing Lead at the firm narrated an incident that occurred the previous day – "*Consignments to Chennai are sent around 1.30 pm and the collection for this begins at 9.30 am. Each consignment contains around 16 varieties of vegetables that together weigh about 30 tonnes. Crops like beans and carrots take more time to harvest and thus arrive late at the collection centre. If we are to follow the grading specifications for each piece in the lot, it will be evening by the time we finish grading. So, we quickly sort and grade the produce by eye approximation. Yesterday, it was very hot and the carrots we sent were said to be having a lot of damage by the time it reached there. It is an 8 hour journey from here to Chennai and the vehicle did not have temperature control mechanism. Right at the sorting stage, we knew that the produce had quality issues. The farmer was also aware of this, so he understood why we penalised. Some farmers don't understand it and create issues. In such cases, the management intervenes."* When enquired about this, Sales Manager at the firm had this to say – *"It is not a penalty in actual terms, but a reduction in the final payment. The produce of deteriorated quality is resold in the local markets and the selling price for that quantity is paid to farmers instead of the price mentioned in the message. This was not something we used to do earlier, but resorted to, when wastage started increasing. But then, farmers started revolting and we had to reduce such instances."*

Difficult to Be Inclusive

All the three firms were not ready to share the exact number of small and marginal farmers from whom they procure. However, they did state that the percentage was very small.

Sourcing manager at Firm C said – *"Our firm is very particular about only procuring produce of the first grade. Managing farms helps us control quality of the produce. Typically, in a non-managed farm only 70% of the produce is of first grade, while in case of farms we manage, 90–95% of the produce is of first grade. We expect a minimum of 80% of the produce from a farm to be of the first grade. Hence, we only select farmers who are ready and have the capability to follow our plan and advisories, like purchase of inputs we mention (including brand), construction of polyhouse etc. It is not possible for small and marginal farmers.*"

Farmers' Worldview

Labour Shortage and Cultivation Reduction

Interviews and conversations with all farmers clearly brought out labour shortage and increasing costs of cultivation as major problems they face. One of the farmers who owns four acres of land said, "*Agriculture is getting to be very expensive, especially labour. Finding labour is very difficult as most of them go take up jobs in local factories or migrate to the cities. A male labourer charges between Rs 700–900 per day and a female labourer charges between Rs 400–500 per day, depending upon the task. Hence, I cultivate only in two acres of my land. Most of the labour work is done by me and my wife. I hire labourers only when it is utmost necessary, like for tasks such as harvesting* *of crops like carrots or beans which is time consuming; or ploughing land or setting up wooden support structure for creepers such as ridge gourd which are strenuous."*

Lesser Transaction Costs and Regular Payment

All farmers who sell to the agritech startups, unequivocally stated that selling to agritech startup firms saves them from the hassle of having to take their produce to regulated markets, paying commission to agents and spending on transportation. In monetary terms, the price they receive is either on par with market prices or a rupee more than that, but most importantly it reduces transaction costs. Another advantage they mentioned about selling to these firms was prompt payment within a week of procurement which is credited to their bank accounts.

Adapting to Changing Quality and Quantity Specifications

More than half of the farmers who have been regularly selling their produce to Firm A and Firm B, said that they initially found it difficult to meet the quality and quantity specifications of these firms, but over time have adapted to changing needs. This they have done by adopting good agricultural practices such as spraying pesticides on time, using sticks for creepers, removing old leaves, and changing cropping patterns and even crops cultivated in some cases. They claim it has helped improve their yield, produce quality (at least 80%) and production cycle,

Interestingly, only one farmer opened up about the penalty that Firm A imposes when there is quality deterioration at final destination warehouse. He said "*Sometimes we also get little selfish and despite knowing that the quality of the produce is not up to the mark, take it to the collection centres. A few staff there accept bribes and pass our produce in the quality check processes there and then it comes back to hit us later. So, we can't blame them too."*

Too Many Buyers vs No Buyers

Three of the five peri-urban areas studied have good presence of collection centres set up by agritech firms, and other private players. Farmers close by thus have several buyers present just next to each other. So, they register themselves with multiple similar firms and hence find regular buyers for their produce. However, in the remaining two peri-urban areas, there is very little presence of agritech firms. Three of the total farmer participants who do not sell to the selected startups mentioned that they are even unaware of the presence of such private players and continue to take their produce to local regulated markets. Here, it is important to note that they all reside in the same taluk where Firm A had a collection centre that was closed due to low procurement levels. The remaining three participants who do not sell to agritech startups belong to another area and sell their produce to a local farmer collective which in turn sells to other private players. Both sets of farmers had different opinions about their farmer collective. A farmer from the former group stated – "*Four years ago, they came saying they will help us find a market for our produce, collected our details, charged rupees thousand and registered our names as part of the collective. After that, we have not seen them or heard anything from them.*" In contrast, a farmer from the latter group said – "*Till fifteen years ago, we used to take loads of vegetables to Bangalore city market and return with just meagre profits and sometimes not even that. But, the formation of the farmer collective has changed our lives. Today, we are continuing to do agriculture only because of them."*

6 Conclusion

Operations of agritech startups as discussed in first part of findings section in this paper clearly indicate that use of ICTs can streamline procurement processes and make the value chain more organized and traceable. Analysis of stakeholders' worldviews using complexity lens suggests that both of them pursue their own goals. Farmers seek higher remuneration and sale of their produce, whereas agritech startups chase profits.

Goal incongruence between the two parties and external influences on them lead to a series of action-reaction interactions and they ultimately lead to inclusion of only a few small and marginal farmers. Few examples of action-reaction interactions in the value chain, visible from the viewpoints of agritech startups and farmers are -

- In order to ensure quality of produce, firms employ strategies such as not procuring green leafy vegetables, procuring only from farmers who purchase inputs they specify, follow advice they provide etc. This excludes a large section of small and marginal farmers who do not meet these conditions owing to shortage of funds, inputs or labour.
- Some farmers who stay in areas close to collection centres of agritech firms adapted to the quality and quantity requirements specified by the firms and changing social and environmental conditions by adopting good agricultural practices, changing their cropping pattern, cultivating on their own, hiring limited external labour etc. Such farmers are able to sell to the firms and make benefits, especially in the form of reduction in transaction costs.
- If competition between private players or wastage across value chain or consumer complaints increase, or firms' revenues decrease, the firms change strategies and increase quality checks, reduce procurement of highly perishable commodities, use traceability feature to shift liability of quality deterioration of produce onto farmers, close collection centres in areas that see low procurement, etc.
- In response to this, some farmers either stop selling to the firms or bribe officials at the collection centre to ensure that their produce passes through quality checks. Firms then realize that they have to walk a thin line between profitability and sustainability and in search of short-term profits, they cannot put their long-term supply at stake. Hence, they take measures such as reduction in quality checks or removal of penalization upon quality deterioration.

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Multimodal Transportation and Net Zero Emission World: An Emerging Research Agenda

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Abstract. Sustainability is an important issue in the era of extensive development in the manufacturing industry due to increasing the carbon footprint of the activities. Manufacturing activities and logistics practices emit a large number of emissions, which is affecting global sustainability. In this regard, the concept of net zero emissions has become popular, which aims to achieve a net zero emissions agenda by the end of 2070. At the same time, industries are adopting multi-modal transportation, which can reduce their carbon footprint and transportation costs. The other benefits of multi-modal transportation include lower transportation costs, lower emissions, and faster delivery times. Despite these benefits, limited literature is available on net zero emissions in multimodal transportation. Therefore, this paper discusses the research progress in multi-modal transportation and its decarbonization. This study also proposes a net zero emission framework for the industries that will be helpful to achieve net-zero targets.

Keywords: Multi-modal transportation · Net-zero emission · Decarbonization · Supply chain · Smart logistics · Green Logistics

1 Introduction

Within business practices, the efficient and effective flow of goods and services, information, and money to serve the end customers is considered supply chain management. In the present scenario, the market, customer satisfaction, customer requirement for customization, efficiency, flexibility, and effectiveness, along with responsiveness, are increasingly putting pressure on manufacturers to increase their logistics networks and increase their coordination and collaboration both internally as well as externally in logistics process and fastening the process of decision making [1]. Multimodal transportation connects various modes of transportation (road, railways, waterways, airways, and so on) to provide a more seamless, cost-effective, and convenient end-to-end journey [2]. Supply chain, multi-modal transportation, and logistics are the most important aspects of the business, especially in industries. A supply chain consists of a set of entities involved in fulfilling customer demand for products and/or services. These entities could be manufacturers, warehouses, retailers, transporters, customers, etc. [3]. The

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supply chain of the multi-modal defines the problems of multiple modes of connecting facilities such as road, ocean, rail, and airway and so on, and the route connecting the facilities one after another in a proper mode of a sequence of transportation and the constraints such as capacity, availability, and the transportation, etc. [4]. Companies have been unable to attempt to reduce emissions in their supply chains due to several factors. One issue is that many businesses still only have modest levels of transparency regarding these emissions, and the mechanisms for achieving greater supplier-level transparency are still in their infancy. The economics of decarbonization are obscured by this lack of transparency, giving the impression that maximizing sustainability may conflict with the objectives of improving performance or reducing costs [5]. To keep the rise in global temperature to less than 2 degrees Celsius and, ideally, to 1.5 degrees Celsius above pre-industrial levels, the international response towards this environmental issue aims to reach net-zero greenhouse gas (GHG) emissions by the year 2070 [6]. Global GHG emissions must be monitored because of concerns about global warming and human-caused environmental damage. As a result, the supply chain node infrastructure must be ready for the low-carbon transition. Due to the need to reduce GHG emissions, the idea of emission control known as "Net Zero Carbon Emissions" was developed [7]. The modes of transportation in multi-modal transportation are the essential components to support the seamless mobility of goods. There are three modes of transportation: land, water, and air, but some more modes of transportation, like pipelines, are also available that can help to reduce emissions [8]. More than 16% of the global greenhouse gas emissions are produced by the transport sector, which is measured in CO2 equivalent. The transport sector is the third GHG emitter in developed countries like the USA, France, and several other countries [9]. To deal with the impact of GHG from the transport sector on climate change, there is a requirement for proper planning and implementation to decarbonize, and electrification is a good initiative towards this goal [10]. For this, the CPS (Cyber Physical System) plays an important role, which consists of smart objects that transform the entire traditional logistics and supply chain processes into smart logistics and supply chain processes [11].

1.1 Multi-modal Overview

Globally, the sector of multimodal transportation is expanding, and it is becoming the backbone of the global supply chain [12]. Multimodal transportation is the use of multiple modes of transportation, such as road, rail, air, and water, in a coordinated and integrated manner to move goods or passengers by a sequence of at least two different modes of transportation from one point to another efficiently and effectively. It involves combining different modes of transportation to optimize the logistics process, improve efficiency, and enhance accessibility seamlessly [13]. Smart transportation uses AI to manage expected price, travel time, and waiting time to overcome the barriers in supply shortages, especially in peak hours and excessive passenger demand regions.

A multimodal supply chain problem to minimize transportation costs and reduce carbon emission over time is considered using a Mixed Integer Linear Programming (MILP) solving approach that has been employed [14]. Problem-solving using multi-modal transportation involves minimizing production, transportation, distribution costs, and environmental impact [15]. However, Fig. 1 represents the evolution of multimodal transportation to achieve net zero emission.

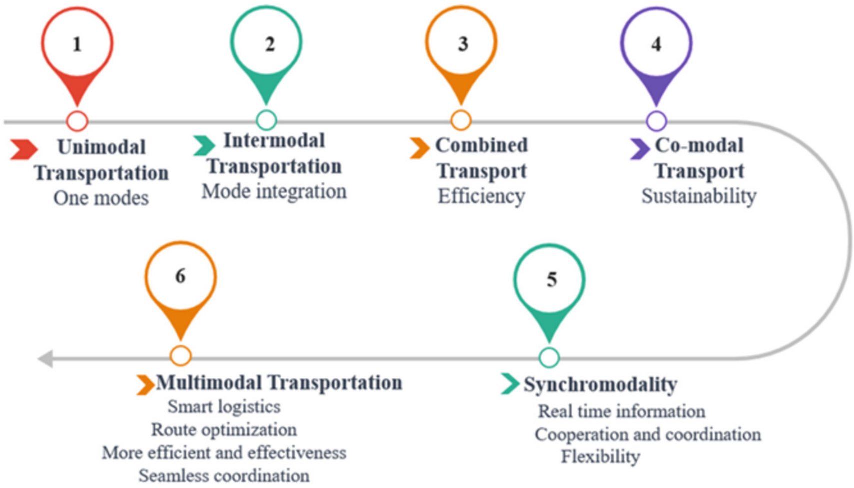

Fig. 1. Evolution of multimodal transportation [16]

2 New Opportunities for Decarbonization in Logistics 4.0

Implementing Logistics 4.0, involving advanced technologies and automation in warehouse and transport systems, necessitates global resource planning. Energy consumption in warehouses and transportation varies across countries, influencing CO2 emissions. High-energy consumption modes should be carefully replaced with alternative, sustainable sources to reduce emissions. [17]. Although the concept of Industry 4.0 is the requirement of today's logistics tech use, implementation of Industry 5.0 is in talk, which requires developing a human-centric, sustainable, and resilient established system [18]. An increase in market confidence for further investments and achieving net-zero targets is required. Various other technologies that can be integrated to achieve net-zero targets can be carbon capture and storage, renewable energy, e-vehicles, sustainable buildings, green hydrogen, and carbon offsetting presents a viable opportunity.

3 Ways to Improve Net Zero Emission Targets in the Supply Chain through Multi-Modal Transportation

The United Nations Paris Agreement for climate change focuses on minimizing global warming and reducing environmental impacts. In this regard, both emerging and developed countries have shown an interest in limiting their emission level by reducing their global warming by a 2 °C compared to pre-industrial temperatures [19]. Supply chain practices have a major role in balancing the sustainability parameters. Industries are still struggling to minimize their carbon footprint and emission levels. In this journey, many industries have developed new innovative solutions for supply chain practices, such as digital transformation and multi-modal transportation, to address climate change issues. The zero-emissions targets can be achieved in the supply chain with multi-modal transportation in the following ways [20–26]:

- **Collaboration:** Efficient supply chain practices necessitate digital transformation, management support, and strong SME collaboration for knowledge sharing, technological solutions, and resources in multi-modal transportation.
- **Green product designs:** To achieve net zero targets in the supply chain, industries should prioritize revisiting product design processes and optimizing the entire supply chain, including how end customers use products (Fig. 2).

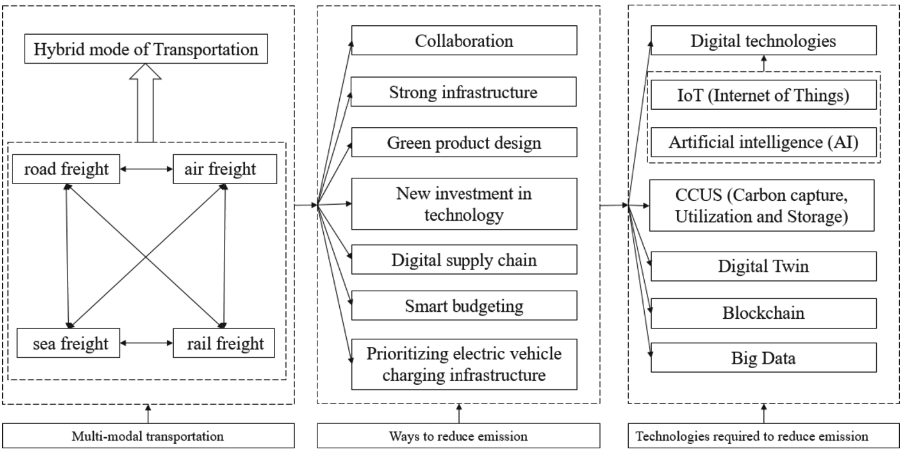

Fig. 2. Framework to achieve net-zero emission.

- **Smart budgeting:** Smart budgeting can be considered an enabler for multi-modal transportation. However, industries can use smart budget strategies to invest in critical areas and sustainability-related projects, which will help to achieve net zero emissions goals in multi-modal transportation.
- **Strong infrastructure:** The transition to multi-modal transportation will expose manufacturing organizations' current skills and knowledge gaps. The role of digital capabilities of an organization will be helpful to adapt to the transformation. There is a need for strong infrastructure and training programs to accelerate the shift of considering sustainability issues in multi-modal transportation in the supply chain practices.
- **New investments in technologies**: In SMEs, there is a lack of investment in technologies. There is a need to invest in technologies that can improve the climate conditions. Industries can invest in their R&D to achieve net zero emissions from their supply chain practices in the next ten years.

- **Digital supply chains**: Supply chain transparency is required to get operational data across the supply chain practices, ranging from raw material extraction to end customer. The development of a transparent supply chain with the help of innovative technologies will help industries monitor their real-time data, which will help to enable better decision-making for supply chain decarbonization.
- **Prioritizing electric vehicle charging infrastructure:** The lack of public charging stations for electric vehicles is a key obstacle to achieving net-zero emissions in multimodal transportation. Industry and academia can collaborate to establish these stations, encouraging fuel consumption reduction and widespread adoption of electric vehicles, thereby mitigating environmental impacts.

4 Future Research Directions for Decarbonization in Multi-modal Transportation

The development of a multi-objective transportation solution to reduce carbon emissions has promising future potential. Researchers can explore optimization techniques to improve efficiency, while real-world implementation and evaluation can provide insights for decision-makers. Integrating emerging technologies can enhance multimodal transportation systems and addressing policy gaps and governance mechanisms is essential for successful adoption and scalability. The study is basically undertaken based on the literature available on Multimodal transportation. The hybrid mode of transportation includes road, rail, air, and waterways. The challenges are to reduce changeover time and documentation, build strong collaboration, invest in technologies, and develop strong infrastructure. Technologies such as the Internet of Things (IoT), Artificial Intelligence, Digital twin, Blockchain, Big Data, etc., can be used for carbon capture and storage. In a developing country like India, the Multimodal Transportation of Goods Act 1993 has been enacted. Still, its implementation is foreseen with obstacles such as poor road quality, interstate check posts, entry taxes, high rail freight tariffs, absence of integrated cargo infrastructure at the airports to name a few [27]. The future research can focus on the implementation of these technologies and evaluate their effectiveness with mathematical modelling and solving with scenarios.

5 Policy Implications

Manufacturing firms are now working on the decarbonization aim, which aims to reduce the emissions on the shop floor and across the supply chain practices by up to 50% by the end of 2070 with the help of digital technologies. The digital technologies represented will help to reduce the environmental impacts by improving environmental performance but will result in high investment. This will result in a new challenge to industrial policies and will have more impact on emerging economies. However, practitioners and policymakers should look for alternative ways to achieve net zero emissions in their organizations. The role of geographical issues will be crucial in this context. The success of net zero emissions will be totally dependent on the demand generated from the market. There is a need to develop several policies related to material efficiency.

- **Better planning and transit-oriented development:** Transit-oriented development integrates land use and transportation planning to create compact and efficient public transportation systems, reducing carbon emissions and promoting sustainable urban living.
- **Local and National level plans for multi-modal transportation:** It is true that local and national level issues can affect the net zero emissions agenda. There is a need to develop both the local and national level sustainable transportation policies, which will help to promote a net zero agenda. The government can also finance electric vehicles, which will help to motivate the various stakeholders to use electric vehicles in multi-modal transportation.
- **Sustainable aviation fuels:** Fuel produced from sustainable feedstock can be used as sustainable aviation fuel, which will help to reduce the emission levels in air transportation. However, there is a need to develop favorable packages by government policies that can financially help airline industries to adopt sustainable aviation fuels.

6 Conclusion

The present study discusses the impact of industry 4.0 technologies in logistics operations and the opportunities that they are presenting with the challenges of achieving the net-zero targets. The study presents a framework for achieving the net-zero targets with interrelation with the different decarbonizing methods and the use of Industry 4.0 technologies that can help to achieve the target. For this, the literature review was done to identify the different components of Multimodal Transportation, such as Air, Rail, Road, and Hybrid modes. Then, ways to reduce the emissions were identified in the Supply Chain functionaries, which can be used to achieve the sustainability targets as well. Lastly, the role of Industry 4.0 technologies (such as Digital Twin, IoT, Blockchain, and Big Data) is presented in the framework to show the implementation of different technologies can play a vital role in the decarbonization process.

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The Intermediary Effects of Perceived Ease of Use, Usefulness, Trust, and Attitude in the Adoption of Cashless Transactions: An Empirical Investigation

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Abstract. Purpose: Intermediaries are crucial in determining individuals' acceptance of cashless transactions (CLT). However, currently, there is a lack of clear evidence regarding the extent to which intermediaries influence individuals' adoption of CLT. Hence, this study investigates intermediaries' role of perceived – usefulness, ease of use, trust and attitude towards adopting CLT.

Methodology: The survey was carried out by the researchers in Hyderabad, India, among 455 participants from all six zones. Subsequently, the researchers used the PLS-SEM approach to evaluate the relationship between the various factors under investigation, using the data obtained from the participants.

Findings: The study's findings indicate that combining all 13 independent variables can account for 68.8% of the variation in the dependent variable, which is the intention to adopt CLT. Personal innovativeness and self-efficacy indirectly influence users' behavioural intentions towards adopting CLT through perceived ease of use and usefulness rather than a direct pathway. Furthermore, perceived usefulness, ease of use, and trust are significant mediators for the factors shaping users' intentions to adopt CLT.

Originality/Value: This research formulated eighteen significant mediator hypotheses based on logical reasoning supported by pertinent literature using a comprehensive research framework. Among these eighteen hypotheses, only five have been examined in previous literature, while the remaining thirteen hypotheses are explored, and their results are uncovered for the first time in this study. As a result, this research provides additional insights into individuals' acceptance of CLT, offering valuable guidance for policymakers and bankers in developing effective strategies to promote the adoption of CLT.

Keywords: Cashless transactions · Intermediary effects · PLS-SEM

1 The Rationale for Conducting Research

The effectiveness of a country's monetary and financial institutions plays a substantial role in its economic development, and the adoption of "cashless transaction (CLT)" systems significantly impacts this effectiveness [12, 13]. Transactions made through

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cashless modes are recorded and traceable, which can lead to improved transparency in the economy [4]. Increased transparency can significantly reduce various economic crimes, such as bribery and corruption, money laundering, tax evasion, and hawala transactions [1, 10, 17]. CLT also contribute to financial security by reducing counterfeit currency circulation and financing illegal activities [9, 10, 17]. In addition, transitioning to a cashless economy has the potential to decrease criminal activities such as robberies, kidnapping, burglary, the trafficking of drugs, and the trafficking of humans. [16]. Cashless transactions can also lead to cost savings associated with producing, supplying, and maintaining physical currency and reduce the need for administering criminal justice systems [9]. In addition, the use of CLT has the potential to promote economic development by boosting consumer spending, company expansion, the enticement of foreign direct investment, and the production of new employment possibilities for locals [14]. Appendix A provides a unified viewpoint on how cashless economies influence economic growth. On the other hand, a cashless economy presents considerable growth and development opportunities for individuals, businesses, and financial institutions [13]. Hence, governments throughout the globe are investing more in infrastructure for cashless transaction systems [7]. However, the country will not realize the full benefits of CLT systems unless they are widely adopted and used. At present, Singapore, Korea, Sweden, Australia, the Netherlands, the “United Kingdom (UK),” and the “United States (US)” are the top cashless countries in the world, with an average number of cashless payments per inhabitant exceeding 500 units (“Bank for International Settlements (BIS)” Statistics Explorer, 2021). On the other hand, India, Mexico, Indonesia, and Russia actively promote cashless economies, but their average number of cashless payments per inhabitant is less than 100 units [5]. Therefore, it reveals that the adoption of cashless transactions in these countries is still in its infancy and holds substantial opportunities for growth. Consequently, to develop and implement strategies to increase the adoption of CLT, it is crucial to understand the factors that influence users’ behavioural intentions to use them. For this purpose, academics worldwide seek a comprehensive theoretical research model to explain and predict the behavioural intent leading to the adoption of CLT.

2 Research Gap

The extensive literature review reveals that several theoretical frameworks have been developed and validated in numerous fields, such as consumer behaviour, health behaviour, organizational behaviour, environmental behaviour, education, communication, technology adoption and social psychology for studying and comprehending diverse phenomena [19, 26]. Well-established theories such as TRA, SCT, TAM, TPB, MPCU, DTPB, IDT, UTAUT, and UTAUT2 contribute to the understanding about the adoption and usage of technologies such as computers and mobile devices [18, 22, 23, 25, 26]. Among these, the TAM, UTAUT, and UTAUT2 theoretical frameworks have gained significant recognition among researchers due to their comprehensive nature and appropriateness in providing valuable insights into explaining and predicting the adoption of cashless transactions [7, 12, 20, 27]. Several researchers have found that employing these models allowed for a deeper exploration of complex relationships and the discovery of meaningful findings that contribute to advancing knowledge in adopting cashless transactions [14, 21, 24]. However, these models have several shortcomings while exploring the intermediaries' effects in adopting cashless transactions (see Table 1). Intermediaries are crucial in determining individuals' acceptance of cashless transactions, which has not been seriously examined in earlier studies. Therefore, this research aims to explore the intermediary effects of perceived ease of use, usefulness, trust, and attitude on the adoption of cashless transactions. The findings of this research may help lawmakers and bankers make informed decisions to encourage more people to use cashless transactions.

Table 1. Hypotheses with indirect relationships: research gap assessment

H	IV	MV	DV	Full Mediation	Partial Mediation	No Mediation
H1d	PEoU	PU	ATT	[8]	[3]	-----
H1e	PEoU	PU	PT	-----	-----	-----
H1f	PEoU	PU	BI	[11]	[2]	-----
H1g	PI	PU	BI	-----	-----	-----
H1h	ANX	PU	BI	-----	-----	-----
H2d	ANX	PEoU	PU	-----	-----	-----
H2e	PI	PEoU	PU	-----	-----	-----
H2f	PI	PEoU	BI	-----	-----	-----
H2g	SE	PEoU	BI	-----	-----	-----
H2h	ANX	PEoU	BI	-----	-----	-----
H3b	PU	ATT	BI	-----	-----	-----
H3c	PI	ATT	BI	-----	-----	-----
H3d	PT	ATT	BI	-----	-----	-----
H3e	PR	ATT	BI	-----	[6]	-----
H4c	PU	PT	ATT	-----	-----	-----
H4d	PU	PT	BI	-----	-----	-----
H4e	PEoU	PT	ATT	-----	-----	-----
H4f	PEoU	PT	BI	[15]	-----	-----

3 Research Methodology

3.1 Development of Survey Questionnaire

The passage describes the process of creating a questionnaire for measuring a construct. The process involved adapting scales from previous works, modifying them, consulting with experts to evaluate the appropriateness of the construct and the clarity of the statements, revising the questionnaire based on their suggestions, conducting a pilot study to minimize response bias and improve comprehension, and pre-testing the questionnaire to validate its quality. The final questionnaire contained 62 items rated on a "seven-point Likert scale" and was approved for use in the final data collection phase.

3.2 Data Collection Methods

The data was collected using the stratified sampling method. For this purpose, the respondents were identified based on the circle from all six zones in Hyderabad. After identifying the respondents, the researchers interacted face-to-face to explain how this study is essential and how they can help with this research development by filling out this questionnaire. Once users accepted to participate in this study, the researcher shared the questionnaire's Google Forms link with them through WhatsApp or email. All participants submitted their responses at their convenient time within two weeks.

4 Data Analysis and Results

At the beginning of the study, this research checked the measurement model's reliability and validity to ensure that the measurements accurately and sufficiently represented the theoretical components. Further, the study assessed the model fit measures, and all the values were deemed satisfactory. Finally, the study employed PLS-SEM to investigate the connections between the components. The results of direct and indirect relationships are presented in the following tables.

5 Theoretical and Practical Implications

Previous research has established that "Perceived Ease of Use (PEoU)," "Perceived Usefulness (PU)," "Perceived Trust (PT)," and "Attitude (ATT)" are crucial in determining individuals' acceptance of cashless transactions. However, these crucial dimensions are also influenced by other variables, including Personal Innovativeness (PI), Self-Efficacy (SE), and Anxiety (ANX). This suggests that these crucial elements, such as PU, PEoU, PT, and ATT, depend on other variables in determining individuals' acceptance of cashless transactions, implying that these crucial elements act as mediators, which have not been thoroughly examined in earlier studies. Therefore, this research examines the direct and indirect effects of PI, SE, and ANX, including the mediating effects of PEoU, PU, PT, and ATT on adopting cashless transactions (see Tables 2, 3 and Fig. 1). Accordingly, this study provides additional insights into individuals' acceptance of cashless transactions, which can assist policymakers and bankers in developing effective strategies to promote the adoption of cashless transactions.

Table 2. The results of Hypothesis for the direct relationship

H	Path	β	SD	T Values	P Values	Results
H1a	PU→ATT	0.164	0.065	2.510	0.012	S*
H1b	PU→PT	0.577	0.046	12.518	0.000	S***
H1c	PU→BI	0.169	0.068	2.478	0.013	S*
H2a	PEoU→ATT	0.068	0.060	1.135	0.257	NS
H2b	PEoU→PU	0.330	0.048	6.894	0.000	S***
H2c	PEoU→PT	0.119	0.041	2.894	0.004	S**
H2d	PEoU→BI	0.209	0.047	4.476	0.000	S***
H3	ATT→BI	0.110	0.043	2.535	0.011	S*
H4a	PT→ATT	0.142	0.065	2.196	0.028	S*
H4b	PT→BI	0.106	0.049	2.178	0.029	S*
H5	SI→BI	0.130	0.054	2.395	0.017	S*
H6a	PI→PEoU	0.330	0.046	7.166	0.000	S***
H6b	PI→PU	0.189	0.050	3.797	0.000	S***
H6c	PI→BI	0.019	0.029	0.650	0.515	NS
H7a	SE→PEoU	0.327	0.045	7.234	0.000	S***
H7b	SE→BI	0.059	0.034	1.744	0.081	NS
H8	PEOR→BI	0.148	0.044	3.384	0.001	S**
H9	PEB→BI	0.056	0.051	1.089	0.276	NS
H10	PES→BI	0.210	0.048	4.386	0.000	S***
H11a	PR→ATT	-0.086	0.050	1.720	0.086	NS
H11b	PR→BI	-0.055	0.028	1.974	0.048	S*
H12	PC→BI	-0.070	0.035	1.969	0.049	S*
H13a	ANX→PEoU	-0.058	0.044	1.314	0.189	NS
H13b	ANX→PU	-0.282	0.047	5.981	0.000	S***
H13c	ANX→BI	-0.102	0.039	2.642	0.008	S**
H14	BI→AU	0.770	0.032	24.400	0.000	S***

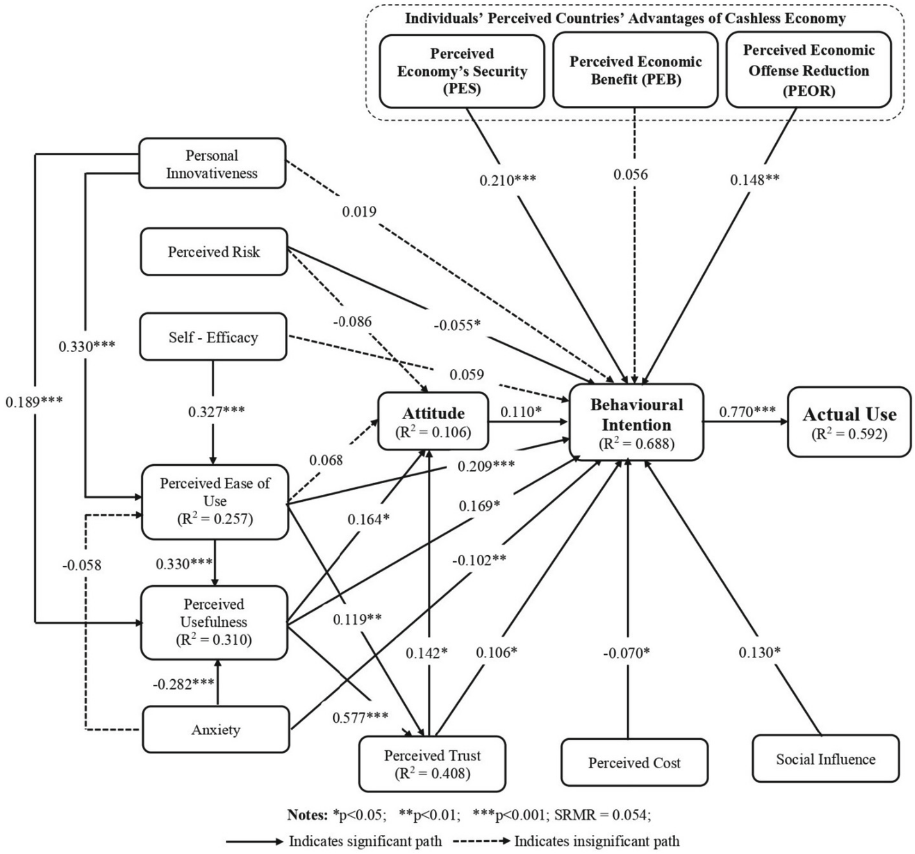


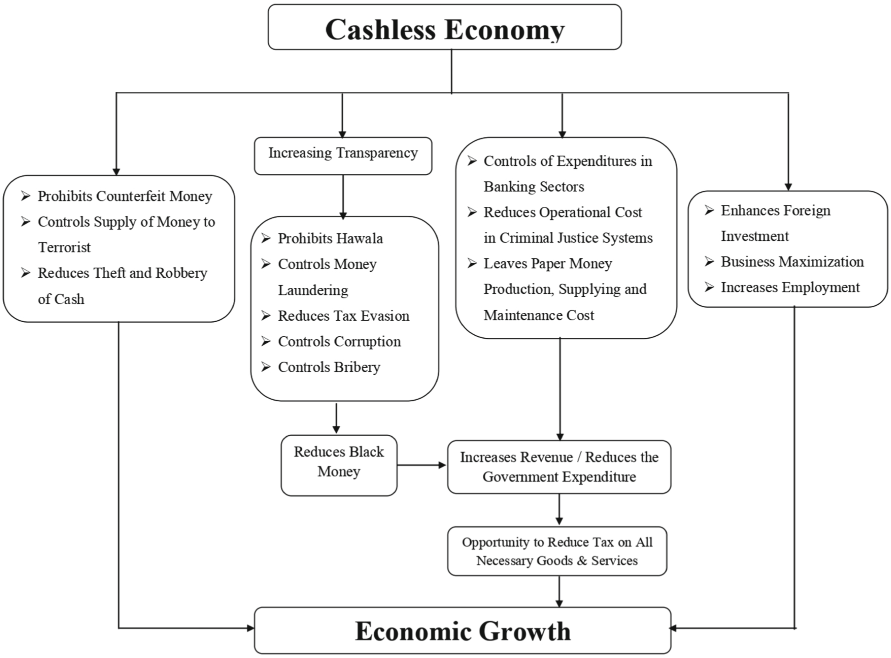
Fig. 1. The results of the structural path analysis

Table 3. The results of Hypothesis for the indirect relationship

H	Hypothesised path	Indirect Effects			Hypothesised path	Direct Effects			Total Effects			Effects of Mediation
		β	T Value	P Values		β	T Value	P Values	β	T Value	P Values	
H1d	PEoU->PU->ATT	0.054	2.247	0.025*	PEoU->ATT	0.068	1.135	0.257	0.166	3.295	0.001**	Full Mediation
H1e	PEoU->PU->PT	0.190	6.581	0.000***	PEoU->PT	0.119	2.894	0.004**	0.309	6.455	0.000***	Partial Mediation
H1f	PEoU->PU->BI	0.056	2.393	0.017*	PEoU->BI	0.209	4.476	0.000***	0.315	5.775	0.000***	Partial Mediation
H1g	PI-> PU->BI	0.032	2.171	0.030*	PI->BI	-0.019	0.650	0.515	0.134	3.998	0.000***	Full Mediation
H1h	ANX-> PU->BI	-0.048	2.007	0.045*	ANX->BI	-0.102	2.642	0.008**	-0.192	3.938	0.000***	Partial Mediation
H2d	ANX->PEoU->PU	-0.019	1.264	0.206	ANX->PU	-0.282	5.981	0.000***	-0.301	6.514	0.000***	No Mediation
H2e	PI->PEoU->PU	0.109	5.524	0.000***	PI->PU	0.189	3.797	0.000***	0.298	6.039	0.000***	Partial Mediation
H2f	PI->PEoU->BI	0.069	3.925	0.000***	PI->BI	-0.019	0.650	0.515	0.134	3.998	0.000***	Full Mediation
H2g	SE-> PEoU->BI	0.068	3.849	0.000***	SE->BI	-0.059	1.744	0.081	0.044	1.094	0.274	Full Mediation
H2h	ANX-> PEoU->BI	-0.012	1.250	0.211	ANX->BI	-0.102	2.642	0.008**	-0.192	3.938	0.000***	No Mediation
H3b	PU->ATT->BI	0.018	1.767	0.077	PU->BI	0.169	2.478	0.013*	0.257	3.469	0.001**	No Mediation
H3c	PEoU-> ATT->BI	0.008	0.938	0.348	PEoU->BI	0.209	4.476	0.000***	0.315	5.775	0.000***	No Mediation
H3d	PT-> ATT->BI	0.016	1.614	0.107	PT->BI	0.106	2.178	0.029*	0.121	2.567	0.010*	No Mediation
H3e	PR-> ATT->BI	-0.010	1.256	0.209	PR->BI	-0.055	1.974	0.048*	-0.065	2.265	0.024*	No Mediation
H4c	PU-> PT->ATT	0.082	2.204	0.028*	PU->ATT	0.164	2.510	0.012*	0.246	4.334	0.000***	Partial Mediation
H4d	PU-> PT->BI	0.061	2.082	0.037*	PU->BI	0.169	2.478	0.013*	0.257	3.469	0.001**	Partial Mediation
H4e	PEoU -> PT->ATT	0.017	1.687	0.092	PEoU->ATT	0.068	1.135	0.257	0.166	3.295	0.001**	No Effect
H4f	PEoU -> PT->BI	0.013	1.879	0.060	PEoU->BI	0.209	4.476	0.000***	0.315	5.775	0.000***	No Mediation

Appendix

Appendix A. The united view on the implications of cashless economies on economic growth.



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Visualizing Perishable Product Supply Chain Using Petri Net Modeling

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Abstract. Rapid development in technology and regular identification of new dynamic factors, offer challenges for modeling supply chain. Particularly supply chain of perishable products. These products require a special attention because of quality of product may deteriorate as product moves from one stage to other. India being, a country of large scale production of food, vegetables, meat and milk, hence require most advanced solutions for improving overall supply chain surplus. Presently high amount of wastage, 20–30% which is predominantly related to inefficient supply chain management. This inefficiency can be minimized by suitable modeling. This paper presents modeling of Perishable Product Supply Chain (PPSC) using Petri Net. Modeling of PPSC is based on concept of dynamic and discrete event system. Considering these two concepts, petri net model has been developed. The model provides a theoretical way to discuss the various states and transitions occur in PPSC. Various stages of PPSC starting from farmer, aggregator, processor, distributor, retailer and consumer provides an insight into the system with different drivers such as inventory, logistics, cold chain management, information technology, tracing and tracking of products. Model is developed using colored petri net technique. Purpose of this modeling is to explain a complex system into a simpler and easier way. Graphical notation of the model allows the visualization of complexity of the system and thus provides a mathematical framework for analysis and verification.

Keywords: Petri net · UML · Perishable Product Supply Chain · Supply Chain

1 Introduction

Supply chain is defined as a network of supplier, producer, warehouse, distributor, retailer and customer, through which raw materials are acquired, transformed, produced and delivered to the customer. It is the continuous flow of information, material and funds among different stages of supply chain. The main objective of supply chain is to increase the customer value and overall lower costs with satisfaction of constraints defined [16].

This paper discuss the supply chain for perishable products. Products which continues to deteriorate over which leads to decline in quality and value to diminish [21]. Products such as fruits, vegetables, blood, sea food, meat, etc. are perishable products.

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Supply chain for these products are complex. These products have short life cycle, behavior of these products are uncertain, and according to supplier, selection pf products are based on speed and quality [7, 17].

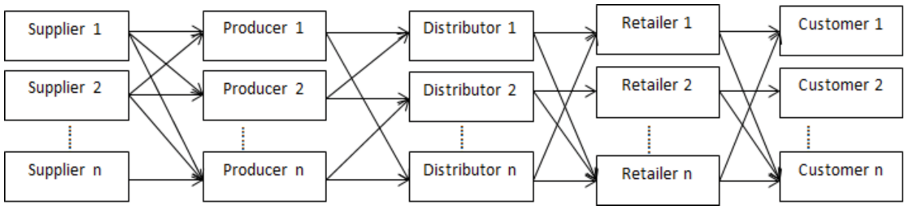


Fig. 1. Supply Chain of Perishable Products

Meat accounts for about 4% of food wastage with 20% of the costs, 70% of fruit and vegetable output is wasted, accounting for 40% of the total cost [3]. The Associated Chambers of Commerce & Industry of India has quoted a study to state that $440 billion of fruits and vegetables or 40–50 percent of the total production in India goes waste every year on account of lack of sufficient number of cold storage facilities [2]. There are several reasons why so much perishable food is lost [3, 13] (Fig. 2).

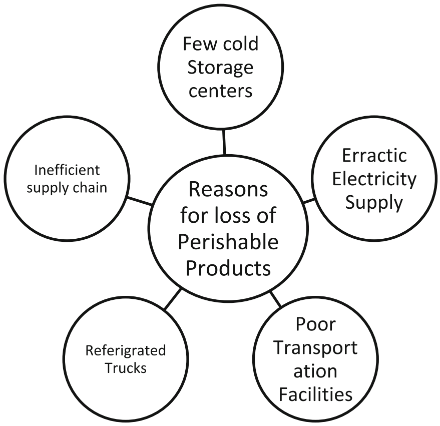


Fig. 2. Reasons for loss of Perishable Products [4]

Considering supply chain, they are discrete event dynamic systems [21]. For discrete event systems and dynamic nature of PPSC, petri net modeling is presented in this paper. Petri net is a mathematical modeling framework for systems having high complexity factor, distributes in geographical regions and concurrent in nature, [15, 18]. They have well-defined mathematical foundation and easy to understand graphical features. Graphical features, make self-documenting and powerful design tool for visual communication [18, 21]. There are disruptions in PPSC, there is a need for more sophisticated tool such as petri net [10, 11, 19]. Pervious model such as Markov chain, limitation leads to state space explosion. Combination of Petri net and Markov chain, analyze the performance of supply chain effectively and results can be used by decision makers of supply chain [7, 9, 15].

2 Related Work

This section provides an extensive work related to PPSC using petri net model. Petri net is a mathematical modeling framework for systems having high complexity factor, distributed in different geographical regions, concurrent in nature. For performance evaluation, petri net proved to be a boon for these complex systems. Petri net gives graphical, theoretical representation process, communication and control patterns in discrete event system. They capture the precedence relation and structural interface of concurrent, dynamic and asynchronous events. The graphical representation modeled, allows the visualization of the complexity of the system. Thus, this visualization provides an advantage for development of mathematical framework for analysis and verification. Table 1, represents some of work presented under petri net modeling.

Table 1. Representation of work presented by authors under petri net modeling

Author	Description
Van Der Frost (2000)	Petri-net modeling for determining the dynamic behavior of supply chain. Proposed the multi-echelon system supply chain redesigns [16]
Feng (2007)	Developed the petri net and object oriented modeling technique for simulation [7]
Liu (2007)	Developed modeling event relationships in supply chain through petri nets and implemented colored and time petri net to evaluate the dynamic behavior [10]
Jain (2009)	Discussed the recent trends in supply chain and analyzed modeling technique multi-agent system and petri net [8]
Khilwani (2011)	Hybrid Petri- Net modeling simulation tool for performance evaluation, risk analysis and assessment of supply chain [9]
Lv (2012)	Combination of RFID and Colored Petri Net modeling to determine the of products in manufacturing system and a feedback system through the use of RFID technology [12]
Song (2015)	This paper explores the supply chain of tea and analyze the overall improved performance and efficiency by using stochastic petri net modeling technique [15]
Chen (2015)	Proposed colored petri nets model for agricultural supply chain considering the uncertainties in the environment [6]
Liu (2018)	Risk assessment of perishable products using colored petri net modeling to identify the overall risk identification and decision-making management model in a unified framework. [11]

The goal is to provide a tool to help the modeling of perishable product supply chain:

- To increase the reliability of the supply chain
- To evaluate the capability and performance

Petri net is a mathematical modeling framework for systems having high complexity factor, distributed in different geographical regions, concurrent in nature. For dynamic propagation of disruptions, there is need for more sophisticated tools such as petri net [18, 19]. As compared to the previous model used such as markov chain. This model limits to space state explosion. Combination of petri net and markov chain, analyze the performance of supply chain effectively and results can be used as decision makers of supply chain [8]. For performance evaluation, petri net proved to be a boon for these complex systems [14]. Petri net is a mathematical modeling framework for systems having high complexity factor, distributed in different geographical regions, concurrent in nature. For performance evaluation, petri net proved to be a boon for these complex systems.

The paper is divided into five section as followed. Section 1, gives a thorough introduction, followed by Sect. 2 which provides an insight into the literature done by several authors. Section 3, provides modeling of PPSC, starting with the description of model flow of PPSC, definition of petri net and its symbol and a conceptual framework of PPSC with petri net modeling. Section 4, provides a visualization of flow management of PPSC with Sect. 5 as conclusion to the paper.

3 Modeling of PPSC

3.1 Flow Diagram of PPSC

In supply chain for perishable products (vegetables and fruits), post harvesting management plays an important role. The consumption of food products by customers is not done directly after the harvesting. It need proper processing, transportation, storage and marketing. So, therefore proper management of food products during supply chain is required [1]. One of the major factor for management of food supply chain is that it can also effect the income of farmer [1]. Thus, the role of new technologies such as Internet of Things, cloud computing, big data, data analytics helps with efficient decision-making which leads to less loss for farmer as well as in the whole supply chain.

Flow of products in the supply chain comprises of farmer, aggregator, processor, distributor, retailer and consumer. Referring to Fig. 1, represents flow model of PPSC of fruits and vegetables. The flow model consists of four types of flow in PPSC [5].

- Farmer-Agent-Processor-Distributor-Retailer-Consumer
- Farmer-Online Sellers-Processor-Consumer
- Farmer-Local Stores/Mandi-Consumer
- Farmer-Consumer

Discussion to the flow model of PPSC are as follows:

- Farmer is the first link in perishable product supply chain. They are responsible for handling post-harvest. This technique involves picking of perishable products from

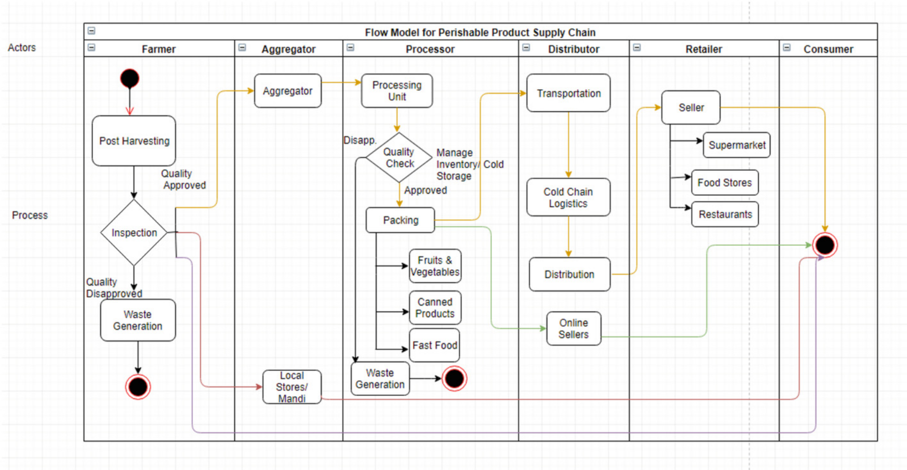


Fig. 3. Flow Model for Perishable Product Supply Chain

farm. Further, farmer inspects for the quality of product by manually inspecting the texture, color, smell and size. Quality disapproved leads to waste generation. Quality approved follows to the next step. The data acquired during this phase includes quality of product, weight in each pallet and product variety.

- Aggregators are the middleman which leads to products to the processing stage.
- Processor is a significant link. During this stage, quality is checked and approval leads to processing and packaging of product. Products are processed with canned, fast foods and are packed for further distribution. They usually maintain cold storage. The data acquired during this stage includes quality of product, distribution information, transportation, production and batch transportation.
- Distributor, transports the products using cold chain logistics. Refrigerated trucks are used for distribution of products. They are packed and labeled for further distribution to retailer and wholesalers. The data acquired during this stage includes batch transportation and final end point distribution information.
- Retailer receives the products and stores in inventory. These products are further distributes to supermarkets, food stores and restaurants and finally to consumers.

3.2 Petri Net Modeling

Petri net is a bipartite, directed, multiway graph. PN are divides into places, transitions, tokens and arc. Petri net is a five-tuple set, PN = {P, T, F, W, M_0}, where

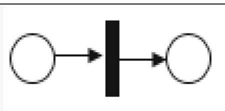
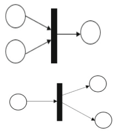
- P = {P_1,P_2…P_n}, T = {T_1, T_2,….T_n}, P and T are finite set of elements, non-empty and disjoint set $P \cap T = Ø$ and $P \cup T \neq Ø$.
- F is defined as the flow of arc with input and output function

  - Input function: defined as flow of tokens from transition to places, I: $T \rightarrow P$
  - Output function: defined as flow tokens from places to transitions, O: $T \rightarrow P$

  - $F = (P \times T) \cup (T \times P)$, defined as set of arcs which transmits information from places to transitions and transitions to places.

- W, represents the weight associated with each arc.
- M0, represents the marking, it denotes the number of tokens in a place, ready to make a transition enable (Table 2).

Table 2. Definition and description of symbol used

Name	Description	Symbol
Transition	Represents action to be taken in the system modeled $T=\{T_1, T_2, \ldots T_n\}$ n>0, T is an integer	
Place	Represent state of the system $P=\{P_1, P_2, \ldots, P_m\}$ m>0, m is an integer Places are discrete set of states in the system	
Single Unidirectional Arc	Directed arc which connects place to transition and vice-versa. These arcs transmits the information. The transition is enabled, if at the defined place token is placed. Information is transmitted from input place to output place when transition occurs through arc $A=\{A_1, A_2, \ldots A_t\}$ t>0, t is an integer	
Multiple Unidirectional Arc	The information is transmitted from multiple places and merges to a single output place or information transmitted from single place to multiple places $A= \{\{A_1, A_2, \ldots A_t\}, .. \{A_p, A_{p+1}, \ldots A_{t+p}\}\}$ t>0, P>0, t, p are integers	

Description of States and Transitions

Supply chain of perishable products starts from collection of fruits and vegetables from farmers to end consumer of 'farm' to 'fork' supply chain. This chain involves farmers, agents/brokers, processor, distributor, retailer and consumer, Fig. 3. There are three types of flow in PPSC: material, information and funds.

Petri net modeling describe the control and information flow of PPSC. This flow represents the dynamic process of supply chain.

Definition: Perishable Product Supply Chain consists of three tuple set $<$ P, I, S, M0 $>$, where.

P_i = Number of Products, where $i > 0$

I = Information Flow

S_j = Stages of PPSC, where $j = 1$ to 6

M_0 = Marking, Number of tokens available to make a transition

Table 3. Description of places and transition of PPSC

Places	Description	Transition	Description
P0	Post-Harvesting of Perishable Products (PP)	T0	Collection of PP
P1	Separation of PP manually based on color, texture and size	T1	Quality Check
P2	PP discarded	T2	Collection of PP by Farmer to Aggregator
P3	PP approved for further transfer	T3	Processing Unit
P4	PP stored at inventory at Aggregator	T4	Quality Check
P5	PP stored at inventory for processing	T5	Collection of PP at warehouse for Online Sellers
P6	PP discarded	T6	Packaging of products to canned products, fast food
P7	PP approved for further processing	T7	Distribution of PP using Cold Chain Logistics
P8	Processing unit for quality check	T8	PP are distributed to different retailers
P9	PP are stored in cold storage for distribution	T9	Selling PP to consumers
P10	PP in temperature controlled trucks (sensors are being used for monitoring)	T10	Distribution of PP to Local stores\Mandi
P11	PP are distributed and stored by supermarkets, food stores and restaurants	T11	Selling PP to consumers
P12	PP are sold to consumers		

Petri net model being developed is followed by a description of places and transitions for whole process of PPSC. Places represents the state of the modeled system while transitions represents the event. Transitions occur only if there is token available at the place.

The data collected from each process stage is collected and linked to the next process stage. This data collected is used for tracking and traceability information of products. Table 3, there are 13 places and 12 transition describing all the four types of PPSC flow, refer Fig. 3.

Figure 4, represents the construction of petri net model. This model being constructed is based on the description of places and transition described in Table 3. The model is developed on CPN Tools, version 4.0.1. Table 4, represents different color for four types of PPSC. Transitions starts if token is available in the particular place. Each place captures and stores the information. This information stored, flows to the next stage of PPSC. This flow of information improves tracking and traceability if the product. Thus, provides transparency to the supply chain. Markings available, represents the current state of the system and provides reachability graph. This reachability graph helps to solve the state space explosion problem.

Table 4. Different color code for flow type in PPSC

Color	Flow type	Description
→	Type - 1	Farmer-Agent-Processor-Distributor-Retailer-Consumer
→	Type - 2	Farmer-Online Sellers-Consumer
→	Type - 3	Farmer-Local Stores/Mandi-Consumer
→	Type - 4	Farmer-Consumer

4 Visualization of Flow Management in PPSC

Inefficiency in supply chain starts with lack of information flow among different stages of supply chain. There is breakage of information tracing and traceability, which leads to delay and loss of products. Petri net model developed in Fig. 4, provides insight and flow characteristics in supply chain. Implementation of RFID, WSN technology, can capture the accurate information of every state identified in Table 3. This information captured integrate the flow of products, information and fund. Petri net model developed capture the dynamic nature of supply chain. It models the discrete events and thus, provides assistance to the decision makers for best results [6]. The information captured uses emerging technologies such as cloud computing, RFID, sensors, WSN and cyber physical systems [20]. Petri net provide semantics to capture the dynamic information [12]. Figure 5, represents a graphical way to explain the flow of products and information in PPSC. The flow has been divided into two cases:

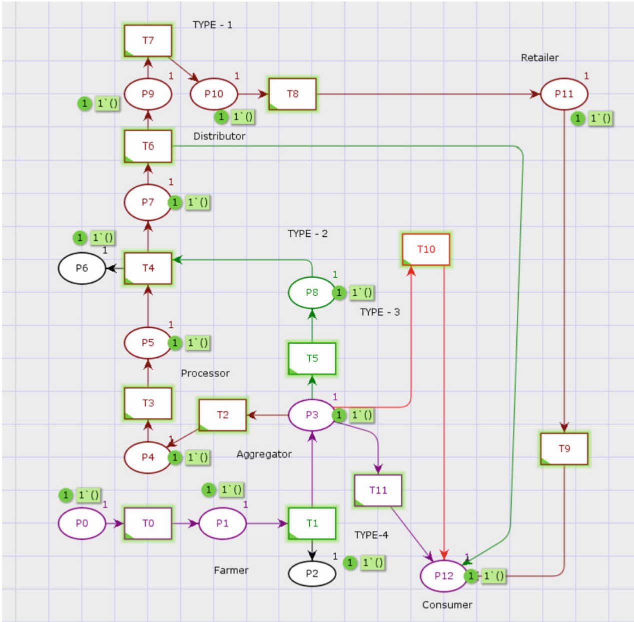


Fig. 4. Petri net model for PPSC

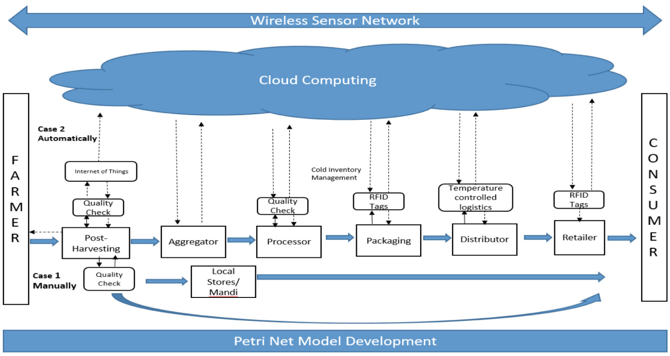


Fig. 5. Visualization of flow Management in PPSC

- Case 1 Manually: This explains the flow of product and information without ant use of information technology. After post-harvesting, quality is check by farmers based on color, texture and size. Finally, distributed to consumers. Efficiency of this type of supply chain is very low.
- Case 2 Automatically: This explains the flow of product and information with incorporation of new technologies such as cloud computing, Internet of Thing and Wireless Sensor Network. The information is stored in cloud, providing transparency to the supply chain. Information flow allows tracking and tracing of products. It allows

transparency to customers by providing information about quality, origin of product to the customers. Cold chain management is one of the issues where RFID technology is capable providing more performance value to the supply chain.

5 Conclusion

This paper discussed the importance of perishable product supply chain. Perishable products are important contributing factor to the economy, so there is need to focus for more research into this area to increase the customer value with decrease in cost. Firstly, this paper presents the flow model of perishable product through different stages of supply chain. The flow model explains four types of flow of product. Secondly, petri net model is being constructed based on the flow model. Petri net model describes different places and transition occurred at different stage in supply chain. It provides an insight into PPSC. Petri net model developed forms the basis of mathematical modeling. This model will improve the operational efficiency of supply chain in consideration to food quality and information flow. The model developed will provide more emphasis on transparency of supply chain.

The research for perishable product supply chain is at a nascent stage and requires a lot of focus. The research needed to be done on the information sharing part of the supply chain, with new emerging technologies such as Internet of Things, cyber-physical system, cloud computing, big data, data analytics can improve the performance and reliability of the system.

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Perceived Threat or Performance Beliefs? What Drives Intention to Continue Usage of Digital Service Apps

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Abstract. In today's smartphone era, digital service applications are essential to most people's daily lives. Even though users get to leverage digital service apps to derive multiple benefits, a big deterrent to continued usage is that users must constantly deal with issues related to invasion of privacy. Borrowing from Technology Threat Avoidance Theory and Multi-motive Information Systems Continuance model, we develop a research model that explains users' intention to continue usage of digital service apps considering both perceived threat and performance beliefs. We test our hypotheses through an empirical study of 256 data points collected from users of these apps. Our findings reveal that while the perceived threat does not have an effect, performance beliefs strongly influence users' intention to continue usage. Through this research, we contribute to the broader IT adoption studies specifically focused on user motivations to make decisions on the continuance intention of these apps.

Keywords: Digital Service Applications · Intention to Continue Usage

1 Introduction

In the wake of the recent pandemic, digital service applications continue to increasingly capture consumer attention and become an integral part of the services ecosystem. The range of services cuts across different categories such as utility, lifestyle, productivity, entertainment, news and social networking. Consumers are relying extensively on such services, often accessed by smartphones, to conduct their day-to-day activities. Depending on their need and specific use case, users can easily download and install apps on their smartphone devices. It is generally free to download; one might have to pay only when services are rendered. Consequently, the sheer volume of downloads, which signals adoption of the service, is not very relevant because retention of users is a significant challenge and only 4% of the users continue to use the service after a year since its first trial [16]. Since the value of these services is realised in the process of consumption rather than initial download [39], the focus shifts from "adoption" to "continued usage" of these services [13].

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Even though users get to leverage digital service apps to derive multiple benefits [4], a big deterrent to continued usage is that users must constantly deal with issues related to invasion of privacy. Previous research [25, 42], suggests that users are most bothered by privacy concerns (e.g., providing access to location, contacts, and other personal data) and in some cases the unethical actions of the developers (e.g., selling the user's personal data). In an examination of the 101 most popular smartphone apps reported by the Wall Street Journal, it has been found that a majority of them transmit the phone's unique identifiers and location to third parties without user awareness [37]. Such findings have only aggravated privacy concerns among users over the previous decade. Privacy concerns about online third-party tracking and monitoring as well as digital network behavior have received much attention in recent years due to the ubiquitous use of smartphones, and the rise of the so-called "Big Five" (Google, Amazon, Microsoft, Facebook, and Apple – large platforms that permanently collect and monetize user data) [4]. For this reason, Kehr et al. [23] suggest that future research should investigate privacy-related decision-making about digital service usage. To respond to this call, we aim to understand user preferences that shape the intention to continue usage of digital service apps. Users assess both the performance benefits they derive from the usage of these apps and their threat perceptions regarding usage in their decisions about continuing usage of the service. Though prior research examined the adoption decision of these digital services, post-adoption intention to continue usage is less explored and there is also a paucity of studies which look at the antecedents that shape the threat perceptions of digital service usage. Accordingly, we ask: *How is threat perception shaped among users of digital service apps? What is the role of this perception in shaping users' intention to continue usage of these apps?*

Borrowing from Technology Threat Avoidance Theory (TTAT) [27] and Multi-motive Information Systems Continuance model (MISC) [7, 31], we develop a research model that explains user's intention to continue usage of digital service apps considering both perceived threat and performance beliefs. We also hypothesize based on the antecedents of perceived threat derived from the TTAT model. We test our hypotheses through an empirical study of 256 data points collected from individuals who are using digital service apps. Through this research, we contribute to the broader IT adoption studies specifically focused on user motivations to make decisions on the continuance intention of these apps.

2 Theoretical Background

2.1 Digital Services

The evolution of digital platforms and services has transformed the entire Information Systems (IS) services landscape [12]. Digital services are defined as "an activity or benefit that one party can give to another, that is, provided through a digital transaction (information, software modules or consumer goods)" [41]. The party that gives the service is called the 'provider' and the one receiving the benefit is the 'user'. A single transaction can be sufficient to provide a digital service, however often these transactions are continuous in nature [41].

In terms of their key features, the replicability of digital service is free as there are no marginal costs and transport costs involved [8]. Digital services are also non-excludable [5]; the open nature of services means many people can receive them concurrently without reducing their availability to others. These two characteristics, replicability and non-excludability, facilitate their global spread [40]. We have witnessed massive consumption of these digital services at a global level. To put things in perspective, the global mobile application market size was valued at $106.27 billion in 2018 and is projected to reach $407.31 billion by 2026, shooting up at a compound annual growth rate of 18.4% from 2019 to 2026[1]. This ongoing explosion is being made possible due to the rapid increase in smartphone penetration across the globe. Smartphone users have grown significantly in every geography over the last decade[2]. This development, coupled with increased connectivity and network bandwidth, has made it possible for more users to engage with digital services effortlessly. Users get to leverage mobile apps even while on the move to derive multiple benefits, which are learning-focused (educative and social networking), utility-oriented (delivery services) and hedonic-seeking (gaming and entertainment).

The process of downloading and installing these digital service apps is extremely easy. Besides, these apps are generally free to access; one might have to pay only when services are rendered. Thus, users may just download the application, but not actually use the service, or may not continue to use it after the initial usage. Therefore, the adoption of a particular digital service is not sufficient. Instead, a more pressing issue is the sustained usage of apps [13]. Though users leverage several benefits from the usage of these services, privacy and security issues have been shown to greatly influence users' intention to continue usage [25, 42]. Prior research highlights the fact that users are concerned about providing access to device location, contacts, and other personal data. Due to the rise of privacy concerns among users over the previous decade, researchers suggested that there is a clear need to investigate the role of threat perceived from privacy concerns about digital services [23]. To address this gap, we focus on the "intention to continue usage of the digital service app" and examine the role of performance beliefs and perceived threat in defining users' intention to continue usage of digital service apps. In addition to the aforementioned gap, we also examine the antecedents that shape threat perceptions of digital service.

2.2 Intention to Continue Usage: Technology Adoption and Diffusion Studies

Technology adoption and diffusion have been extensively studied from multiple perspectives in IS research. The main focus of these studies has been technology adoption. Besides, even in studies that looked beyond adoption, such as diffusion and assimilation of several IT product and process innovations: E-Commerce [45], and EDI [33], the focus was primarily at the organizational level [14].

Even though digital service apps are transforming the nature of IT and shifting the focus to service ecologies [12, 38], they have been weakly examined until recently and the field has remained broadly confined to organizational and industry-level technology

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[1] Research and Markets Report 2020 (accessed on 20th Apr 2022).
[2] Newzoo Global Mobile Market Report 2019 (accessed on 22nd Apr 2021).

adoption studies [43]. Several studies examine individual level 'adoption' decisions of digital services (such as [19, 24, 30]) and have identified salient factors such as relative advantage, ease of use and compatibility which influence adoption decisions [2]. However, there is a need to focus on the entire process of diffusion of these digital services which includes post-adoption decisions such as user intention to continue usage. There is a clear paucity of studies that focus on the continued usage of digital service applications. This study seeks to contribute to the literature by focusing on user beliefs and intentions that drive continued usage of services.

2.3 Performance Beliefs and Intention to Continue Usage

The long-term viability of IS and its eventual success depends on the continued use of users rather than their first-time use [6]. Prior research has considered IS continuance as not merely an extension of IS adoption and has reflected upon individual behaviour of using a particular IS over a period [29]. The term "post-adoption" is used as a synonym for "continuance".

The Multimotive Information Systems Continuance model (MISC), developed by Lowry et al. [31] and Bhattacherjee and Premkumar [7] provides a framework to understand the "intention to continue usage". It has its roots in Expectation Disconfirmation Theory and its basic premise is that the role of expectations must be considered for system use. In this context, Bhattacherjee and Premkumar [7] stated that disconfirmation refers to a deviation from the initial expectation that may be above or below that expectation. MISC explains and predicts how the fulfilment of motives and expectations leads to continuance intentions [31]. Overall, MISC addresses three primary motives and expectations: hedonic motivation such as joy, intrinsic motivation such as learning, and extrinsic motivation such as usefulness. These indicators increase the explanatory power of the model to predict continuance usage. Overall, MISC serves as a comprehensive model to analyze how user motives and expectations influence continuance intentions. However, available suggestions on this issue in the specific context of digital service apps, such as mobile apps, are scarce [20]. User intent is to leverage performance benefits from these services and it is therefore important to understand the role of performance beliefs in shaping their intention to continue usage.

The usage of digital services often comes with privacy-related issues. For instance, mobile apps which involve any kind of delivery service need access to users' live locations to be able to cater to and deliver the purchased products. Some users consider the sharing of their whereabouts to a third party as an invasion threat. MISC does not account for such threat perceptions. MISC solely focuses on expectations and performance beliefs about the service to predict continuance intention usage. When this is combined with users' perception of threat, it has the potential to offer fresh insights, especially in the context of digital services usage.

2.4 Technology Threat Perception and Intention to Continue Usage

Based on cybernetic theory and coping theory, Technology Threat Avoidance Theory (TTAT), developed by Liang & Xue [27], discusses the role of threat perceptions and avoidance behaviour. It asserts that an individual's awareness of the threats (defined as threat calculus) is influenced by their perceptions of susceptibility to and the resulting severity of the threats [27]. This threat calculus, in turn, has a direct effect on an individual's motivation and behaviour towards avoiding threat. TTAT has provided the foundation for many studies, and research has leveraged it in various contexts. In originally developing TTAT, Liang & Xue [27] relied on the general context of spyware threats. Since then, several empirical studies have been conducted in broader contexts: IT security [28], phishing threat [3], malware threat [44] and volitional computer users' IT threat [13] avoidance behavior. A unifying theme across these studies is the intent to validate TTAT as a useful theoretical lens to study individuals' coping behavior. However, research has often examined only the partial model and provided some inconsistent findings. Specifically, studies have found contrasting results for the relationship between severity, susceptibility and threat perception [9]. Examination of empirical TTAT studies suggests that there is a lack of clarity about the role of severity and susceptibility. This indicates that additional work is needed to further test and provide clarity on the antecedents of threat perception [10]. Besides, we note another salient limitation in the TTAT literature. The existing studies focus solely on understanding threat perceptions and how motivated IT users are to avoid such threats by taking safeguarding measures. Extrapolating this, there is a strong likelihood that if a user perceives privacy or invasion threat as high, this will significantly impact his/her intention to continue usage. There is little evidence in the literature to explore this understanding to focus on continuance intention among users. We address this gap in the context of digital service by considering both perceived threat and performance beliefs in a single model that addresses the intention to continue the usage of digital service apps.

3 Research Model and Hypotheses

Building on the theories and foundations discussed in the previous section, we develop our research model to understand the key antecedents of perceived threat in the context of digital service app usage and the role of perceived threat in shaping the users' intention to continue usage of the digital service app. Figure 1 depicts our research model. The perception of threat is considered, in conjunction with benefits accrued from leveraging digital service apps, to understand continuance intention. Performance beliefs involve user perspectives on three aspects: hedonic, intrinsic, and extrinsic motivations.

3.1 Perception of Threat

Prior research suggests when perceived susceptibility to negative effects of privacy and security due to digital service app usage is high, users suspect that their personal information will be compromised owing to app usage and that their devices will get infected [27]. When users perceive such greater susceptibility to negative effects they become concerned about the negative consequences of app usage related to privacy such as (1) app/platform provider accessing personal information without his/her knowledge, (2) app usage details being shared by a third party, and (3) information collected being put to unauthorized use or used to commit crimes [9, 27].

Therefore, IT users develop a perception of threat by monitoring their application environment, especially when sharing personal information, and providing access to

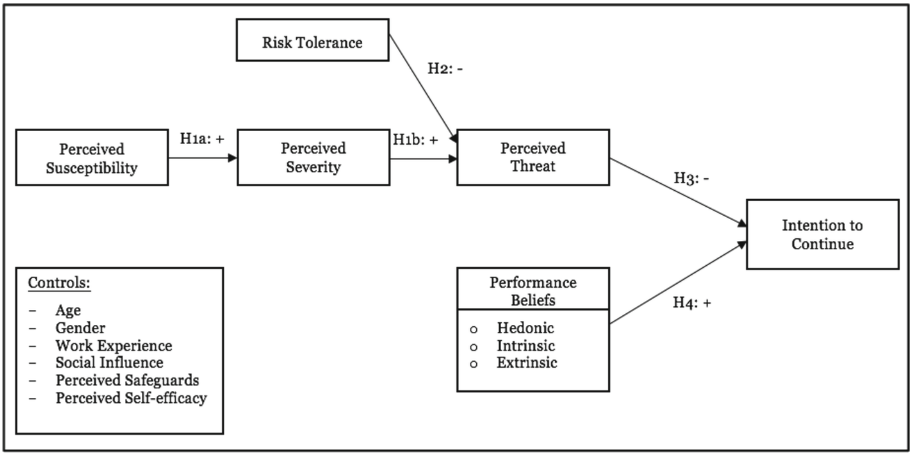

Fig. 1. Research Model

contacts or media on their smartphone devices to third parties. Thus, perceived threat is defined as the extent to which an IT user perceives leveraging a digital service app as dangerous or harmful [28]. Despite conflicting findings, the consensus in the literature is that threat perception is influenced by IT users' evaluation of susceptibility and severity of the threat (in this case, privacy invasion being posed by leveraging digital service app). In line with Boysen et al. [9], we consider the direct effect of susceptibility on severity, which in turn influences threat perception. Thus, we hypothesize:

Hypothesis 1a: *Perceived susceptibility to negative effects positively influences perceived severity of negative consequences of digital service app usage.*

Hypothesis 1b: *Perceived severity of negative consequences mediates the relation between perceived susceptibility and perceived threat from digital service app usage.*

Developed in the finance literature, risk tolerance is considered an important factor in affecting one's financial decisions [21]. Since then, this has been found to be relevant in contemplating non-financial decision-making as well. However, Liang & Xue's [28] proposition does not shed much light on the relevance of risk tolerance in influencing user response to any form of IT threat [11]. Risk tolerance is considered the maximum level of uncertainty that one is willing to accept when making IT-related decisions [11]. Users who are risk-tolerant generally do not perceive a great threat from digital service app usage. They do not worry about app ratings or the number of prior downloads before downloading apps from App Store. IT threat is acknowledged as essentially a form of risk; risk-related personal traits help explain users' perception of threat. Thus, we contend that risk tolerance can play a direct role in influencing users' perception of threats. This leads to our hypothesis:

Hypothesis 2: *Risk tolerance negatively influences the extent of threat perceived by the user of the digital service app.*

3.2 Intention to Continue

Past research suggests that user assessment of perceived risks and benefits during the current usage of any IT service shapes their future intentions of usage [18]. Here, in the context of the intention to continue usage of digital service apps, users assess the potential performance benefits that accrue to them from usage and privacy and security risks they are subject to before they decide to continue usage. Therefore, we contend that IT users assess both the threat perception as well as performance benefits to arrive at an overall evaluative appraisal of digital service apps which influences their decision to continue usage of the applications. Accordingly, we frame the hypotheses related to the user's intention to continue usage of a digital service app.

Clearly, when users perceive a greater threat to their personal data, they tend to get dissatisfied as the service does not meet their expectations. For instance, an individual is often required to provide access to personal data (such as contacts, and/or live location) to third parties to continue using the service. They are concerned about the traceability of their app usage behaviour and their data being shared with third parties [4]. The resulting threat calculus, which may differ from one individual to another, has the potential to negatively influence continuance intention among users. Theories of reasoned action and planned behaviour [1, 15], posit that such mismatched expectations increase dissatisfaction among users and this dissatisfaction shapes their attitude towards the usage of the service. Therefore, extending this notion and borrowing from previous research in this area [7, 31], we posit that when users perceive the threat from the usage of a digital service app, they intend to protect their data by discontinuing the usage of the digital service app. Under such scenarios, they do not recommend the service to others and they do not use the service when an opportunity presents itself again. Therefore, we hypothesize:

Hypothesis 3: *Threat perceived by the users through the current usage negatively influences the intention to continue usage of the digital service app.*

Contingent to the type of service, user beliefs are expected to be influenced. For instance, an individual perceives a music streaming service primarily for hedonic benefits, while an essential delivery service for extrinsic benefits. Theory of reasoned action and planned behaviour [1, 15], posits that positive expectations promote satisfaction. Therefore, extending this notion and borrowing from previous research in this area [7, 31], we posit that performance beliefs of digital service apps will lead to satisfaction for individual adopters. These performance benefits reveal the user-derived value from digital service apps by meeting or exceeding their hedonic (joy), intrinsic (learning) or extrinsic (usefulness) motivations [31]. For instance, an individual may perceive a music streaming service primarily for hedonic benefits, a social media platform for intrinsic benefits and a food delivery service for extrinsic benefits. The accrual of these benefits in totality leads to satisfaction among users through positive reinforcement. Satisfied users recommend the service to others and use the service again whenever there is an opportunity. Therefore, we hypothesize:

Hypothesis 4: *Performance beliefs perceived by users through the current usage positively influences their intention to continue usage of the digital service app.*

4 Methods

4.1 Data and Sample

This study follows a survey-based methodology to collect data. The survey instrument was developed to collect data from individuals who have adopted digital service apps. The survey focused on understanding individuals' intention to continue usage of digital service app once they have adopted the service. We have identified two prominent digital service apps - food delivery and social networking – for data collection. Wherever possible, existing scales were used after they were adapted to the context of the present study. We reached out to 256 industry professionals from across various industries for data collection. Most of the respondents of the survey were professionals who were participants in the executive education program of a top business school in India and other professionals with similar profiles were reached out through researchers' professional contacts. The sample consisted of 81 women and 175 men. The age group of the participants of the survey varied from 22 years to 64 years with an average of around 36 years. The average work experience of the participants is around 13 years. Data was collected from individuals who have adopted either food delivery services or social networking platforms. 110 participants provided information about food delivery services and 146 participants about social networking platforms.

4.2 Operationalization of Variables

Dependent Variable

The dependent variable of the study is "*intention to continue usage*" and it is defined as the user's intentions to return to an application if the opportunity presents itself again and the intention to recommend the service to others. It is operationalized based on the scale provided by Galletta et al. [17].

Predictor Variables

The following three predictor variables are operationalized based on the definitions provided by Liang & Xue [28] in the TTAT model. a) *Perceived Susceptibility* is defined as the user's subjective probability that usage of the digital service app will negatively affect him or her where the devices could be affected and information on the devices compromised. b) *Perceived Severity* is defined as the extent to which the user perceives that negative consequences caused by a digital service app will be severe. It includes consequences where the service invades user privacy, accesses personal information without users' knowledge and circulates to third parties. c) *Perceived threat* is defined as the extent to which the user perceives usage of a digital service app as dangerous or harmful. These privacy and security issues bother the user, and he feels threatened by the consequences.

Performance beliefs is defined as the user's beliefs regarding intrinsic, extrinsic, and hedonic benefits accrued from the actual usage of a digital service app. This variable is operationalized as three different constructs: hedonic performance benefits, intrinsic performance benefits and extrinsic performance benefits based on the scale provided by Lowry et.al [31].

Risk tolerance is defined as the maximum level of uncertainty that one is willing to accept when using a digital service app. Based on the definition provided by Chen & Liang [11], it is operationalized as the extent to which the user is worried about the digital app/service ratings and prior downloads before downloading and using the service.

Control Variables
In addition to the predictor variables, we also controlled for important variables such as user age, gender, and work experience. We have also controlled for the type of service (social network platform or food delivery service) through a dummy variable.

Besides, we have identified important variables from the TTAT model and controlled for them. They include *perceived self-efficacy and Perceived avoidability.* In the context of digital service app usage, *perceived self-efficacy* is defined as the extent to which a user feels confident about protecting his data and devices while using a digital service app. This definition has been adapted from Liang & Xue [27]. *Perceived avoidability* through safeguards is also derived from the scale provided by Liang & Xue [27] and defined as the extent to which users believe they can avoid privacy and security threats associated with digital service app usage by implanting safeguards in the form of permissions to SMS, phonebook, gallery, location etc.

Finally, we have also included social influence in our model as an important control variable that influences user intention to continue usage [36]. The variable *social influence* has been modelled based on the definition provided by Atteneder & Collini-Nocker [4]. It is defined as the extent to which the usage of digital service app is influenced by social pressures.

5 Results

5.1 Instrument Development and Validation

All analyses in this study were conducted using Stata 14. To assess scale reliabilities, Cronbach alpha values were inspected and items with low item-total correlation were dropped from the scales. Results are reported in Table 1. Having established the measurement properties for the various scales in the study, items were then appropriately averaged to form variable scores that were used in regression analysis.

5.2 Hypotheses Testing Results

Accordingly, all the multi-item and multi-dimensional constructs were aggregated, and the data was then used to test the hypotheses proposed in the study. A **sur** (seemingly unrelated regression) model of OLS regression was used to test our hypotheses as our model consists of mediation effects. Results in Table 2 suggest substantial pseudo-R2 values for each of the regression models.

An inspection of the variance inflation factor (VIF) for the explanatory variables revealed that the highest VIF is 3.95 and the mean VIF is 1.34, which are below the cut-off value of 10, indicating that our results do not suffer from a multicollinearity problem. Finally, we do not expect common method bias to be a serious threat to the results of

Table 1. Descriptive Statistics and Measurement Properties of Scales

Variable	Mean	Std. Dev.	Min	Max	Cronbach Alpha	AVE													
Age	35.977	8.558	22	64			1.00												
Gender	0.684	0.466	0	1			0.12	1.00											
Work Experience	12.928	7.597	0	44			**0.93**	**0.26**	1.00										
Food Delivery Service Dummy	0.429	0.496	0	1			0.05	-0.05	0.05	1.00									
Social Influence	4.613	1.644	1	7	0.795	0.852	-0.04	0.05	-0.03	**-0.17**	0.92								
Perceived Self Efficacy	4.477	1.529	1	7	0.871	0.855	0.03	-0.01	0.06	-0.02	**-0.25**	0.93							
Perceived Safeguards	5.023	1.432	1.4	7	0.756	0.514	0.05	-0.04	0.05	-0.01	**0.15**	0.08	0.72						
Perceived Susceptibility	5.154	1.579	1	7	0.807	0.839	**0.17**	0.09	**0.21**	-0.02	0.09	-0.05	**0.22**	0.92					
Perceived Severity	5.430	1.308	1	7	0.908	0.639	**0.16**	0.04	**0.18**	-0.02	**0.17**	-0.08	**0.17**	**0.57**	0.78				
Risk Tolerance	3.486	1.871	1	7	0.722	0.782	-0.12	0.02	-0.10	0.06	**0.18**	**-0.39**	0.06	-0.01	0.07	0.88			
Perceived Threat	5.237	1.383	1	7	0.734	0.633	**0.18**	**0.12**	**0.17**	-0.01	-0.04	**0.25**	**0.17**	**0.24**	**0.18**	**-0.19**	0.80		
Performance Benefits	4.648	1.288	1	7	0.940	0.517	**-0.12**	-0.05	**-0.13**	-0.09	**0.43**	**-0.39**	0.02	0.07	**0.15**	**0.27**	**-0.23**	0.72	
Intention to Continue Usage	5.004	1.481	1	7	0.910	0.849	**-0.20**	0.01	**-0.21**	**0.17**	**0.16**	**-0.19**	0.02	0.01	0.04	0.09	-0.09	**0.31**	0.92
Note:																			
1. Significant correlations (p<0.05) are reported in bolded typeface.																			
2. Cronbach's alpha, AVE reported for variables measured using multiple items.																			
3. sqrt(AVE) is reported on the diagonal for variables measured using multiple items.																			

Table 2. Regression Results

	Coef.	Std. Err.	Z	P<|Z|
DV: Perceived Severity				
Constant	2.861	0.620	4.620	0.000
Food Delivery Service Dummy	-0.041	0.135	-0.300	0.763
Age	0.003	0.023	0.150	0.882
Gender	-0.087	0.158	-0.550	0.581
Work Experience	0.009	0.026	0.360	0.720
Perceived Susceptibility (H1a)	**0.467**	**0.043**	**10.790**	**0.000**
DV: Perceived Threat				
Constant	3.126	0.802	3.900	0.000
Food Delivery Service Dummy	0.034	0.166	0.210	0.836
Age	0.034	0.028	1.200	0.230
Gender	0.364	0.194	1.880	0.060
Work Experience	-0.020	0.031	-0.630	0.529
Risk Tolerance (H2)	**-0.140**	**0.044**	**-3.170**	**0.002**
Perceived Severity (H1b)	**0.254**	**0.064**	**3.980**	**0.000**
DV: Intention to Continue Usage				
Constant	1.709	0.969	1.760	0.078
Food Delivery Service Dummy	**0.572**	**0.164**	**3.480**	**0.000**
Age	0.024	0.027	0.900	0.371
Gender	0.298	0.190	1.560	0.118
Work Experience	-0.049	0.031	-1.590	0.111
Perceived Self Efficacy	-0.016	0.059	-0.270	0.783
Social Influence	0.038	0.055	0.690	0.492
Perceived Safeguards	0.039	0.057	0.690	0.492
Perceived Threat (H3)	0.021	0.062	0.340	0.733
Performance Benefits (H4)	**0.260**	**0.073**	**3.570**	**0.000**
Seemingly Unrelated Regression	**RMSE**	**R-sq**	**chi^2**	**P**
Perceived Severity	1.067	0.332	129.680	0.000
Perceived Threat	1.310	0.099	35.880	0.000
Intention to Continue Usage	1.268	0.264	90.530	0.000
Note:				
1. Coefficients, Standard Errors, P and Z values are reported				
2. Significant correlations (P<0.005) are shown in bolded typeface				

this study as we have reverse-coded some of the questions in the survey and questions related to the dependent and independent variables are placed in different blocks of the survey.

A significant positive coefficient for perceived susceptibility ($\beta = 0.467$, $p = 0.000$) provides support for H1a. Similarly, a significant positive coefficient for perceived severity ($\beta = 0.254$, $p = 0.000$) provides support for H1b. A negative and significant coefficient for risk tolerance ($\beta = -0.140$, $p = 0.002$) provider support for H2. However, surprisingly, we do not find support for our hypothesis H3 which states that the greater the threat perceived by individuals from the usage of digital service apps, the lower the intention to continue usage of the services. Finally, a significant positive coefficient for performance benefits ($\beta = 0.254$, $p = 0.000$) provides support for H4.

Among the control variables, food delivery service variable showed a strong influence on user's intention to continue usage, which suggests that users intend to continue usage of food delivery services in comparison to social network platforms. Similar to the findings in prior empirical studies, the control variable, perceived avoidability through safeguards did not show any significant results (cf. [28]). Neither the demographic control variables such as age, gender, work experience nor social influence and perceived self-efficacy showed any significant influence on the user's intention to continue usage.

6 Discussion

Through this study, we contribute to the broad literature on technology adoption and diffusion with a specific focus on user motivations and intention to continue usage of digital service apps. We identified two main gaps in the research related to digital services: Borrowing from the theories of TTAT which focused on technology threat and MISC which provided a framework to understand the relationship between performance benefits and usage intentions, we develop a research model which focuses on the intention to continue usage simultaneously considering perceived threat and performance beliefs. Our results find support for TTAT in the context of digital service apps. We find that perceived susceptibility to negative effects of digital service app usage influences perceived severity of consequences and perceived severity mediates the relationship between perceived susceptibility and perceived threat.

However, one of the major and surprising findings of the study is that perceived threat has no significant influence on user intentions of continuance. To make sense of this, we draw upon an attention-based view [32]. This theory suggests that when individuals make decisions considering various facets of information relevant to the decision, they do not give equal weightage to all of them [22, 35]. Depending on the complexity of these decision facets, they may give more weightage to those aspects which are easier to assess [32]. This finding points to the fact that performance benefits which are accrued in the present are easier to assess, but negative consequences of privacy and security-related threats only present themselves in the future and cannot be assessed ex-ante. Therefore, users tend to make the decision to continue usage based on the performance benefits. This also highlights the information asymmetry in the context of digital service apps between the service providers and users. Despite ongoing discussions about political and legal regulation strategies in the light of General Data Protection Regulations (GDPR), there is a lack of transparency and users are unable to assess the consequences of threats perceived by them.

This study successfully integrates MISC and TTAT theories using the fundamental principles of Theory of Reasoned Action and Planned Behavior. This brings the focus on the important variable "intention to continue" specifically in the context of digital service apps. Our study identifies the issues with the assessment of threat perceptions and its role in shaping user intentions to continue usage of digital service apps. This highlights the lack of transparency in data handling by the service providers. In the future, longitudinal studies can investigate the dynamics of change in threat perceptions and usage behaviors. Due to the limitations in data size, we could not study the interaction effects between the different perceptions. This is a potential avenue for future studies. We also acknowledge that the lack of support for threat perceptions may be related to the selection of the sample. We aim to replicate the study in a different context to clarify this bias.

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Accelerating Product Success: Designing a Digital Adoption Framework to Elevate Developer Experiences

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Abstract. The proliferation of service-based software in the past decade has prompted organizations to reconsider their software development approaches. The scenario is further infused with the complexity with the wave of generative artificial intelligence adoption. This effects on one side how organizations address customer issues, motivate developers to create scalable solutions and on the other side how businesses will evaluate software solutions and their adoption to improve their business processes. This transformation impacts the customer experiences, although harmonizing the experiences of both developers and customers presents a challenge due to existing processes and procedures.

To improve both consumer and producer productivity, it is essential to enhance the end-user experiences and usability of all software tools and associated processes within organization's internal ecosystem. The importance of programs that under-score organizational psychology, mindfulness, design thinking and the nurturing of a growth mindset has been acknowledged by organizations to have influenced digital adoption.

Our research tries to understand the paradigm of customer-centric software development, its connection to developer ecosystems and how it influences the adoption of the solution in various industry verticals. It explores the existing and cur-rent state of approaches, improvements, and challenges to come up with a framework to nurture their developer ecosystem by fostering a culture focused on design.

Keywords: Developer Experience · Technology Adoption · Business Value · Mindset · Productivity · User Experience · Design Thinking · Machine Learning and Artificial Intelligence

1 Introduction

The field of software development is evolving at a rapid pace with new methodologies and architectural approaches shaping customer requirements. The wave of generative Artificial Intelligence (GenAI), coupled with its integration with other AI and machine learning (ML) layers, is revolutionizing the field of software development. This recent

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change also influences how business users use the technology and adopt it. As a result, it has been a key focus for most organizations to dive into the topic of engineering excellence and understand the aspect of developer experience [1] and correlate the study to the end user perspective as well. We always associate engineering excellence with the highest standards of quality, strict adherence to engineering best practices, and the consistent delivery of a seamless user experience [2].

However, to effectively scale operations, enable proficient change management and sustain a software-based business model, it is imperative to look into another significant dimension. This involves allocating resources to and fully embracing emerging technological transformations and paradigms [3]. The value of empirical studies is gaining recognition within the software engineering community in the development and enhancement of processes, methods, as well as communication and collaboration approaches [4].

With the constantly evolving software landscape driven by technology innovations organisations also realise the benefits these approaches have on enhancing software development methodologies like Agile, using AI evaluations for real-world applicability and effectiveness circumvented by design thinking. Hence triggering innovation and user-centricity in product development, enabling decision makers on adoption and thus complementing the empirical approach. There is an increasing demand for developers to attain a more granular understanding of the quality of the software they create [5] and how they impact any business process in case of a deviation. Academics have sought to delineate dependable indicators that can be employed when assessing the aptitude and skill of individuals engaged in software development [6].

Additionally, a substantial volume of research has been dedicated to investigating the association and credibility of these substitutes [7]. The Fig. 1 suggests the various parameters that influence a developer which includes the tools – related to the process or development, the environment including the team and organisation culture, topics of interests which is critical for the management to understand for assigning them to the right projects and hence the training parameters which provides the motivation for the developers to work on new topics.

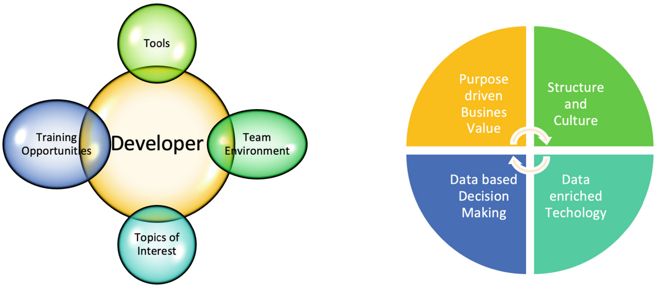

Fig. 1. Factors influencing developers and the future of organisation imperatives.

There are numerous research endeavors that have probed the intricacies of developer engagement with tools such as virtual agile boards that hold considerable sway within the developer community [8]. The studies have revealed the dimensions encompassing usability and their consequential impact on customers [9]. This, however, is significant to study and correlate which is exactly missing from the decision maker's model of adopting a business change. This aspect of the decision makers can be significantly influenced with transparency and less emotional bias that is dominating due to the ecosystem [10]. The need for decisions to be based on data and how the data can help adoption and productivity in wholesome manner is also depicted in Fig. 1.

Now with the integration of intelligent technologies, the era is now characterized by an unprecedented abundance and complexity of data. Consequently, the necessity for a robust framework to assist decision-makers in fully harnessing the extensive potential of the changing technology dimensions and keeping into considerations the social impact become increasingly critical. Such a framework equips decision-makers with the capacity to navigate complex terrain and respond adeptly to rapidly changing circumstances while facilitating well-informed choices in real-time. This is precisely where our framework steps in, primed to offer invaluable support to decision-makers as they navigate this uncharted terrain.

1.1 Literature Review

In recent years, there has been a substantial transformation in the domain of technology project execution within the software industry and its corresponding adoption in target markets. This transformation has led to methodologies like user-centered de-sign, aimed at cultivating enriched user experiences for the intended audience of a software product. Accompanying this evolution is a set of challenges revolving around evolving technological trends. The complexity is particularly accentuated by the introduction of Gen AI and compounded by the growing relevance of low-code and no-code approaches which have a serious impact on adoption and productivity alike. In response to this enduring state of flux, the adoption of agile methodologies presents itself as a viable solution.

However, there is no second opinion that customer needs are the foremost priority for any organization and businesses alike and it becomes the core of our incrementally evolving environment and with it the ecosystem. The amalgamation of user experience and agile methodologies offers a promising confluence to the presented challenges in the era of Web 5.0 and Web 4.0. Yet, this fusion simultaneously ushers in an array of opportunities and responsibilities, all aimed at ensuring the expected quality of all software components delivered to the designated users. The realization of this objective depends upon an organization's capability to enhance the experiences of software developers and business users alike [11]. With developer experience, the idea is to explore new approaches to engage distributed development practices to harmonize collaboration to deliver value to the end user. In this context, there are several parameters that we need to focus on to understand developer experience in depth. Two critical classifications which we can do for enriching the knowledge on the factors would be technical and non-technical attributes [12].

If the organization is large, then the aspects of technical environment would be governed which would mean that the factors that hinder the developer experience be it be the access to expert knowledge and rewarding mechanisms. The parameters that form the cohort of the non-technical part of classification influencing developer experience would be communication, transparency, trust, and collaboration. We try to come up with abstract ideas to improve on the antipatterns organically within any product/platform/service development ecosystem so that it can be incrementally improved and sustained over the course of the transformation and further technology changes.

The current research tries to understand and map the key aspects of "user experience" using the parameters of intuitiveness, and holistic approach to help organizations approach product improvements with evidence-based approach [13]. We can stack the aspects that impact the developer experience and at its core foundation layer, we depict that in Fig. 2 below where the top layers are easier to improve if we have the right cultural environment.

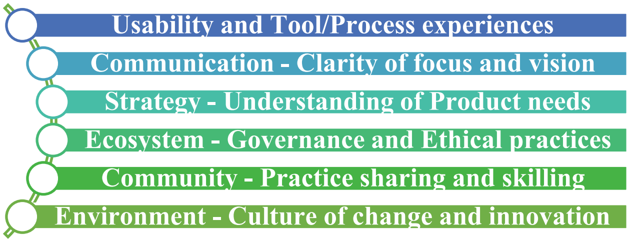

Fig. 2. Foundational layers which impact developer experiences.

Developers are the driving force behind software development, and their efficiency is pivotal. Low-code and no-code approaches streamline development, allowing developers to focus on higher-level tasks [14]. Accountable governance within development teams ensures that roles and responsibilities are clearly defined, maintaining accountability throughout the project lifecycle [15]. Additionally, the integration of AI and ML for automated code analysis and bug detection can significantly reduce development time, enhance code quality, and, consequently, improve developer productivity.

Key to progress in software development is the swift product development cycle, critical for success in a fast-evolving market. Agile methods are essential, enabling quick responses to market demands and feedback. AI, ML, and GenAI expedite this process by analyzing vast datasets for insights that enhance products and align them with user expectations. Success also hinges on safeguarding user and complying with data protection regulations like GDPR, building and maintaining user trust for long-term success [16].

The conscientious utilization of digital technology has gained paramount importance. The aim is not solely to develop functional solutions but also to do so in a manner that promotes environmental and societal well-being. All the organizations' commitment involves instructing developers in ethical coding practices and the protection of individuals' data [17]. In this way, our software endeavors not only to attain its objectives but also to enhance the digital landscape for the betterment of all.

1.2 Software from the Social Lens

A good mix of technology and social elements is required to establish an environment conducive to a developer which would also require changes to the overall leadership to achieve the right developer experience required from the organization. From enabling the sense of impact, empowering ownership, and responsibility, driving towards a common goal, and the most important aspect of allowing failures is critical. We also must keep the negative aspects to tackle them in the right way to create a productive scenario. Moving away from a blame mindset, diluted responsibility, lack of time to try out and fail, and uncertainty leading to a hostile competitive environment which leads to failures.

A comprehensive solution necessitates a multidisciplinary strategy, drawing expertise from various domains like computer science, philosophy, law, and sociology. Actively involving stakeholders, including users, developers, and policymakers, is vital to infuse ethical considerations throughout the development process. Moreover, recognizing the potential for AI misuse, encompassing surveillance, discrimination, and manipulation, underscores the need for robust safeguards and regulations. Protecting individual and community rights requires the establishment of ethical frameworks guiding responsible AI deployment and the implementation of measures ensuring transparency and accountability in AI systems.

2 Conceptualizing the Problem

The concept of developer experience may appear closely linked to the developer's immediate environment. Nonetheless, to gain a more comprehensive understanding, it's advantageous to consider it from a broader perspective. It becomes more and more critical to not only address the scope triangle but also add another dimension of social factor be it human emotion and bias.

The first step should also realize the significance of understanding security decisions and consider them as business decisions. Based on the risks, prepare for mitigations, and enable testability of developed features. Even if these aspects are not formally part of the feature planning, we need to ensure that the SAAS ecosystem product management considers such aspects including legacy refactoring as important as new development. This change will drastically change how product management collaborates with engineering and keeps a direct touch base with developers during the feature design and development phases.

The varying issues from the phase just after customer requirements would be to design the platform and in context of present scenario would be even to choose a most reliable existing platform. Taking these aspects into context we need to choose a platform or even an architecture pattern. In the context of delivery timelines, we seldom take this decision in a hurry and sometimes the lack of understanding or management pressure can also create issues in later stages of development.

There is a psychological aspect that we need to understand here, and all these small aspects can lead to serious repercussions in future environment of the development ecosystem. Another important element to consider when it comes to creating an environment for developers would be the choice of tools and processes [18]. In fact, this is where the core of the problems lies when it comes to developer experience. This environment on how we design it will either lead to some or all or none of the challenges like incomplete documentation which makes it difficult to understand the tool set and platform interactions, complex tool interfaces lead to frustrating usage and cumbersome enhancements, inactive community of practice and no/limited access to experts, lack of good step-by-step guides and best practices availability and poor integration between application and integration between tools and applications leading to rework and complexity.

So major factors are often related to the aspects of "reuse" or "reinventing the wheel". One of the commonly observed patterns of lower experiences in context of development is also the fact that organizations prioritize the delivery over quality and even if there are safeguards for quality, it is often surrounded by the sea of exemptions leading to the habit of skipping the core practices and only focus on delivering on time and "just make things work". All the antipatterns lead to an environment where we start to see frustrations and drop in productivity and finally, we would see a surge in developers, managers, architects leaving the organization [19]. Improving developer experience can help with the retention in number of ways including but not limited to the following: - (a) Reducing stress among developers, (b) Creating an enjoyable working environment, (c) Proactive support system, (d) Encouraging collaboration over sense of isolation. (e) Rewarding based on accomplishing delivery and development, and (f) Ease of upskilling and learning.

The final aspect is to ensure that the deliverables by the teams are generating value for the organization and this needs to be measured. The value will be generated if customers use the product/service and provide their feedback. This can also be positive if there are minimum, or no customer incidents reported over the subsequent releases for the product/service updates. As we realize by experience, it is important that any organization which wants to focus on improvement must measure constantly the changes which can be done via the methods [20] like surveys, establishing metrics and in-depth interviews. Hence, there are 2 critical research questions that we must consider as part of the research:

1. What strategies and frameworks can organizations implement to cultivate developer ecosystems and foster design-focused cultures, addressing the requirements and expectations of both software providers and consumers? This entails integrating emerging technologies like GenAI, traditional AI, and machine learning to enhance product experiences, while also improving usability and productivity for software consumers.
2. How does the adoption of generative artificial intelligence and customer-centric software development practices affect software evaluation processes in various industry sectors?

3 Design Methodologies and Its Impact

Before we go into designing an organic ecosystem, let us understand the design methodologies [21]. We know that often in case of a product/service or even a platform, there is no specific best fit of any design methodology, but it is often seen that we need to consider all or some of the following factors -

- Problem type and solution requirement. Are we looking to understand and address user needs or is there a possibility that we have a constant need to reiterate for a solution?
- The objective of the project also plays an important part where it needs to be answered whether we need to focus on experience or need to focus on a specific flow.
- Team and its member preferences which can range from structured to highly flexible approaches.
- Resources and constraints of the team can also present the criteria for choosing the best fit approach as there may be time and cost constraints.

Based on the factors, we can either choose any one of the approaches from lean, agile, human-centered design, or design thinking.

4 Framework to Accelerate Adoption and Elevate Experience

If we want to focus on long term improvement and not take up transformations in an organization as mere check lists, then it is critical that we have to setup the right processes starting with how we want to gather customer requirements to how we want to deliver the experience to the customers [22].

4.1 Product Management

In the overall scheme of the product management, it is important that we create a decision-making template to resolve conflicts if it arises during prioritizations of the requirements and requests and create a common database for the optimal capabilities of the product and make it centrally available for the entire organization to bring in the transparency required.

Key elements of product management which impact the developer experience are product roadmap providing directions, refined requirements and prioritizations, continuous alignment with developers. Hence based on our design we can simplify the factors influencing developer experience [23]. Another key element that influences the developer experience will be the architecture and this has a significant impact on the developer experience as the core basis of all interactions will be done via the guidance and the approach decided with the architecture.

4.2 Architecture

Often, we have encountered that the architecture of any product be it an established organization or a startup, is never perfect and the tendency to grow from simple to a complex one is seen. To keep the experience of working with architecture at a measure that is not frustrating for developers requires to take step by step approach to infuse the complex features which are currently trending in the software development ecosystem.

There is no perfect approach, but a good architecture will allow plug and play, and provides faster feedback. The idea of infusing capabilities of isolation, microservices and zero down time aspects very early into product development is not a great idea and this will lead to lots of operational support along rewriting modules to fit the technology requirements, but it also doesn't make sense to start with a monolithic approach and we need strike the right balance to incrementally adopt complexity while preserving the right developer experience [24].

4.3 Development Process

Few aspects that we need to consider may not be limited to the following, but it is good starting point for most organizations to have cloud based integrated development environments, testing and integration environments, serverless infrastructure and seamless infrastructure provisioning and management along with container based local environments.

Quality and test strategy also needs to be streamlined and made lean with focus on test automation. Let us note the aspects that needs to be considered while establishing an ecosystem for development and delivery teams like a full integrated automated test framework with organization's recommendation of IDE, emphasis on unit tests, test isolation concepts, enabling continuous integration and code reviews holistically for all development environments and promoting performance testing.

Based on the established frame, we can focus on what to measure and how to measure the metrics which significantly impact the developer experience which are "code quality", "productivity", "time to deploy", "defect rate" and "mean time to recover". Now we have an end-to-end design for improving or in case any organization or team starting with enabling better developer experience. We now need to focus on the mindset aspects which influence the development units and is a key dimension to focus to establish a healthy environment for teams [25, 26].

5 Enhancing the Framework with the Improvement Cycle

Framework objectives will involve coming up with actionable factors, identifying contextual characteristics, identifying cross product barriers, and knowledge strategies to feed into the developer ecosystem.

Components in the framework can be enhanced by incorporating "capturing developer mood and cognition module" where we can analyze combination of measures: combining multiple measures to gather a more complete picture of cognitive workload. Another module can be using AI, the framework proposes to automate repetitive tasks, monitoring business and developer. There are several mathematical models and methods that can be used to represent developer experience, such as: "flow theory" [27], "workload models" [28] and "models of subjective experience" [29].

As depicted in Fig. 3, this iterative approach within the Continuous Improvement Cycle establishes and nurtures a culture rooted in the principle of perpetual enhancement. It guarantees that the developer experience flourishes and advances positively, solidifying its pivotal role in the overall success of software projects.

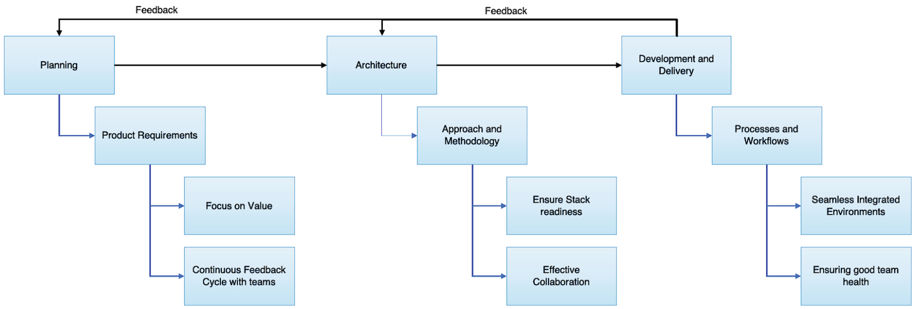

Fig. 3. Continuous Improvement cycle for developer experience.

6 Impact of Enabling the Developer Experience Framework on Decision Makers

Enabling the framework holds profound implications for decision makers, revolutionizing their strategic approaches through tangible outcomes like informed decisions, enhanced collaboration and accountability, optimized resource allocation, customized toolset, improved transparency/trust, enhanced governance, improved socio-economic impact, continuous improvement and engaged talent [30]. In telecom companies, stakeholder engagement enhances online child protection, driving innovation in products, services, and corporate policies with notable social impact [31]. The same can be mapped to other industry verticals and assessment of whether the business adoption experiences are enhanced. Lastly, trust is pivotal in the relationship between management and systems developers, profoundly affecting project success and collaboration [32]. Improving developer experience can lead to a better ecosystem where software developer can be more productive and less affected by change management.

From the standpoint of the customers, enhanced experiences for developers can yield software systems of superior quality, as developers who have a positive experience are more inclined to produce products that effectively fulfill user and business requirements in a technologically sophisticated manner [33]. Moreover, emphasis on developer experience, in context of integration of AI extensions in product development, can contribute to the overall user experience of the software system, thereby resulting in heightened customer satisfaction and an improved quality of experience [34].

7 Conclusion

There are several emerging trends in developer experience that are likely to shape the way developers work in the future. As the complexity of these technologies' increases, the developer experience will need to be adapted to ensure that developers have the skills and resources they need to be effective. This requires developers to have different skills and knowledge than traditional application development, and tools to support cloud-native development are becoming more prevalent.

The problem has highlighted the need for better tools and processes for remote collaboration, which can help to improve the developer experience. It's important to note that these trends are likely to evolve and change over time, and that the developer experience is a multifaceted concept, influenced by a variety of factors such as technology, culture, processes and people. Therefore, organizations need to be aware of these trends and adapt their approach to developer experience accordingly.

Organizations face challenges in maintaining developer experience like keeping up with the pace of change in technology, frameworks and languages and developers need to adopt and effectively integrate learnings into the product scope as either improvements or new capabilities. It's important to note that while the challenge of optimally solving the "improving developer experience" issue is complex, it's not insurmountable. Enhancing developer experience nurtures innovation, bolsters collaboration, and ensures superior software quality. This environment optimizes resource allocation, benefiting developers, the organization, end-users, and stakeholders alike.

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Enhancing Customer Support Services in Banking Using Generative AI

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Abstract. Amid the evolving financial landscape, enhancing customer experience remains paramount for banks. One key area underpinning this experience is Customer Support Services (CSS). While the banking sector has historically employed various technological aids like Interactive Voice Response (IVR) Systems and chatbots, their rule-based nature often renders them less versatile. This research explores the potential of Generative AI in transforming Customer Support Services in banking. Unlike traditional systems, Generative AI's ability to create unique content offers a more personalized and context-aware interaction. We have compared conventional methods with advanced Generative AI capabilities through a scenario-based approach. The findings provide insights into how Generative AI can revolutionize Customer Support Services across digital platforms, promising an enriched customer experience.

Keywords: Generative AI · Customer Support Services · Banking

1 Introduction

In the fast-changing financial landscape, banks prioritize innovative Customer Support Services (CSS) as essential for business success [11, 24, 33]. They have evolved from voice systems to CRM to chatbots to meet diverse customer needs and enhance loyalty [18, 23]. Nevertheless, limited by rule-based frameworks, conventional chatbots struggle with complex queries and linguistic nuances and often require explicit user inputs [4, 12, 13, 15]. These limitations can be easily overcome by Generative AI, which offers a more dynamic, personalized, and context-aware solution [42].

Generative AI holds unique potential in the highly regulated banking sector, streamlining compliance and offering personalized financial advice while enhancing security and fraud detection [3, 17, 42]. It addresses diverse tech literacy levels, setting it apart in the competitive financial landscape. As Generative AI continues advancing, this study assesses its potential impact on the CSS within the banking sector. A distinguishing attribute of Generative AI lies in its ability to produce unique content from diverse structured data. This includes capabilities like text-to-image, image-to-text, text-to-video, text-to-audio, and text-to-text [20]. These capabilities go beyond the traditional technology-based CSS (e.g., chatbots) often used in the banking sector and

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have the potential to upgrade customer service systems to a large extent. Accordingly, the research question (RQ) we aim to address is:

RQ: *How can Generative AI impact CSS in the banking sector?*

While many studies have recognized the promise of Generative AI for improving CSS [10, 12, 19, 20, 31], there has been a notable gap in the literature concerning its specific capabilities for enhancement in the banking sector. This paper addresses this gap by detailing how Generative AI enhances CSS, contributing to the literature on technology adoption and customer satisfaction. In this study, CSS refers to multi-channel digital customer support, including phone, email, and online platforms, equipped with advanced tools and specialized expertise, consistent with Saberi's view [32].

The subsequent section of this study explores CSS in banking by focusing on Generative AI's potential to enhance it. It takes a scenario-based approach to discuss the implications of various models of Generative AI. The study further outlines associated risks, implications, limitations, and future research directions.

2 Literature Review on CSS

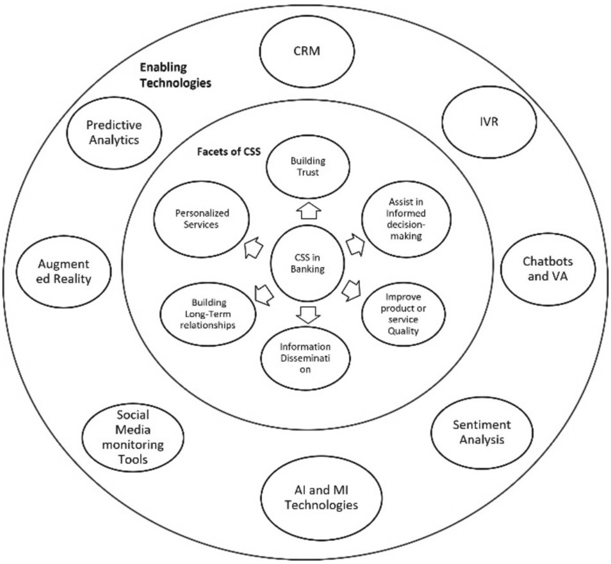

Fig. 1. Benefits of CSS in Banking

Customer-centric Support Services have become essential for business success [33, 34], offering personalized interactions [41] and proactive solutions that impact customer satisfaction, retention, and cross-selling [5, 37]. The rise of technology, particularly AI-powered chatbots, has been crucial in enhancing CSS and offering consistent availability and quick complaint resolution that boosts customer satisfaction and organizational value [2, 27].

In banking, CSS is vital for building trust [5, 8, 9, 30], ensuring compliance, and maintaining competitiveness. It aids in customer education [6], fosters long-term loyalty, and provides valuable feedback for innovation [1], while poor support risks revenue and reputation. Figure 1 illustrates the benefits of CSS in the banking sector. For instance, efficient customer support in banking aids in fraud detection [35] and serves as a unique selling point in a competitive market. It facilitates customers' digital transition, enables personalized financial solutions [2], and nurtures long-term relationships through positive engagements.

Advancements in technology have revolutionized banking CSS through AI-powered chatbots, IVR, and CRM systems that offer 24/7 support [23], personalized service

[14], and customer data management [39]. These technologies also employ predictive analytics to anticipate customer needs and automate routine tasks [22, 28]. Banks also leverage social media monitoring and AI-powered sentiment analysis for real-time customer feedback and incorporate biometric authentication for enhanced security [40]. Emerging technologies like Augmented Reality offer virtual guidance to deliver efficient, personalized support to boost customer satisfaction and loyalty [7].

3 Generative AI in CSS of Banking

Generative AI is a part of artificial intelligence models specifically tailored to produce original content. This content might manifest as text, images, music, videos, or other formats. Usually, the content produced is unique, stemming from patterns the model discerned from pre-existing data [12]. Generative AI can be utilized to craft or modify realistic images, transfer the artistic style from one picture to another, generate supplementary training data when real data is limited, compose contextually appropriate text narratives, songs, or poems, design new musical compositions based on identified patterns, formulate molecular configurations for potential medications, design new game levels or surroundings, and produce authentic-sounding voice recordings [20].

Generative AI has the potential to influence the banking sector profoundly. By employing Generative AI tools, banks could boost customer satisfaction, make more informed decisions, and reduce vulnerabilities through enhanced fraud and risk surveillance [42]. These tools can also tailor responses to individual needs and accurately address customer queries [25]. Recent advanced generative models like ChatGPT, DALLE-2, and Codex serve diverse roles from Q&A to media transformations, offering significant potential to enhance CSS and boost customer satisfaction [10, 20, 29].

Figure 2 shows the framework to enhance the facets of CSS in Banking using the Generative AI models. We have illustrated their advantages using diverse banking customer service situations.

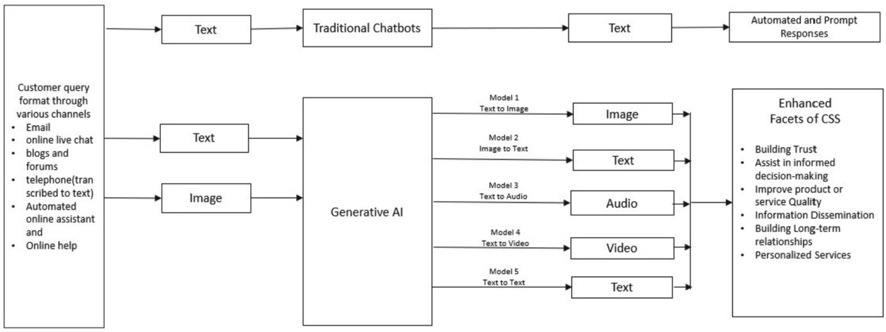

Fig. 2. Framework to Enhance Facets of CSS in Banking

As shown in Table 1, we hypothesized a scenario for every Generative AI model where the customer approaches contact center-based CSS. We then contrasted the actions of traditional chatbots with the anticipated steps of Generative AI. The discussion showcases Generative AI's remarkable potential to amplify the efficacy of CSS.

Table 1. Benefits of Utilizing Generative AI Models Across Various Scenarios

Model	Scenario	Benefits
Text to Image	A customer writes to the bank's online support because they are confused about where to find the "International Money Transfer" option in their newly updated mobile banking app	The Text-to-Image capabilities can transform complex financial details into a visual format. The customer can easily understand and digest the information. It addresses customer concerns more accurately by allowing them to "see" the breakdown rather than just hearing or reading about it
Image to Text	A customer faces difficulty navigating the bank's new ATM interface. S/he takes a photo of the ATM screen, which appears confusing, and sends it to the bank's online support for assistance	The Image-to-Text capability effectively bridges the gap between visual interfaces and user understanding by allowing customer support to address concerns more effectively, thereby ensuring the customer's confidence and satisfaction with the platform
Text to Audio	A visually impaired customer needs assistance understanding a banking service's new terms and conditions. They prefer audio instructions and reach out to the bank's customer support	By leveraging Text-to-Audio capabilities, Generative AI transcends the limitations of traditional chatbots by providing an audio response tailored to the customer's specific needs. This not only enhances accessibility but also adds a human touch to the interaction, making the transaction more personal
Text to Video	A customer needs help with the online banking interface, explicitly setting up a recurring transfer to another account. They reach out to the bank's customer support for guidance	By leveraging the Text-to-Video feature, Generative AI offers a dynamic, visual solution that addresses the customer's concern intuitively and engagingly. The visual and auditory components can clarify points of confusion far more effectively than text alone
Text to Text	A customer contacts the bank's customer support, concerned about unfamiliar charges on their recent bank statement	Text-to-Text feature of Generative AI provides a context-rich, detailed, and tailored response, enhancing the support experience. Presenting potentially relevant transactions and offering actionable steps can accelerate problem resolution and instil user confidence

4 Risks and Challenges

Even though Generative AI offers promising enhancements to banking CSS, it is essential to consider the risks associated with it [16, 38]. Human oversight remains crucial to ensure accuracy, appropriateness, and ethical considerations in AI-generated responses [19]. Additionally, maintaining transparency with customers about AI-driven interactions and ensuring data privacy is paramount for successful and trustworthy AI integration in customer support. The implementation of Generative AI also includes certain risks. Inaccuracies or biases in the training data can lead to misleading or biased outputs [12]. Thus, initial investments required for training and implementing Generative AI models can be significant [26]. Besides, merging Generative AI with existing customer support systems could pose integration and compatibility issues [36]. Further, the financial sector is heavily regulated, and AI interventions might require rigorous validation, compliance checks, and audits [21]. In summary, Generative AI's implementation requires careful consideration of risks, including biases and data privacy.

5 Discussion

5.1 Implications

While we acknowledge the potential of Generative AI in CSS, little is known about what specific capabilities this advanced technology possesses and how it can change the customer service landscape in the banking sector. This study is one of the first to address this research gap and describes how Generative AI can enhance CSS, extending the literature on technology adoption and customer satisfaction.

This study uses a scenario-based approach to illustrate how Generative AI can elevate customer engagement. Specifically, it shows how Generative AI can offer hyper-personalized, context-aware services, boosting customer engagement and satisfaction. It indicates that the technology can serve customers with varying tech literacy, aiding banks in expanding engagement strategies. Banking practitioners can gain key insights from this study for strategic investments in Generative AI for CSS. The study also notes real-time fraud detection capabilities, enhancing security and customer trust. Lastly, it offers guidance on using Generative AI to serve customers with special needs, increasing both satisfaction and market reach through inclusivity. Taken together, we argue that this research acts as a foundational step for future studies focused on integrating Generative AI into banking CSS.

5.2 Limitations and Future Research Directions

In this research, we have delved into specific aspects of CSS in banking that could be improved by established Generative AI models. While we have covered multiple dimensions, many other potential areas within CSS could benefit from Generative AI, indicating a rich field for future inquiry. Firstly, our study primarily relies on scenario-based insights, underscoring the need for empirical validation to deepen our understanding. Future studies could explore this area through various methodologies, such as A/B testing, use case evaluations, or customer surveys, particularly those involving users who have transitioned from conventional chatbots to Generative AI [29]. This would offer rich insights into Generative AI's capacity to transform customer service experiences. Secondly, our focus has been limited to five validated Generative AI models that analyze text or image data. However, there may be additional models suitable for enhancing CSS that warrant exploration in subsequent studies. These could include AI models capable of adapting to and learning from individual customer interactions, offering a truly personalized banking experience. Lastly, the vast potential of Generative AI extends beyond the scope of our current study, touching on other facets of CSS like sales optimization and product quality enhancement. Future research could venture into these unexplored territories to further elucidate the expansive capabilities of Generative AI in customer support.

6 Conclusion

To the best of our understanding, this is the inaugural study probing the transformative impact Generative AI can have on CSS within the banking sector. While numerous studies posit that Generative AI holds significant potential in refining CSS [12, 19, 20, 31], past research has seldom contextualized its application as we have. This research highlights the significance of CSS in banking. In addition, it explores how Generative AI can enhance customer support interactions and increase satisfaction. In summary, this study delves into an exciting discussion of Generative AI, which will extend the IS literature and inspire further research.

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Effect of Parents, Elder Sibling, and School on Adolescent's Online Activity and Internet Anxiety

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Abstract. The increasing adoption of online content in education requires adolescents to be frequent internet users. The use of the internet among school-going children has led to problematic internet use (PIU) and internet addiction. Most parents are warned about these adverse effects and are usually advised to monitor the activities of their child. Previous studies have shown the positive effect of parental monitoring in controlling addiction. However, studies show that high levels of parental control cause anxiety among the students. Thus, schools need to be careful when adopting online learning elements. Our exploratory study shows that although monitoring was associated with decreased time spent online, it was also linked to higher internet anxiety. This effect was further found to be dependent on schools. Therefore, parents and schools need to work on promoting healthy internet use among adolescents. These findings emphasize the importance of striking a balance between monitoring and allowing autonomy for adolescents in their internet use.

Keywords: Internet Adoption · Adolescent · Parental Monitoring

1 Introduction

Problematic internet use (PIU) has increased with the increase in use of internet enabled devices, attracting more research on how to mitigate it. School educators are increasingly relying on digital communication tools such as email, Whatsapp, etc. to share learning materials [1]. This has led to increased Internet usage among school going children. Adolescents between the ages of 12 and 17 are the most frequent internet users among all age groups due to the importance of online content for academic achievements [2]. Furthermore, adoption of flip classroom-based learning, schools require students to initiate learning at home which often requires Internet [3]. Although Internet is becoming a necessary part of high-school education, there is also the danger of adolescent becoming addicted to Internet. Researchers have investigated the issue of problematic internet use (PIU) and Internet addiction among adolescents [4]. The default response by parents to prevent addiction has been to monitor the activities of their children. Studies have shown

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positive effect of parental monitoring on academic performance, and reduce PIU [5, 6]. At the same time studies show that parental monitoring can cause stress and anxiety among adolescents [7, 8]. Thus, the act of monitoring intended to protect youth from addiction could have unintended consequences. We intend to investigate the association of time spend online and internet anxiety with Parental monitoring. As adolescents going to school are often required to use internet to learn and interact with peers, we explore the variation in this association due to the school the student may attend.

2 Background

Over the past two decade there has been significant adoption of online technologies in education, resulting in many schoolchildren needing and gaining access to web-enabled devices. Several researchers have investigated the effects of inter-net access on the academic performance of school children. Studies by Leech et al. [9], Jackson et al. [10], and Sang et al. [11], have found a significant positive correlation between internet usage and academic performance among secondary school students. But, the improvement in performance depends on school and socio-demographic characteristics viz. age, gender, and family income [9, 10]. Furthermore, active parental involvement, such as recommending websites and using the internet with their children, lead to more effective use of internet [12], thereby contributing to the academic success of students.

However, this increased access has also led to an increase in problematic internet-related activities among schoolchildren, which has been linked to greater psychological distress and addiction disorders (such as online gaming addiction) [13]. Youth are exposed to a vast array of online content, which can have both positive and negative effects. As such, it has become increasingly important for parents to monitor the use of internet to ensure safety and well-being of their children [14, 15]. Sometimes parents underestimate the level of addiction among adolescents because of lack of communication [16]. In the similar vein, there have been calls for taking internet addiction more seriously [17]. Countering addiction among youth has always been a challenge within society. One of the ways to mitigate addiction is to monitor the activities of their child, it is often recommended that parents monitor their adolescent's internet-related activities [18]. Gentile et al. [5] found a significant effect of parental monitoring on children's time spent online, resulting in improvement in academic, social and physical outcomes.

Parental monitoring consists actions taken by parents to track the internet use activities of their children. Such actions limit the adolescent from developing their own self-control skills. Love et al. [19] argues that as per self-determination theory [20] such actions by parents have a detrimental effect on goal orientation and motivation of their ward. Love et al. [19] show that extreme parental monitoring contribute to burnout in college students thus has negative implications for higher education practices. Van Der Bruggen et al. [8] based on their review argue that increased parental control leads to child anxiety. Multiple studies have shown that helicopter parenting, i.e., closely monitoring children, can hinder the development of self-control skills. For instance, a study by Darlow et al. [21] found that helicopter parenting was linked to school burnout, which negatively affected students' grade point averages (GPAs). Another study by Padilla-Walker and Nelson [22] found that helicopter parenting was associated with lower levels of school engagement among college students. Thus, monitoring, could potentially lead to adverse effects. Sela et al. [4] argued that family's socio-economic background influences not only parental control but also its impact on children's anxiety.

Most of these studies have been conducted in developed world context where parenting, which is dependent on culture, is different from a developing world context. Further, educational institutions in developing countries are rapidly introducing technology into their teaching and learning practices. These contextual differences necessitate an exploratory study on the relation between parental monitoring, time spent on device, and anxiety.

3 Method and Findings

3.1 Survey Instruments

We used a Joiner et al.'s [23] scale to measure internet anxiety among adolescent students. The survey also asked participants to indicate the time they spent online in terms of hours per week. Students were asked to report if their online behaviour was monitored by their parents. Respondents also indicated if they had an elder sibling and if their elder sibling assisted them in their online tasks.

3.2 Data Collection

Responses were collected from students in grades 9th and 11th from three schools. Prior permissions were taken from the school administration. A brief on the purpose of the study was shared with the school principal. After data collection a summary report of the survey responses was sent to the principal.

All three schools were private schools from a prominent city from western India. In terms of annual fees the schools ranked as School2 > School1 > School3. All schools had adopted elements of online learning requiring internet use.

3.3 Analysis

We used MPlus 8.5 [24] for analysis of the survey data. First, we conducted confirmatory analysis of the internet anxiety scale. We also checked for measurement invariance of the scale across the three schools. Finally, we performed regression analysis to determine the effect of monitoring pupils' internet use on internet anxiety and on their time spent online.

A total of 387 students from three schools responded to the survey study. More than 50% of the students indicated that they had a high-speed internet connectivity at home (75.96% in School 1, 57.8% in School 2 and 57.3% in School 3). Further overall 98.4% mentioned having atleast one phone with internet and 96.63% atleast one computer at home. A summary of the background of the participants is tabulated in Table 1 below.

Table 1. Participant response to background, parental monitoring and sibling interactions

		School 1	School 2	School 3
No. of. Obs		105	64	218
Age	Mean	15.16	14.48	16.28
	Range	13–17	13–17	14–17
	Missing	–	2	6
Gender	Male	52	37	108
	Females	52	27	104
	Missing	–	–	6
Parental Monitoring	No	45	34	112
	Yes	24	12	36
	Maybe	35	18	64
	Missing	–	–	6
Siblings	No	35	14	113
	Yes	16	33	49
	Yes & Assists	27	16	48
	Missing	26	1	8

3.4 Confirmatory Analysis of Internet Anxiety

Student's responses to the Internet Anxiety Scale were recorded on a 5-point Likert scale, where 1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree and 5 = Strongly Agree. From the responses we noted that most responses to the scale were in the first three levels of the Likert Scale. Hence, we treated the response as categorical in all our analysis. The analysis of the responses indicated that one of the items, "IA3: My anxiety about using the Internet bothers me" had to be dropped to improve model fit. We used the Mplus codes provided by Groskurth et al. [25] to obtain Cronbach Alpha (α), Composite reliability (ω) and Average Variance Explained (AVE) for the latent construct. The findings indicate that measure of Internet Anxiety of students within each school were reliable and valid. Table 2 below presents the student responses to the Internet Anxiety Scale.

3.5 Measurement Model and Measurement Invariance

We run the three-item model within each of the three school and find that the model structure fits well. As students are clustered within school, we proceed to test for equivalence of the scale across the different schools. As the factor structure of the construct is same across all the schools, we first develop an unrestricted multigroup model. By fixing the factor variance to 1 the factor loadings were estimated for each school. This unrestricted model was a good fit ($\chi2 = 14.885$, df = 16, $\chi2/df = 0.93$, RMSEA = .00 90% CI [.00 .08] PCLOSE = .791, CFI = 1.0, TLI = 1.0, SRMR = .018). Next, we ran a restricted

Table 2. Responses to Internet Anxiety Scale

	1	2	3	4	5	Missing
School 1 [N = 104, α = .765, ω = .735, & AVE: .503]						
IA1: I feel anxious all the time when using the Internet	27	30	19	14	12	2
IA2: I tend to find excuses to avoid using the Internet	44	31	21	3	3	2
IA3: My anxiety about using the Internet bothers me.*	31	28	28	7	8	2
IA4: I am more anxious about using the Internet than I should be	33	23	26	14	6	2
School 2 [N = 64, α = .742, ω = .715, & AVE: .514]						
IA1: I feel anxious all the time when using the Internet	18	19	17	7	3	0
IA2: I tend to find excuses to avoid using the Internet	22	18	13	9	2	0
IA3: My anxiety about using the Internet bothers me.*	18	16	16	11	3	0
IA4: I am more anxious about using the Internet than I should be	18	13	23	6	4	0
School 3 [N = 218, α = .826, ω = .873, & AVE: .697]						
IA1: I feel anxious all the time when using the Internet	57	62	49	20	11	19
IA2: I tend to find excuses to avoid using the Internet	80	62	38	14	5	19
IA3: My anxiety about using the Internet bothers me.*	75	49	55	13	7	19
IA4: I am more anxious about using the Internet than I should be	64	52	57	17	9	19

Note: * item was dropped during model fit and hence not included in computation of Cronbach Alpha (α), Composite reliability (ω) and Average Variance Explained (AVE).

model and also found it to be good fit ($\chi 2 = 27.258$, df = 22, $\chi 2/df = 1.24$, RMSEA = .04 90% CI [.00 .09], CFI = .996, TLI = .998, SRMR = .028). The comparison of the two models indicated that the constraint model is not significantly better than the unconstrained model (DIFFTEST (9) = 9.49, p = .15) and the measurement is invariant across schools. Thus, we can implement the constrained model of Internet Anxiety for our analysis (Table 3).

Table 3. Standardized loadings of the Internet Anxiety Scale

	School 1	School 2	School 3	Combined
	λ [Std. Est. (SE)]	λ [Std. Est. (SE)]	λ [Std. Est. (SE)]	λ [Std. Est. (SE)]
IA1	.771 (.07)	.662 (.11)	.876 (.02)	.810 (.03)
IA2	.517 (.07)	.608 (.10)	.787 (.03)	.678 (.03)
IA4	.902 (.06)	.838 (.11)	.834 (.03)	.853 (.03)

3.6 Analysis of the Effect of Parents and Siblings on Internet Anxiety and Time Spent Online

To detect the influence of parental monitoring and sibling effects on student's internet anxiety and time spent online we set up the structural model as indicated in Fig. 1. The regression equations of the full model can be interpreted as the following two equations being estimated simultaneously along with the correlation between internet anxiety and time spent online. Findings of the analysis are tabulated in Table 4

$$Anxiety_i = Age_i + Gender_i + Parental\_Monitoring_i + Sibling\_Effect_i + \varepsilon_i \quad (1)$$

$$Time\_Online_i = Age_i + Gender_i + Parental\_Monitoring_i + Sibling\_Effect_i + \varepsilon_i \quad (2)$$

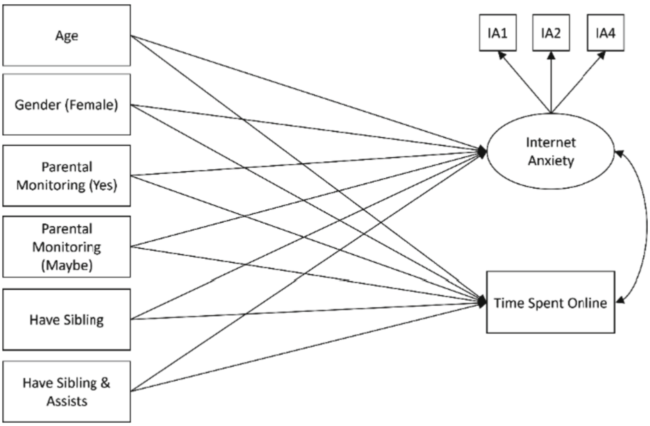

Fig. 1. Structural Model of the Analysis

We first estimated the effects of Parental Monitoring (Model 1), then the effects of Siblings (Model 2) and finally the full model with effects of both parental monitoring and siblings (Model 3). As the time spent online was recorded as a categorical response, we used the WLSMV estimator for our analysis. We found that having a sibling (B =

Table 4. Effect of Parental Monitoring on Internet Anxiety (IA) and Time Spent Online (TSO)

	Model 1 (Monitoring)		**Model 2 (Siblings)**		**Model 3 (Full Model)**	
	IA	**TSO**	**IA**	**TSO**	**IA**	**TSO**
	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)
Age	.010 (.05)	.081 (.06)	-.005 (.05)	.127* (.06)	.011 (.05)	.106Ɨ (.06)
Gender (Female)	-.150 (.10)	.029 (.11)	-.284** (.10)	.080 (.12)	-.242* (.10)	.037 (.12)
Parental Monitoring						
Yes	.433** (.13)	-.677*** (.15)			.387** (.14)	-.615*** (.16)
Maybe	.344** (.11)	-.151 (.13)			.272* (.12)	-.110 (.14)
Sibling						
Have Sibling			-.029 (.12)	.316* (.14)	-.008 (.12)	.301* (.14)
Have Sibling & They Help			.439*** (.13)	.025 (.15)	.416** (.13)	.036 (.14)
Anxiety <=> Time Online	.012 (.05)		-.018 (.05)		.018 (.05)	
R^2	.065	.070	.078	.030	.113	.077
N	376		348		348	
Model Fit Indices						
df	10		10		14	
χ^2	33.565		38.696		40.530	
RMSEA	.079 90% CI [.051 .109]		.091 90% CI [.062 .122]		.074 90% CI [.048 .101]	
CFI	.977		.969		.971	
TLI	.949		.932		.937	
SRMR	.035		.038		.037	

Note: * p < .05, ** p < .01, *** p < .001

Table 5. Differential Effect of School

	Model 4 (School 1)		**Model 5 (School 2)**		**Model 6 (School 3)**	
	Internet Anxiety	**Time Online**	**Internet Anxiety**	**Time Online**	**Internet Anxiety**	**Time Online**
	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)
Age	-.035 (.10)	.231 (.15)	.263* (.11)	.049 (.17)	-.015 (.06)	-.102 (.08)
Gender (Female)	-.310 (.22)	-.328 (.30)	-.004 (.22)	-.441 (.36)	-.201 (.12)	.356* (.16)
Parental Monitoring						
Yes	.212 (.28)	-.350 (.38)	.027 (.28)	-1.30** (.47)	.390* (.16)	-.517* (.21)
Maybe	-.005 (.24)	-.177 (.31)	.056 (.24)	-.657‡ (.37)	.428** (.15)	.178 (.18)
Sibling						
Have Sibling	-.384 (.29)	.419 (.36)	.417 (.27)	.173 (.43)	-.107 (.15)	.325‡ (.19)
Have Sibling & They Help	.351 (.22)	.136 (.30)	.688* (.35)	.037 (.48)	.264‡ (.16)	-.089 (.20)
Anxiety <=> Time Online	.063 (.08)		-.067 (.08)		.017 (.06)	
R^2	.148	.146	.318	.227	.138	.102
N	78		61		209	
Model Fit Indices						
df	62					
χ^2	77.309					
RMSEA	.046 90% CI [.000 .076]					
CFI	. 984					
TLI	. 977					
SRMR	. 051					

Note: * p < .05, ** p < .01, *** p < .001

.301 (.14), $p < .05$) result in more time spent online. While explicit parental monitoring (B = −.615 (.16), $p < .001$) results in less time spent online. Students also reported significantly higher Internet Anxiety (B = .387 (.14), $p < .01$) when parental monitoring was explicit. Also, when monitoring was not explicit student reported higher internet anxiety (B = .272 (.12), $p < .05$). We also find that students who reported siblings to have assisted them in their school work expressed significantly higher Internet anxiety (B = .416 (.13), $p < .01$). We also find that female students had a significantly lower Internet Anxiety (B = −.242 (.10), $p < .01$) than their male counterparts.

3.7 Differential Effects of School

To measure the differential impact of school environment we adopted multigroup analysis to evaluate the structural model within the three schools. As the measure of internet anxiety is invariant, we used the constrained model for our analysis. The multigroup analysis was performed by declaring schools as grouping variable. The model fit of the multi group analysis indicated a good fit. Results are tabulated in Table 5.

Students of school 1 reported no effect of parental monitoring and siblings on internet anxiety or time spent online. In school 2 we found that parental monitoring was not associated to internet anxiety but explicit monitoring was linked to reduced time spent online (B = −1.300 (.47), $p < .01$). Age (B = .263 (.11), $p < .05$) and siblings who assisted in school work (B = .688 (.35), $p < .05$) were found to be a significantly associated to internet anxiety. Now for School 3 both explicit monitoring (B = .390 (.16), $p < .05$) and implicit monitoring (B = .428 (.15), $p < .01$) had a significant effect on internet anxiety. While explicit parental monitoring (B = −.517 (.21), $p < .001$) results in less time spent online. We also find that female students from school 3 spent significantly more time online (B = .356 (.16), $p < .01$) than their male counterparts in school 3.

4 Discussion

Our study found instances where explicit parental monitoring was linked to higher internet anxiety levels, and even in cases where the respondents only perceived the possibility that they were being monitored it led to some level of internet anxiety. These findings contribute to recent research that investigated to what extent parental mediation practices affect children's online learning [18]. We can see the importance of parental monitoring in managing time spend online by adolescents but in some cases, it is also associated to internet anxiety. This emphasizes the importance of parents understanding how to manage their children's media use by engaging in conversations and monitoring their online activities [14, 15]. Additionally, students who received assistance from siblings for school work reported higher internet anxiety, which could be an effect of inadvertent monitoring by elder sibling when assisting. Further, female students reported lower internet anxiety possibly because male students may be subjected to more monitoring compared to female. Interestingly, when analyzing the variation due to schools, it was found that internet anxiety was affected in Schools 2 and Schools 3. In School 3 it was associated to parental monitoring. This could be for two possible reasons 1. School

3 catered to families of lower socioeconomic background compared to the other two schools and 2. School 3 incorporation of online learning component may have inadvertently caused students to contest for more device time against monitoring efforts by parents. In School 2 student's reported internet anxiety was associated to age and instances of receiving elder sibling's assistance. The differential effects of school environment indicates that schools may also have a crucial role in ensuring student's avoid problematic internet use without developing internet anxiety.

The results also revealed that explicit parental monitoring was associated with decreased time spent online. This effect was also observed for schools 2 & 3 but not for school 1. The reasons for this variation due to schools would need further investigations. Additional we note the effects of sibling presence and their assistance on time spent online which would also need further study. In summary, our analysis shows that parental monitoring does affect student's time spent online and internet anxiety. Also, we find that other factors like school, age, gender, and also siblings have a significant effect on the relationship of parental monitoring on time spent online, and internet anxiety.

5 Conclusion and Future Research

These findings highlight the need for further contextual studies to understand the factors that enable healthy internet use habits among adolescents. Given the differential effects of school environment, schools can consider incorporating digital literacy programs and providing resources for parents to develop understanding of healthy internet use and parental monitoring. Parents should be made aware of the impact of excessive internet use on their children's well-being and consider appropriate levels of parental monitoring to promote healthy internet use habits.

Also, there is a need for regulatory solutions to address the issue of addictive online systems and promote responsible internet use among adolescents. Further, the role of siblings in shaping adolescents' internet use behaviors should be further explored to better understand how it impacts their well-being. A larger study is needed to look at the differential effects due to the school and understand how a school's pedagogical practices may be conducive to parental monitoring of internet activities without leading to internet anxiety.

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Dwelling on Wickedness in Societal Systems: A Case of ICTD Intervention in Indian Agriculture Markets

Full Research Paper

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Abstract. This paper critiques the tendency of totalising societal problems into the binary of tame or wicked and, in such ways, generalising towards 'one solution fits all' since there are no other qualifiers. Taking the premise that every societal problem is unique and highly contextual, we use the lens of the wicked problem concept to explore the case of state-mandated ICTD intervention relating to agriculture market reforms. By operationalising a two-level typology and contingency framework, we place the case in a continuum between the tame and wicked territories. This enables us to typify the issue as wicked and establish the attributes and degree of wickedness in the problem. Our findings show that traits of wickedness in the issue have severely impacted the diffusion and adoption of ICTD itself at the local level and that the state's push for ICTD-based transformation has led to a multi-dimensional intensification of wickedness traits, including additional complexities, heightened distrust, hardening of divergence and value positions, and increased uncertainty. The outcomes are adverse due to a templated single strategy ICTD intervention, which neither carries a complete understanding of the issues nor is receptive to the local knowledge.

Keywords: Societal Problems · Wicked Problems · ICTD · Agriculture Markets · E-Markets · Diffusion · Adoption · Framework

1 Introduction

Poverty, healthcare, food security, use of land for development and many other societal issues are complex, confounding, and difficult to get a handle around, and hence are tagged as wicked [5, 19]. Borrowing from Rittel and Weber [19], wicked problems are those that are unclear and solutions ill-defined; knowledge is scattered with divergence in values; interests conflict and abound with power asymmetries. While Rittel and Webber [19] set forth ten characteristics to qualify a problem as wicked, many studies totalise wickedness into the binary of tame or wicked [11, 21], leaving policy-makers nowhere nearer to even attempting a solution and thus limiting the utility of wicked problem concept [1]. The totalising approach implicitly posits a binary choice between either

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transformative success in case the problem is tame or ongoing defect in case it is wicked [1, 7]. This approach shuts out ways of looking at the issue to lie in between two extremes, and it discourages systematic thinking about the degree of wickedness and its constituent elements in a problem [1].

On the other hand, the quest for a panacea or silver bullet to solve vexing issues of society has led to a discourse where development is seen as morality and ICT (Information Communication Technologies) as the moral force [23] useful to address such issues which can be broadly tagged as ‘complex societal problems’, in between the tame and wicked territory [19]. However, contrarian views question whether the benefits have accrued to all the rightful beneficiaries in such ICT-enabled development (ICTD) programmes [27]. For example, prior studies on large-scale state (government) led ICTD programmes like India’s Aadhaar digital identity system or the targeted food security program have narratives of being exclusionary, perpetuating associated injustice, creating new forms of corruption, impacting vulnerable subjects, and resulting in deviant development outcomes for the beneficiaries [9, 15].

In this paper, we answer the question, ‘How does ICTD intervention enable or constrain the problem and solutions in a societal system that portrays traits of wickedness?’ Here, enabling is defined as augmenting or supporting solutions for complex social problems and constraining as worsening existing social problems or creating new problems [14]. The approach is to understand whether there is moderation, maintenance or aggravation of wickedness in the problem in the face of an ICTD intervention. Towards this, we will consider a large complex societal system, operationalise a two-level typology and contingency framework of Alford and Head [1] to situate the problem on the tame-wicked terrain and follow up with a more granular examination to establish the key features and causal factors which make it wicked. The case considered is a state-mandated ICTD programme that transforms traditional agriculture markets into an E-Market system in Karnataka, India, called the ReMS E-Market platform.

This study potentially informs the policy-makers and technology designers on how to deepen and qualify the understanding of a societal issue and foster a reformation process by caution with follow-throughs to ensure the movement of any wickedness in a problem towards moderation and create possibilities to reach a better situation.

The paper flows thus, after a literature review, we introduce the framework by Alford and Head [1], followed by a section about research design, and then the case of agriculture E-Market is introduced. The following section presents a truncated set of findings limited to the diffusion and adoption of ICTD intervention in agriculture markets while pushing a more extensive set of findings to the next section, where it becomes integral to operationalise the framework. Further, to achieve substance and context in a better way, certain parts of the analysis and discussion are melded into the operationalising section. The outcomes from the operationalised framework are analysed to enable a nuanced understanding of wickedness. After that, we examine the ICTD intervention’s role in its influence on wickedness and understand how wickedness responds to the intervention’s design.

2 Related Research

Complex societal issues with traits of wickedness present difficulties for planners and policy-makers as the underlying social and economic forces are deep-seated, interdependent, emergent, and constantly shifting [5]. Wicked problems go beyond technical and involve some societal aspects or interaction with people whereby context is fundamentally essential, and hence technical solutions are insufficient [5, 19].

Many studies totalise wickedness [11, 21], leaving a policy-maker far from even attempting a solution, and such discourse does not even allow for thinking about degrees of wickedness [1]. Instead, it ends up looking at binaries of tame or wicked [1, 7] and the concept gets applied indiscriminately. Totalising as wicked gives an impression of a 'one best way' approach for tackling the issue, and the same gets applied in a 'one size fits all' fashion to various situations [1, 7]. By all this, the wicked problem concept has become stretched and more of a fad in present-day policy analysis [7]. Amongst all this, Roberts [20] believes that the concept of 'wicked problems' has definite utility but requires a conceptually mature framework to move it from an esoteric concept to a practical construct leading to better formulation with identified traits and potential resolution paths of progress.

Pursuing this line, one approach is categorising the problem and linking it to intervention strategies [20, 22], which is critiqued for unrealistic expectations that it sets on leadership and stakeholders [1]. Another approach is to contract the characteristics set forth by Rittel & Webber [19] into groups on the lines of complexity, knowledge uncertainty and stakeholder divergence [8] or other basis relating to knowledge and resource sufficiency, linkage entanglement, and issue formulation [4]. However, the need is for a fine-grained framework to operationalise the wicked problem concept in an empirical setting [20].

As Alford & Head [1] observe, there is a paucity of empirical studies about societal problems portraying traits of wickedness, and the lack is attributed to the difficulty of operationalising the concept [20]. This is the context of our study, and through operationalising a two-level framework put forth by Alford and Head [1] in an empirical setting, we aim to understand the characteristics of a societal problem that makes it wicked and further examine the role of ICTD in enabling or constraining the problem and solutions as devised by the policy-makers of the state.

2.1 Typology and Contingency Framework by Alford and Head [1]

Alford & Head [1] propose a two-level typology and contingency framework. The first level framework, called typology framework, is helpful to arrive at the nature of the problem in a continuum between the tame and wicked territory and draw preliminary judgements on the extent of the problem's wickedness. The second level framework, called contingency framework, applies causal factors across specific dimensions to synthesise the preliminary judgements into a picture of 'degree' and 'type' of wickedness useful to policy-makers to develop appropriate resolution sets.

Typology Framework: First-Level Analysis. The first level typology framework provides a broad typology setting out alternative possibilities on a twin axis. The y-axis signifies the nature of the problem in terms of increasing complexity and the extent of tractability and informs us whether the problem side is driving the wickedness. The x-axis relates to increasing difficulty concerning stakeholders. It shows whether the people's perspective is driving wickedness, which is defined through three factors relating to knowledge fragmentation, conflict of interest and power factors. The convergence of two axes is the territory of the deeply wicked, as such problems stem from the dual effect of the nature of the problem and the people's perspective and their interplay (Fig. 1).

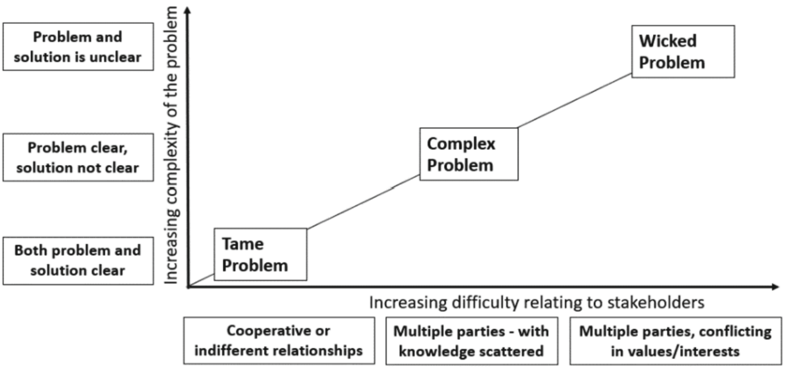

Fig. 1. Typology Framework to establish wickedness - Adapted from Alford and Head [1]

Contingency Framework: Second-Level Fine-Grain Analysis. The contingency framework involves taking the two dimensions of the problem and people and interrogating these attributes against specific causal categories for a more nuanced analysis useful for the practical needs of policy-makers.

While problem-solution is considered against the causal factors of inherent complexity, clarity of problem and solution in one angle, the people are considered against causal factors of knowledge, interests, and power separately. By bringing all these dimensions and categories of causal factors together, we establish six conditions whose occurrence makes a problem wicked [1]. The conditions are structural complexity, knowability factor about the problem, knowledge fragmentation, knowledge framing or whose knowledge gets precedence, interest differentiation (conflicts in stakeholder value system), and finally, the power factor within the stakeholders. Through this fine-grained analysis, wickedness and its characteristics can be gauged based on the presence of several (or most) of the above conditions in a problem [1].

3 Research Design

Our argument draws on fieldwork spread over two phases, between October 2019–February 2020 and December 2021–June 2022, done in Karnataka's eastern dry agricultural zone in Southern India. In agro-climatic terms, the area is dry and rain-fed with a broad spectrum of crop cultivation, including grains and high-value horticulture perishables like vegetables. Such diversity appealed to us as it created a strong dependency on the market system for the farmers.

Our field site was the agriculture markets in the zone. The studied markets were not pre-selected; instead, they turned out to be the major ones in the zone with large-scale trading, and notably, both the ReMS E-Market platform and the Karnataka Government list them as using the E-Market platform for all their operations. Given that it was an exploratory study to capture the context and uniqueness, we adopted the interpretive research approach along with qualitative methods of participant observation and semi-structured interviews to enable us to understand the case in itself and further explore the phenomenon from the participants' perspective within a particular cultural and contextual setting which is ongoing [28]. This approach allowed us to observe the emergent nature of relationships between the actors and their negotiations during daily activities. Added data sources included the study of press reports, websites, and various secondary sources.

We observed thirteen agriculture markets trading both perishable and produce with shelf life. We traced the produce from harvest to market multiple times. We interviewed seventy respondents comprising of farmers, commission agents (intermediary), buyers, market officials and other actors in market spaces and other adjoining informal settings. Many interviews were hour-long or more; some were conversations with multiple participants simultaneously, and some were short interactions of 10–15 min. In a few cases, we conducted follow-up interviews. Then, using the traditional approach, we translated and transcribed the notes as the interviews were in local languages. From these transcriptions, we coded to glean out the interesting themes and analysed them further. All the names were pseudonymised.

4 Case Description

After several reforms in the post-independence era, the Agricultural Produce Market Committee (APMC) operated physically trading regulated market yards (in short, the APMC market system) has dominated the Indian agriculture markets. They number about 7566 markets across India, with 162 major and 354 sub-markets in Karnataka [17]. A locally elected market committee called local APMC governs each market yard. The farmers and buyers interact through the APMC-registered Commission Agents, who function as the intermediation layer for a fixed commission fee approved by the law.

Karnataka, a pioneer province in adopting ICT for development, launched the first agriculture E-Market platform in India called ReMS (Rashtriya e Market Services Pvt Ltd) as a part of the government's development targets to double farm incomes by 2022 [6]. ReMS E-Market system is a much-awarded ICTD programme widely publicised as the 'Karnataka Model' of ICT-enabled Agri-market reforms [3]. Though ReMS is a separate joint venture company, it has to operate the E-Market platform in the physical markets in cooperation with the local APMC/local market operator. According to a NITI Aayog (Government think-tank) policy paper, Karnataka realised 38% more income to farmers in 2015–16 than in 2013–14, immediately following the implementation of the E-Market platform [6, 18]. The ReMS website claims a full-scale rollout across all the APMC markets in Karnataka with support for 60 commodities including perishables [18].

5 Findings

5.1 E-Market Platform – A Reality Check on Diffusion and Adoption

The state claims successful diffusion and adoption of the ReMS E-Market platform across all its major and sub-major market yards since 2014, exemplifying the system as time-tested and widely used [18]. Contradicting this claim of the state, our study showed that all the agricultural markets across our fieldwork dealing with various produce operated in the old and traditional way. The E-Market platform was generally not adopted. While interviewing a few APMC officials about using the ReMS E-Market platform, one of the officials said, *"We have discussed a lot on this issue in our meetings with ReMS authorities. We have told them that we cannot use the system. It may work for agriculture crops with fewer lots and only 2–3 varieties. None of us are convinced about its viability."* Along with poor adoption of the E-Market platform, we also observed that many of the complementary, yet essential infrastructures and processes needed for the E-market platform to function were not in place. We spotted the following as missing: guarded security gates with weigh-bridges to issue lot IDs, registered assayers, and assaying labs to assess and issue quality certificates for each lot, warehouses for farmers to unload the produce and exchange with the buyer after payment, the e-settlement process for the buyer to pay the farmer and e-permit for seamless movement of the goods across the geography.

5.2 Omnipresent Price Information – Pulse of the Market Compromised by False Compliance

In the markets we studied, the agriculture department disseminates price information. Further, it is forwarded around repeatedly through SMS and WhatsApp by all the stakeholders, including input companies, farmer groups, transporters, and commission agents. A farmer showed us his phone with price information from four different sources. However, how price information was compiled without the E-Market platform was a mystery. While the local market operator officials claimed that they compile daily reports based on the commission agents' data, the commission agents clarified that they do not provide the data daily; instead, it is filed once a fortnight. A prominent commission agent, Gopal, cleared the confusion, "*It is simple. One of the local market operator officials walks around a few auctions, randomly picks up the bid prices, and uses them to compile the reports. Sometimes, they acquire information informally by calling a few commission agents."* In other words, the local market operator officials guestimate the arrival, traded volume, and price information and share it with the distant state. Inaccurate data, at best, is further disseminated by the distant state to provide a technological façade of efficient and transformed market operations. A clear case of false compliance to give an impression of E-Market in use to the distant state.

6 Operationalising Two Step Framework [1] to Understand the Agri-Market Reforms Through Wickedness Lens

6.1 Framework – First Part – Typology Framework: Placing the Agri-Market Reforms Problem Between Tame and Wicked Territory

Typology Framework Y-Axis: Nature of the Problem and Solution Unclear. This axis establishes the details about the problem and solution as seen by the policy-makers and the stakeholders for which the state's position was established through a literature review. The stakeholder's positions were gathered from the field through long hours of observation and interviews. The detailing fleshes out 'how the state sees the problem and puts out resolutions', and in a counter, we establish 'how the stakeholders see the problem in terms of needs and their wishlist of the resolutions'.

State: *Problem* - Fragmented markets lack scale with value lost between the farm and the fork due to intermediation, manual auction process and buyer oligopsony [2, 17]. Lack of codified practices and ineffective local governance complicates.

Solution - The primary strategy is the state-mandated ICTD intervention to (a) create a centralised E-Market platform in a joint venture with private enterprise and disempower the local governance, (b) enable online buyers from across the country to create scale, (c) Disintermediate and scientific price discovery by automated auctions and (e) codified quality assessment processes through registered assayers and assaying laboratories.

Stakeholder Farmer: *Problem/Needs* - Poor infrastructure in and around the market. Lacks space for the display of produce, and the common facilities are missing. Financial difficulties in cultivating and harvesting and managing crises like borewell drying up or pump set failure.

Wishlist/Solution - Develop infrastructure in and around the markets to enable efficient processes and reduce time spent in the market. Cold storage to hold perishable produce and manage during market meltdowns. Cleaning and grading yards. Enable accountability on weighing, wastage calculation, and commission rates. Financial support for cultivation and harvest. Minimum price support during the market meltdown.

Stakeholder Buyer: *Problem/Needs* - Markets lack scale in quality and quantity terms to meet their demands. Risks due to inefficient process delays and multiple checkpoints across the journey. Risk huge losses if perishables like Tomatoes and Vegetables fail to reach 2500–3000 km destinations within 48–56 h using regular non-refrigerated lorries.

Wishlist/Solution - Create a market scale to meet all the requirements quickly. Efficient market process and permit mechanisms to enable quick exchange process and least checks with good roads to ensure speed of delivery. Recognise their occupation to enable formal banking support.

Stakeholder Intermediary: *Problem/Needs* – Both farmers and buyers prefer markets that have scale and good facilities. Commission agents suffer specifically due to inadequacy in the shop front as whoever has a larger shop front can unload more lots, resulting in huge contention between the commission agents. Routinely collateralise personal properties to borrow at steep interest rates (30–36%) to fund the exchange as farmers expect cash settlement, while buyers enjoy extended credit periods. Prominent commission agents claimed more than Rs. 20 million in exposure in the market during the season. The informal process pushes the risk of default on the commission agent.

Wishlist/Solution - Infrastructure and process improvements to ensure that farmers and buyers flock to the market and commission agents can unload large numbers of lots in their shopfront and display them properly. Since they are the 'go-to' person in the market, the state may utilise them as a conduit to support farmers and buyers. Recognise their occupation to enable formal banking support and reduce the need for private borrowings. Insurance against the risks of business.

Stakeholder Local APMC/Local Market Operator: *Problem/Needs* - Policy changes in short order due to changes in ruling dispensation create confusion and uncertainty. Even the ICTD intervention to transform the market into an E-market does not involve the local market operator in any implementation or operations except that the local market operator is supposed to cooperate. Deep concerns as the intervention creates uncertainties in terms of disempowerment.

Wishlist/Solution - Though most of the seats on the local market operator body are reserved for farmers, elite capture happens as commission agents use the ploy of owning agricultural land to get elected to seats reserved for farmers, thus creating a huge conflict of interest, and rendering the system ineffective. Local market operators claim that, unless empowered, attempts at reform may only bring new forms of elite capture and hegemonies.

Typology Framework X-Axis: People Involved - Relating to Stakeholders' Value System, Conflict of Interest and Power Asymmetries. This axis concerns the key people (stakeholders) and their institutional context and how they affect the tractability of the problem [1]. The propensity to address the problem adequately is a function of three factors listed below:

Factor One: Locus of Important Knowledge About the Problem. The problem definition shows that the distant state considers the agriculture market as a place focused on economic exchange, operating as a simple system aligned with the enacted laws [6] and, in doing so, fails to engage with the local nor give cognisance to the knowledge resident with the stakeholders. On the other hand, our findings point to a significant presence of knowledge in various stakeholders. In many cases, they are unaware of it because it is not schooled to them nor treated as formal knowledge captured in any canons. Consider the role of the commission agent. They carry the knowledge about the farmers in their network regarding what they have cultivated and the extent of cultivation, which they use to reach out to the farmers, offering them support in the form of inputs investment and retaining them as their customers. Similarly, they carry deep knowledge of various markets, buyers and the demand and supply cycles.

The fragmentation of knowledge is due to two reasons. Expertise and knowledge are domain-specific and held within specific social groupings with no motive to exchange or share. For example, a farmer's knowledge of agriculture is of little use to the buyer. Secondly, knowledge is tacit, and the associated activities need practical skills and on-the-job acquired intelligence. Another finding from our study is that knowledge is deeply embedded in relationships. Santhosh, a prominent buyer, explained, "*When I got into the* *business, my Madhya Pradesh buyers supported me. Even today, they give me requirements when I call them for demand. They will not give the requirements to anyone else in this market."*

Factor Two: Divergence and Interest Conflict Between Policy-Makers and Stakeholders. The interest factor affects the degree of conflict among and with the stakeholders, making decision-makers and stakeholders adopt different positions about the causes and solutions. In our case, the state's solution framing blames the stakeholders, resulting in threat perception and uncertainty in the ranks of the stakeholders who frame the problem in infrastructure and financial risk dimensions. We asked a few farmers, "*Will the electronic market be useful to you? Will it improve the market?"*. Many answered, "*We do not know what you are talking about. We need a good market system. However, it is more about facilities and fair practices."* A confirmation of the divergence.

Regarding disintermediation, Srivatsa, a prominent commission agent, claimed, *"Let any government or company bring any technology. No one can displace us."* Confidence and belligerence come from the hold they exercise on the system and the belief that they are indispensable to the market operations, which is proved in many studies [10, 26]. The state's reform process signals an existential crisis for specific stakeholder groups, and they respond with belligerence. In that milieu of conflicting interests, and distrust expecting goodwill and convergence with the state is implausible.

Factor Three: Relative Power of the Policy-makers and Stakeholders. Power factor distorts, mediates, and bridges the impact of other factors. In this case, the power obviously flows in the direction of the state, given its propensity to legislate new acts, push the programmes top down, and control the discourse and the machinery of the state that comes to bear [12, 16]. On the other hand, the stakeholders at the local level are no 'David' to the state's 'Goliath', and they have significant power in their social groups that they bring to bear, leading to resistance resulting in poor diffusion and adoption of the ICTD programme in the markets that we studied.

The interviews with the farmer, buyer, and commission agent show that the spaces controlled by the commission agents are real power spaces. To gain this hallowed position, a person starts at the bottom of the rung as a worker in a commission agency, grows steadily through the hierarchy over several years and the ones who are entrepreneurial build contacts and networks to enter informal mediation and finally become a commission agent by bidding for space in the market when such rare opportunity comes along. According to Sridhar, a prominent commission agent, "*There is a need for influence, political affiliation and money power. After all, it is the steppingstone for the future in adjoining political spaces"*. Similar are the cases with buyers. Since these powers are acquired by enormous effort and expense, it is not easily frittered away without a fight. This leads to symbiotic arrangements between stakeholder groups, which include the local market operator.

6.2 Framework - Second Part – Contingency Framework – Applying Causal Categories to the Findings from the Typology Framework

Now, applying causal categories to the basic dimensions of the X and Y axes and looking at detailed dimensions of the issues, we come up with the degree and type of wickedness under six clear conditions: Structural complexity, Knowability, Knowledge fragmentation, Knowledge framing, Interest-differentiation and Power distribution.

Structural Complexity. Structural complexity involves two aspects: the clarity about the problem and solution to the decision maker and the inherent complexity, which has to do with the relative tractability of the problem in terms of the extent of problem clarity that allows interventions without generating other problems [1].

Clarity About the Problem and Solution to the Decision Maker. Our studies show that the markets are messy, and the roles are unclear and mingled, leading to difficulty in understanding the issue. The lack of clarity on the problem and solution is starkly visible throughout the problem framing section. Taking the example of automating the role of the commission agent, our fieldwork shows the presence of many more intermediaries who are not clearly visible. The buyers are also a category of intermediaries as they are not end consumers or processors of the produce. Instead, they buy to trade elsewhere. The lack of infrastructure and institutional weakness is completely sidestepped.

Inherent Complexity. The complexity of reforming the agriculture market lies in multiple factors that make it wicked. Historically, attempts to reform agriculture markets have caused new problems. APMC markets came into existence in the 1960s to manage and control the excesses of the buyers who dealt with unfair practices, opaque pricing, and interlocking credit relationships [2, 17]. The reforms at that time ushered in the commission agents and local APMC as the market operator, who today figure prominently in the problem framing by the state. The problem of lack of infrastructure and the solution thereof has all the potential to turn into new and different forms of wicked problems in the adjoining area of land acquisition and re-development [25].

Knowability: Knowledge About the Problem and Solution to the Policy-Maker. The framework shows that the problems are likely wicked where the knowledge about them is hard to access, less visible or less tangible. Further, if the cause-effect linkages are not being examined deeply, the problem framing may go wrong, leading to inappropriate intervention during the attempted reform.

Our study shows that the state has framed the problem as related to productivity and efficiency. The solution approach is the unitary strategy of E-Market intervention to automate the market processes and eliminate specific stakeholders. Rittel and Webber [19] observe that 'engineering solutions are undermined due to the sheer pluralistic tendencies of the modern society with many social groups with different attitudes and values'. As observed in the section about problem formulation, significant dissonance exists between the policy-makers and the stakeholders about the problem definition and solution set. This shows that the wickedness perspective also relates to this attribute.

Knowledge Fragmentation. Factor One of the typology framework provides a deep analysis of knowledge fragmentation; hence, we will move the conversation forward without repeating it. In this case, knowledge is tacit and involves practical skills, which dodges codification. A good example is the state's failure to codify the assaying process. As part of the E-Market platform, assaying standards have been set for about 60 crops [18]. However, none of the markets in our study had assaying laboratories nor were any registered assayers present. Our fieldwork shows the buyers' intense physical involvement in every part of the transaction, from assaying to bidding. The involvement extends to overseeing the loading into the lorries and departure with quality checks at every point. Ramanna, a local buyer, pointed out, "*None of these activities can be trusted with anyone, let alone bid from a long distance. The item goes many a mile and must retain quality until it reaches its destination; otherwise, I am not paid.*"

Knowledge Framing. Considering the section relating to problem understanding and solution definition, it is clear that the state frames the problem in a particular way and gives no cognisance to the issues as seen by the local actors. On the other hand, the local stakeholders frame the problem as issues with infrastructure, recognition of roles, and support to manage risks associated with those roles, which, in their view, is indispensable for market operations. While no doubt it is difficult to ascertain the issues at the local, the problem does not become apparent when the state chooses 'not to see' nor 'engage' with the local stakeholders to understand their issues. In this dissonance between the two vantages of 'seeing the market like a state' and 'seeing the market like the local stakeholders', the monopoly is with the state's discourse.

Interest-Differentiation/Conflict. While the state in India has always been forming regulations, providing infrastructure and governance at the local level, the perspective of state-mandated ICTD programme is grander and more all-encompassing. In one act, the whole market is being shaken and disrupted, and at such a juncture, expecting cooperation is a far cry. By cooperating and synchronising interests, many stakeholder roles will cease or may shrink and lose relevance. The milieu of uncertainty naturally breeds conflict of interest.

The problem formulation section shows a clear difference in perception between the state and the stakeholders and between the stakeholder groups. In 2019, the federal government amended farm bills that allowed private market yards and contract farming. Since that day's federal and provincial governments were synchronised, the same was adopted in toto in Karnataka province. When the provincial ruling dispensation changed in May 2023, the new provincial government took up an amendment process in the legislature, and press reports cited it as an attempt to remove uncertainty for lakhs of farmers, arrest revenue loss to the market system and save the livelihood of 100,000 people working in the market [24]. The back-and-forth movements result in increased distrust and uncertainty and, in such ways, aggravation of wickedness in this aspect.

Power Relations. Our studies show that though the farmer is the prime reason an agriculture market exists, the farmer seems to be the last in the power structure. Among the stakeholders, power is within two groups, one the commission agents and two the buyers. The hush that comes into the market as buyers move around inspecting the lots before the auction is a sight to behold. Palani, a buyer from the adjoining province of Tamil Nadu in his crisp white linen shirt and a fancy Rado watch, claimed proudly, *"This market would not exist if not for us. We have created the demand in Tamil Nadu and linked up more than twenty-four buyers on the other side."* Sridhar, a prominent commission agent, shared, “*Getting the buyers to the market is the biggest challenge. To reach the heavyweights among them entrenched in multiple markets, we have to guarantee the best lots and extend attractive credit terms.*”

The commission agents are no less potent as they control the supply chain from the farm to the buyer. Additionally, the fillip they provide in terms of soft marketing and guarantee of mediating agriculture lots of any quality and quantity creates a position of hegemony whereby they end up charging more than approved commission charges for their services. It is this hegemony that the state aims to disembed through the ICTD intervention.

7 Discussion and Conclusions

7.1 Implications of Operationalising the Framework

The twin axial analysis of the problem in terms of the nature of the problem and the people involved shows huge dissonance between the policy-maker and the local stakeholders on the problem definition and solution focus. The state’s endeavour to simplify the issue and template the solution blind spots the problems plaguing the market system. This results in an off-target, incomplete solution. In such a sense, the problem and solution are ill-defined. From the people involvement perspective, knowledge is fragmented; there is divergence, conflict of interest, and the power differential between policy-makers and stakeholders. Hence, the problem falls into the extreme ends of both axes, making the type of the problem wicked in both ‘problem definition terms and from the people perspective’. The presence of wickedness on both axes indicates interaction between the two dimensions, pushing the problem deeper into wickedness territory.

The refined analysis using the contingency framework shows the presence of most of the six conditions outlined in the framework, making reforms in agricultural markets a problem that portrays a high degree of wickedness. Structural complexity is proven by the historical precedence where the state introduced the intermediary system, which is presently framed as one of the principle issues, and the ongoing disintermediation effort may open Pandora’s box of new problems. Another example is the infrastructure issues, which may turn the market reform issue into a land acquisition problem. A case in point is the Yeshwanthpur APMC market near Bangalore, whose relocation attempt has become an ongoing problem for over a decade [25]. Knowledge is fragmented, and its tacit nature makes it even more challenging to capture and codify without deep collaboration with the local. Knowledge, the prized commodity in the market, is stowed safely within the stakeholder groups. There is no incentive to share; even when it is shared, it is potent and valuable only when the relationship between the two parties undergirds it. Conflict of interest and divergence is natural, given that the problem framing blames the stakeholders squarely. While the state reigns supreme in the power hierarchy, the stakeholder groups are powerful in their limited domain, resulting in the poor adoption of the E-Market platform and false compliance.

7.2 Using the Findings from Operationalising the Framework

The problem construct becomes evident due to the framework and points to specific resolution strategies. Since local voices and knowledge are overlooked, the problem becomes ill-defined, and the resulting solution is incomplete and off-target; hence, the rectification needs the appointment of the local stakeholders to the problem. While doing so, there is a need to address the issues of conflict of interest and distrust by adopting the age-old approach of confidence-building measures, among which the first one must be to discard the present way of problem framing, which implicates the stakeholders by assuring them of their rightful place in the market system. Flipping the discourse and recognising these local stakeholders as ambassadors ensures their inherent issues are considered and can lead to better accountability practices. This milieu of goodwill and vision of collective progress may well foster an open knowledge-sharing environment. Care is essential to ensure that existing issues of elite capture in the local market operator are arrested at the root by empowered local authority through clear clauses about conflict of interest. For example, a commission agent should not be allowed to contest for a local APMC position reserved for a farmer, even if they own agricultural land. Structural complexities magnify when incomplete interventions are pushed to the field, and the E-Market intervention is an example that is pushed without creating the critical accompanying elements such as infrastructure, processes, and financial linkages. Such incomplete solutions create new wickedness like false compliance, where the most crucial market parameter, price information, is gathered unscientifically. Its inaccurate form is circulated across the geography to satisfy the state and creates a façade propagating a false narrative of adoption and use of the E-Market platform. In contrast, the markets we studied continue to operate in traditional ways.

7.3 Role of ICTD in Enabling/Constraining the Problem and Solutions in Agri-Market Reforms

Firstly, we posit that the underwhelming diffusion and adoption of the E-Market platform is due to the wickedness in the problem across both the axial, 'nature of the problem' and 'people involvement' perspectives and their interplay makes the problem deeply wicked. Though the ICTD intervention is not adopted, its elephantine aura is felt across the market. The local stakeholders have a clear visibility that ICTD intervention will disembed and disempower them. Our findings through operationalising the framework show that significant power rests with the stakeholder groups, especially the commission agents and buyers. Also, their tacit knowledge and relationships provide the vital links that hold the market together. Neither their networks nor relationships are replaceable by technology, and any such attempts may usher in new forms of wickedness. The attempt to disempower local market operator has sown distrust within the state's apparatus, and it is no wonder the local market operator aligns with powerful stakeholder groups and indulges in false compliance that leads to a false narrative. The back-and-forth style of promulgating legislation and amendments leaves none wiser and results in further uncertainty. From all this, we argue that the role of ICTD in its present form is constraining the problem and solutions in the agriculture markets we studied during our fieldwork. Further, we find that the state's push for ICTD-based transformation has led to a multi-dimensional intensification of wickedness traits, including additional complexities, heightened distrust between the state and the stakeholders and between the stakeholder groups, hardening of value positions, increased divergence of interests and uncertainty. All of this may present higher barriers when subsequent reforms are attempted.

In conclusion, the framework proposed by Alford and Head [1] provides an approach to avoid totalising and generalising a problem as wicked. At the same time, it enables a more explicit conceptualisation of the problem. Establishing the attributes of wickedness against multiple dimensions and causal links allows new mindsets and thought patterns that may result in innovative approaches and potential resolutions. Here, the nature of the resolution setting can be a combination of technology (ICT and others), institutional reform, infrastructure development and other complimentary systems that enable a societal system to reach a situation better than the previous. The resolution sets used to address the problem may hopefully moderate some attributes of wickedness while maintaining a few and provide an ability to observe specific attributes where the wickedness may intensify due to the intervention. More empirical studies involving varied and different societal systems may deepen this study further.

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Exploring the Early Diffusion of Next Generation Mobile Communication Technology: Insights from an Emerging Economy

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Abstract. The Fourth and Fifth Generation (4G and 5G) Mobile Communication Technology (MCT) is a crucial development that is expected to bridge digital divides worldwide and has significant economic implications for nations. However, there is a lack of research regarding the interplay of market heterogeneities with the diffusion of such 4G and 5G MCTs, particularly in emerging economies. This study aims to fill this research gap by conducting a quantitative analysis, by taking the case of early diffusion of 4G MCT across the twenty-two administrative regions (aka telecom circles) of India, where a new Mobile Network Operator (MNO) had simultaneously launched the 4G service. Using the Diffusion of Innovations theory and the Heterogenous Markets Hypothesis, the study puts forth several propositions that emphasize the role of market heterogeneity in mobilizing different forces in diffusion, such as imitative influences through word of mouth, and the power of innovation to mobilize Innovators and Early movers.

Keywords: Diffusion · Telecom Circles · 4G · 5G · India

1 Introduction

Diffusion of Mobile Communication Technology (MCT)[1] - a distinct type of Information and Communication Technology (ICT) – remains an important research theme for social scientists the world over. This is evident in the substantial body of literature dedicated to exploring the various facets of such diffusion of the MCT innovation [14]. To date, there have been five successive generations (Gs) of MCTs, commercialized by the Mobile Network Operators (MNOs) globally, with each generation separated roughly by a decade in time from the other (please refer to Annexure A, Fig. 3 for details). Each subsequent generation has demonstrated enhanced capabilities in terms of data exchange speed (data

[1] In simple terms, Mobile Communication Technologies (MCTs) could be understood as Mobile Network Infrastructures (including radio towers, electronic equipment, fiber/copper cable, etc.) adhering to specific types of “networking standards” (e.g., GSM, CDMA, etc.), facilitating the provision of voice and supplementary services through handheld and mobile devices (for a detailed discussion regarding MCTs, please refer to [9]).

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rate), real-time delivery (latency), and traffic carrying capacity (network bandwidth), to name a few. It is worth noting that the successive generations of the MCT innovation, namely 2G, 3G, 4G, and 5G, have independently attracted significant research attention, which is not surprising considering the increasing scale and scope of socio-economic implications associated with the diffusion of these MCT generations [12].

The wider literature focused on analyzing the diffusion of "newer products and services in the market" primarily originates from the discipline of marketing [1, 11, 22]. These studies are predominantly quantitative in nature - the methodology adopted being that of the estimation of model parameters using non-linear regression technique. While there are several models of diffusion used in the aforementioned literature, the Bass model and its extensions have garnered the highest popularity so far [2, 18]. An important advantage of using Bass model (and the various extensions) is the relaxation of the criteria concerning the need for external variables to model the diffusion phenomena, notwithstanding the simplicity of these models. Notably, most of these diffusion models, including the Bass model have drawn inspiration from Evertt Rogers' Diffusion of Innovations (DOI) theory, by way of their model parameterisation [25].

The extant literature on the diffusion of MCTs largely follows the approach undertaken in the wider marketing literature, as mentioned above. Previous studies regarding the diffusion of MCTs have largely focused on analysing specific MCT generations, emphasizing quantitative assessment of the various diffusion characteristics, such as the "rate of diffusion", "time to market saturation", and the "ultimate market potential", etc. [29]. Such prior literature has also analysed the impacts due to various macro-level factors and drivers of such MCT diffusion at the national level, proving very helpful to policymakers, especially in the developing and underdeveloped regions of the world [15, 16]. An extensive review of the extant literature, however, points to the following limitations and possibilities for further research endeavours. *Firstly*, we find that, to the best of our knowledge the extant literature lacks in the diffusion analysis of recent MCT generations, namely 4G and 5G diffusion, especially in the context of the emerging market economy. This could be owing to the lack of secondary data, more so given that the rollout of 5G services have only begun recently for many countries. *Secondly*, extant literature on the MCT diffusion have taken a comprehensive view of the demand-side, without accounting for the existing heterogeneities owing to variations in economic conditions (*aka* willingness-to-pay for mobile services), demography (rural vs. urban), geography, e-literacy levels, etc. [30]. *Finally*, prior literature is silent on the interplay regarding the effectiveness of "communication channels" (formal and informal) in the diffusion process, and the socio-economic conditions prevailing in the market.

In light of the gaps in prior literature and the opportunity provided thereof, we posit the following research question for investigation in the current study: *To analyse the dynamics regarding the diffusion of 4G and 5G MCTs in an emerging market economy, by accounting for the demand-side heterogeneities.* We explain further below.

For our investigation, we take the case of the mobile services market in India. The rationale is explained as follows. The telecom market structure in India is unique, as India is divided into twenty-two administrative zones - with each zone referred to as a Telecom Circle (TC) - for the targeted implementation of telecom policies in the country. These twenty-two TCs are further grouped into four categories, namely "Metros, "A". "B", and "C" categories. These respective categories indicate (in decreasing order) the potential for revenue generation for MNOs, which is in turn used for valuation of the reserve prices (base prices) of the radio spectrum. Therefore, Metro TCs signify greater potential for financial returns compared to category-A TCs and so forth. Such hierarchy in the "attractiveness" of TCs mimics the order of socio-economic development in these TCs, with category-A TCs faring better on the development indicators than category-B, and so forth. For MNOs, such heterogeneity in TCs translates into the varying potential for financial returns, which has considerable bearing on the decision to undertake capital investments and deploy Mobile Network Infrastructures in the TC. In addition, due to such heterogeneity, the potential revenue to the government resulting from the allocation of critical resources, such as radio spectrum, is also affected. This necessitates differentiated policies and regulatory imperatives for different regions [30]. To the best of our knowledge, studies on the diffusion dynamics of 4G and 5G MCTs, in the presence of such heterogeneous market conditions have not been conducted in the literature and could be useful.

We realise that analysing the diffusion of specific MCT generation is challenging due to various reasons. For example, there is lack of availability of longitudinal data regarding number of subscribers for the specific MCT generation. Moreover, MNOs rarely provision services using a single MCT generation, combining instead multiple MCT generations together. For example, 2G, 3G and 4G MCTs could all coexist in the market at a given point in time. Therefore, independent diffusion analyses of specific MCT generation would pose problems of accuracy. Furthermore, granularity of data is an important concern in such scenarios, as too few data separated widely across time, could lead to erroneous conclusions. Furthermore, the number of data points concerning the diffusion of 5G may not sufficient, in the statistical sense, especially in the emerging market context. We overcome these challenges through the following approach.

For investigating the stated research objective, we take the unique case of the market entry of the "4G only" MNO, Reliance Jio Inc (henceforth Jio) in the year 2016 in India. A new entrant in the Indian telecom market, Jio launched its 4G services simultaneously, across the twenty-two TCs in India. This could be argued to be a unique market intervention, which presents the opportunity to analyse the diffusion dynamics of an important innovation (viz., 4G MCT based on the Voice-over-Long-Term-Evolution (VoLTE) standard), in the "pure" greenfield scenario. We restrict our focus on analysing the "early-diffusion" of Jio's 4G services, by making use of a micro time-series (monthly) dataset, which comprises the total number of 4G subscribers, across the twenty-two circles in India, during September 2016 to March 2019. *We further restrict our focus on the pre-Covid era, to rule out the confounding impacts due to the pandemic on the diffusion process.* In line with the literature, we follow the non-linear least-squares (NLS) regression methodology for estimating the diffusion model parameters, using four different diffusion models, namely Bass, Gompertz, Logistic, and Weibull, in a comparative sense. To analyze our findings, we make use of two theoretical strands – Rogers' DOI theory, and the Heterogenous Market Hypothesis (HMH) theory from the domain of finance [32]. Considering the space constraints, we have briefly explained these theoretical underpinnings in later sections.

The rest of the paper is organized as follows. Section 2 presents the background and literature review on the diffusion of 4G and 5G MCTs. Section 3 explains the various diffusion models chosen for analyses. Section 4 and 5, respectively, highlight the research framework, and data and methodology pertaining to our analysis. Section 6 provides the results and discussions from the analysis. Finally, Sect. 7 implications and concludes the work.

2 Background and Literature Review

2.1 Evolution in 4G and 5G MCT Generations

The standards for 4G MCT were specified by the International Telecommunication Union-Radio communications sector (ITU-R), in the form of the International Mobile Telecommunications Advanced (IMT-Advanced) specifications [13]. The key features included a peak theoretical data rate of 100 Mbps (megabits per second) and 1 Gbps (gigabits per second) for high and low mobility situations, respectively [4]. Long-Term Evolution (LTE) is the predominant mobile network standard that powers the 4G MCT, so much so that 4G is synonymous with LTE networks and gets commonly referred to as 4G-LTE. The demand for higher data rates and ubiquitous internet connectivity, driven by an increase in the use of social media, e-commerce, and over-the-top (OTT) services, has led to a steady migration of existing 2G and 3G subscribers to 4G the world over. As a result, we are observing a rapid diffusion of 4G MCT worldwide, although different countries are at different stages of such diffusion. Figure 3 provides a snapshot of the evolution of various MCT generations,

A variant of LTE, the Voice-over-LTE (the technology used by Jio, the case in point), was first launched during the year 2012 in the United States (US). Since then, the VoLTE network has become quite popular amongst MNOs the world over. For example, over 253 MNOs across 113 countries have either already deployed VoLTE or are on their way to such deployment (as of February 2019) [8]. VoLTE deployments have also proven quite successful in terms of their market adoption by mobile subscribers the world over. This is especially true for the case of growth markets in the developing world, such as India and China. For example, within three years (2016–2019) of the launch of VoLTE in India by the new-entrant MNO, Jio, a total of 300 million mobile subscribers were added. This also resulted in Jio acquiring the major portion of the overall market share for 4G subscribers in India, which amounted to approximately 400 million subscribers as of February 2019 (the cutoff point of our analysis) [19]. Much of the subscription acquired by Jio is posited to be a result of the loss in the mobile subscriber base of the incumbent MNOs in India. Similarly, in China, the VoLTE mobile subscriber base of MNOs, such as China Unicom and China Mobile, is witnessing a steady rise reportedly; China Mobile has deployed VoLTE across 313 cities in the country, investing over $66 billion in the process [24]. Similar examples can be cited for various other countries as well.

The fifth generation (5G) of MCT, which is the latest addition to the MCT family, is a significant leap on all the important parameters of MCT performance, namely, data rate, latency, and network bandwidth, and is being hailed as the "lifeblood for the business of the future", especially Industry 4.0 [3]. Such "transformative leap" is posited to have large scale implications for the growth of several emerging technologies, such as the Internet of things (IoT), Augmented and Virtual Reality (AR and VR) and Edge Computing, to name a few. 5G's low latency and high bandwidth could also have significant impacts on healthcare through telemedicine, remote surgery, and real-time patient monitoring, etc. Currently, 5G comprises three main business use cases, namely Enhanced Mobile Broadband (eMBB), Ultra-Reliable Low-Latency Communications (URLLC), and Massive Machine-Type Communications (mMTC): eMBB leverages 5G's high data speeds and capacity to deliver superior mobile internet experiences, enabling seamless high-definition video streaming, immersive augmented and virtual reality applications, and bandwidth-intensive content consumption; URLLC focuses on providing ultra-low latency and high reliability for critical applications, such as autonomous vehicles, remote surgery, and industrial automation; mMTC enables the connectivity of a massive number of IoT devices, facilitating smart city infrastructure, industrial IoT, and remote monitoring [23].

2.2 Prior Studies on Diffusion of MCT Generations

The quantitative perspective on *diffusion* is concerned with the dynamics of *cumulative market adoption* of innovation *over time* in a particular market. Thus, diffusion is a group-level phenomenon, which slowly manifests over time as the information about the innovation spreads in the market (e.g., newer network generations have been found to appear in the telecom market after every ten years). Diffusion studies are, therefore, temporal and rely on the longitudinal data of market adoption (total subscribers in our case) of the innovation. As mentioned earlier, prior literature on the diffusion of mobile innovations uses growth models, which parameterize the various characteristics of the diffusion process in non-linear functional forms [1, 17, 25]. To estimate the growth model parameters corresponding to various innovations, researchers take the help of suitable non-linear regression techniques for fitting the functional expressions of these growth models with the historical data of sales of the innovation [28]. Bass, Gompertz, Logistic, and Weibull models are examples of the most widely used growth models, especially for mobile innovations. Such growth models have found their application in studies investigating the diffusion of 2G, 3G, and 4G networks the world over [9, 10, 31]. In addition to analyzing the diffusion of various network generations, the above-mentioned growth models have also found applications to innovations in several other domains – ranging from agricultural sciences (e.g. hybrid corn), corporate finance (e.g. financial investments), marketing (e.g. consumer durable goods), to several industrial innovations (e.g. IBM Mainframes and IPTV) [5].

2.3 Research Context

The research context in this paper comprises the market for mobile services in India. India is currently the world's second-largest market for mobile services in terms of volume, having over 1.2 billion mobile subscribers as of June 2018 [30]. The mobile economy in India also contributes substantially to its overall Gross Domestic Product (GDP). India is also the world's second-largest market in terms of mobile Internet subscribers. However, this was not always the case. At the end of the year 2016, the total

Mobile Broadband (MoBro) subscriptions (3G + 4G) in the country stood at a little over 230 million (approximately 20% penetration). In September 2016, Jio, the new entrant, launched VoLTE services across the twenty-two circles in the country. Jio was the first 4G-only MNO, which achieved pan-India 4G coverage, enabled by an extensive VoLTE network deployment drive across the country. Notably, Jio rolled out its *services for free during the initial six months*, beginning to charge its subscribers only after March 2017, adopting a low-price-based "growth-hacking" strategy all the while [26]. Jio acquired 16 million subscribers within the first month of its launch, creating a world record for the fastest ramp-up by any MNO in the world [7]. As of March 2019, the new entrant had already become the second-largest MNO in India and sixth largest MNO in the world, having over 306 million VoLTE subscribers. Notably, MoBro connectivity in the form of 3G and 4G was launched in India many years ago - 3G in 2009 and 4G in 2012, however, the incumbent MNOs were finding it difficult to increase their base of MoBro subscribers during these years. The entry of Jio changed this scenario. The incumbent MNOs witnessed significant attrition in their subscriber base, which led to the MNOs reducing tariffs for mobile data services. The resulting "price wars" led to an overall decline in the average revenue per user (ARPU) figures for both voice and mobile data services, resulting in reduced revenue margins for the incumbent MNOs. The disruption in the telecom market, brought in due to Jio's entry, also precipitated the ongoing business restructuring and consolidation trends in India. Consequently, there remained only three private MNOs, namely Bharti Airtel (Airtel), Vodafone Idea (Vi), and Jio, in India. Bharat Sanchar Nigam Limited (BSNL) and Mahanagar Telephone Nigam Limited (MTNL) are the other two state-owned MNOs in the country. Figure 4 in Annexure highlights the trend of mobile subscriptions for the majority of MNOs in India.

3 Research Framework

Our research framework is summarized in Fig. 1. Notably, we are motivated by two main theoretical strands for explaining our analysis: (a) the Diffusion of Innovations (DOI) of Rogers, and (b) the Heterogenous Market Hypothesis (HMH) theory from the discipline of Finance. We explain the details below.

The DOI theory was first proposed by Everett Rogers in 1962, and it has since become one of the most widely used theories in management [25]. The theory seeks to explain how new ideas, products, or technologies spread through a social system over time. In addition to identifying various stages in the diffusion process, Rogers also identified five categories of adopters: *innovators, early adopters, early majority, late majority, and laggards* [25]. Innovators are the first to adopt an innovation, while laggards are the last. Early adopters are opinion leaders who adopt the innovation early on and help to spread it to others. The early and late majority adopt the innovation after it has been tested and proven successful by the innovators and early adopters. The diffusion of innovation theory has been applied to a wide range of fields, including technology adoption, marketing, and health. By understanding the factors that influence the adoption of new ideas or technologies, researchers and practitioners can develop strategies to promote their adoption and accelerate the diffusion process.

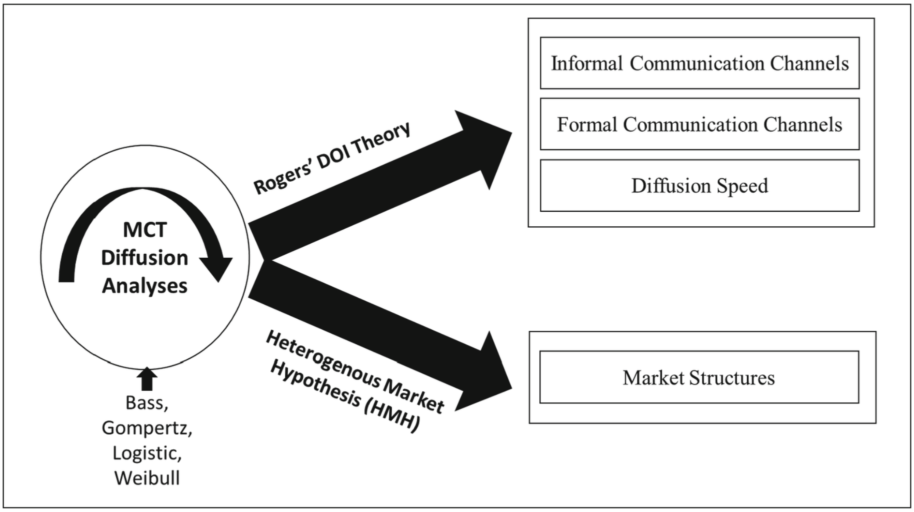

Fig. 1. Research Framework

The Heterogenous Market Hypothesis (HMH) theory suggests that market participants may have different beliefs and expectations about future asset prices, which can lead to price fluctuations and volatility in the market [32]. According to HEH, investors have varying levels of information, analysis, and interpretation of market data, leading to different expectations about future events and outcomes [32]. With specific reference to HMH, while the theoretical underpinnings do not directly apply to the domain/phenomena under consideration in this study, the rationale and the core elements of the theory seem to be useful in explaining the interplay regarding the perceptions' of the twenty-two TCs for the supply-side stakeholders (MNOs and government); considering the heterogeneity across these TCs across various factors, such as the distribution of adopter categories, socio-economic conditions of general populace, market structures, geographic conditions, demography, usage patterns and the overall E-literacy levels.

4 Theoretical Overview of Diffusion Models

4.1 Bass Model

The probability density and the cumulative distribution function equations for the Bass model can be expressed, respectively, as:

$$n(t) = (p + qN(t))(1 - N(t)) \tag{1}$$

$$N(t) = M\left[\frac{1 - e^{-(p+q)t}}{1 + \left(\frac{q}{p}\right)e^{-(p+q)t}}\right] \tag{2}$$

where $n(t)$ is the noncumulative number of adopters at time t, $N(t)$ is the cumulative number of adopters till time t, p is the coefficient of innovation, q is the coefficient of imitation, and M is the ultimate market potential of the innovation. The coefficient of innovation also corresponds to the probability of an initial purchase during the beginning of the product's lifecycle and has direct relationships with the initial critical mass of the adopters, i.e., the innovators. This factor influences significantly the rest of the diffusion process involving the imitators, which constitutes the remaining population yet to adopt. Essentially, innovators are the earliest adopters who gather information about the new innovation through formal channels of communication, whereas imitators rely on informal sources, such as word-of-mouth, interpersonal interactions and direct observations of product use, in order to make the decision to adopt [21].

4.2 Gompertz Model

The probability density and the cumulative distribution function equations for the Gompertz model can be expressed, respectively, as:

$$n(t) = b_1 \, ln \frac{K}{N(t)} \tag{3}$$

$$N(t) = Ke^{-e^{-b_1(t-b_2)}} \tag{4}$$

where $n(t)$ and $N(t)$ are the same as in the Bass model, K is the asymptote, which also corresponds to the ultimate market potential (similar to M in Bass model), $b_1 > 0$ is a scaling factor indicating the "intrinsic growth rate," i.e., the "rate of diffusion," b_2 is the offset in time scale, and the product $b_1 b_2$ is related to the "point of inflection" [20]. Two main characteristics of Gompertz curve are the occurrence of the point of inflection before the point of saturation, and the rate of growth being always non-negative, even though it may exhibit a decrease over time [6]. Gompertz model was originally proposed by the mathematician Benjamin Gompertz for modeling human mortality in society and since then, has been used for fitting and forecasting the diffusion of technological innovations.

4.3 Logistic Model

The probability density and the cumulative distribution function equations for the Logistic model can be expressed, respectively, as:

$$n(t) = b_1 \left(1 - \frac{N(t)}{K}\right) \tag{5}$$

$$N(t) = \left[\frac{K}{1 + e^{-b_1(t-b_2)}}\right] \tag{6}$$

where the notations have similar meanings as in the Gompertz model. Similar in nature to the Gompertz model, the Logistic model was proposed by the Belgian mathematician Pierre Francois Verhulst in 1838 and was also originally meant for demographic studies.

The rationale behind the Logistic model is that the growth (referring to human population) slows down as the population approaches its uppermost limit, essentially due to the feedback limits on the system [3]. The point of inflection of the Logistic model-based diffusion curve lies about midway between the asymptotes (where it differs from the Gompertz model).

4.4 Weibull Model

Weibull model is found to effectively model the technological diffusion successfully in a variety of situations [27]. Unlike other models, Weibull provides flexibility in the *skewness* of the diffusion curve. The probability distribution function (cumulative p.d.f.) equation of the Weibull model can be expressed as:

$$n(t) = \left(\frac{\beta}{\alpha}\right)\left(\frac{t}{\alpha}\right)^{\beta-1} e^{-(t/\alpha)^{\beta}} \tag{7}$$

$$N(t) = K(1 - e^{-(\frac{t}{\alpha})^{\beta}}) \tag{8}$$

where t is time; $n(t)$, $N(t)$, and K have similar interpretations as in the Gompertz model; and α and β are constants. While both α and β determine the steepness of the curve, β alone determines the shape of the curve. For estimating the model parameters, we use the transformed equation of the Weibull model [27].

5 Data and Methodology

We use twenty-two unique time-series micro-datasets (monthly), one corresponding to each circle in India, which comprises the 4G-VoLTE subscription in the respective TCs. We extract our datasets from the publicly available "Telecom Subscriptions Reports," which is published monthly by the Telecom Regulatory Authority of India (TRAI). Such monthly data corresponds to the period from September 2016 to March 2019 (a total of 31 data points). We use R and Tableau applications for our data analysis and visualizations, respectively. Non-linear models, such as Bass model, which are *non-linear in parameters*, require a different approach for fitting the observational data unlike the linear models, where simple linear-regression techniques may serve the purpose. For non-linear models, the observational data are fitted to the model expression by following a method of "successive approximations," which requires the use of a suitable non-linear regression technique, such as Non-linear Least-Squares (NLS) regression, Maximum Likelihood Estimation (MLE), or Bayesian approximation techniques. Of these available techniques, we use NLS regression for estimating our model parameters, which matches with the approach highlighted by [28]. Notably, when compared to the other techniques, the key advantage of NLS regression lies in obtaining valid standard error estimates of the model parameters.

6 Results and Discussion

Table 1 summarizes the results of the NLS regression-based estimation of diffusion parameters for the considered Bass model. The remaining results from other diffusion models are summarized in Table 2, Annexure A. We can infer the following from the diffusion analyses results summarized in Table 1.

6.1 The Formal vs. Informal Channels of Communication in MCT Diffusion

We find that, the Bass model parameter estimates for the coefficient of imitation (q) are much higher than those for the coefficient of innovation (p), across the twenty-two TCs. This could potentially indicate *the relatively higher impact of informal channels of communication, such as word-of-mouth and interpersonal signalling, towards the subscribers' decision to adopt the 4G MCT across the twenty-two TCs.* This also signifies an overbearing presence of the potential adopters belonging to the "imitators" category, when compared to the "innovators" category, amongst the larger pool of 4G subscribers in India. However, given the market heterogeneities prevailing across the TCs, further analysis is warranted to understand the q vs. p scenarios in these TCs. Therefore, we further clustered the TCs using an unsupervised clustering technique, based on the p-q variations. Such analyses resulted in two main clusters displaying distinct characteristics in their "innovation-imitation dynamics". Figure 2 highlights the clusters.

The Y- and X- axes in Fig. 2 represent the 'coefficient of innovation (p)' and the 'coefficient of imitation (q)' from the Bass model. The four distinct bubble sizes correspond to the four categories of TCs, as summarised in the legend in Fig. 2. An *unsupervised clustering* analysis clearly reveals two distinct clusters (Clusters 1 and 2), as shown in different colors, and on both sides of the solid line. The majority of TCs belonging to Cluster 1 are 'Metros' and 'A' category TCs, whereas those in Cluster 2 are 'B' and 'C' category TCs (except one TC in Cluster 2, namely Maharashtra, that is borderline and belongs to 'A' category).

Interestingly, *the inferences from* Fig. 2 *are very counterintuitive.* For example, we find that the majority of B and C category TCs, which are perceived to yield lower financial returns for MNOs, as reflected in the relatively lower base prices of the radio spectrum in these TCs, comprises high values of 'coefficient of imitation'. This signals that the impacts due to informal channels of communications are much greater in the overall diffusion process. Notably, these TCs are also characterized by relatively lower per capital income of their populace, as compared to Metros and A categories. The same is true for other socioeconomic indicators of development, such as Health and Education. On the other hand, the power of innovation (in this case 4G MCT) is significant towards catalyzing the adoption of 4G MCT by the Innovators and Early adopters. Notably, such TCs fare better in terms of the various socioeconomic indicators of development. Thus, market heterogeneity seems to have a strong association with how the twin dimensions of diffusion, namely innovation power and interpersonal influences, are mobilized and activated. While we do not intend to ascertain causality amongst variables through our analyses, we could formulate propositions, based on the results from the early diffusion dynamics of 4G MCT in various parts of India. The propositions warrant investigation for the diffusion of 5G MCTs too.

Table 1. Bass model parameter estimates of VoLTE diffusion in India's Telecom Circles

Category	Telecom Circle	Bass model parameters			
		p	*q*	*M*	RMSE
Metros	Delhi	0.0054	0.0676	7.63E+08	9.44E+05
	Mumbai	0.0052	0.0813	4.99E+08	9.28E+05
	Kolkata	0.0049	0.0751	3.99E+08	1.08E+06
A category TCs	Andhra Pradesh	0.0038	0.0733	1.28E+09	1.04E+06
	Gujarat	0.0047	0.0749	9.02E+08	1.19E+06
	Karnataka	0.0039	0.0661	9.67E+08	4.21E+05
	Maharashtra	0.0031	0.0763	1.26E+09	3.04E+05
	Tamil Nadu	0.0039	0.0710	1.05E+09	5.67E+05
B category TCs	Haryana	0.0038	0.0717	4.03E+08	7.62E+05
	Kerala	0.0061	0.0770	3.12E+08	9.81E+05
	Madhya Pradesh	0.0020	0.0804	1.46E+09	1.09E+06
	Punjab	0.0047	0.0773	5.45E+08	1.01E+06
	Rajasthan	0.0018	0.0756	1.51E+09	1.21E+05
	UP (East)	0.0031	0.0800	1.06E+09	1.19E+05
	UP (West)	0.0034	0.0708	8.89E+08	1.60E+05
C category TCs	Assam	0.0028	0.0965	2.49E+08	2.27E+05
	Bihar	0.0027	0.0857	1.08E+09	3.39E+05
	Himachal Pradesh	0.0043	0.0862	1.20E+08	8.60E+05
	Jammu & Kashmir	0.0040	0.0838	1.51E+08	4.25E+05
	North East	0.0033	0.0860	1.28E+08	6.24E+05
	Orissa	0.0027	0.0791	4.95E+08	1.01E+06

We formulate our propositions as follows.

Proposition 1: *The early diffusion of 4G MCT is primarily propelled by informal communication channels, including word of mouth and interpersonal signaling, among others. The diffusion of 5G MCT is likely to follow a similar trend.*

Proposition 2: *The impact of informal communication channels on the diffusion of 4G MCT is more notable in markets where the purchasing power is lower, in contrast to those with higher purchasing power. Such impacts are likely to persist for the diffusion of 5G MCT too.*

Proposition 3: *In markets where purchasing power is higher, the effects of formal communication channels, such as advertising and mass media, on the diffusion of 4G MCT*

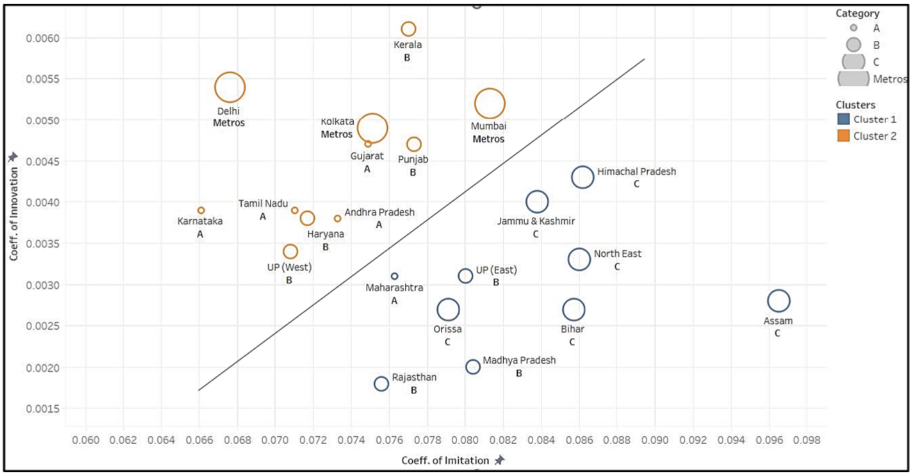

Fig. 2. Coefficient of Innovation vs. Coefficient of Imitation plot for TCs

are more pronounced compared to those with lower purchasing power. Such differentiation in the effects due to formal communication channels are likely to persist for 5G MCT diffusion as well.

6.2 The Speed of MCT Diffusion

We find that the speed of 4G MCT diffusion (as assessed through the Logistic model parameters) is much higher in TCs that are otherwise lower in their attractiveness quotient from the point of view of the MNOs, considering the lower levels of socio-economic development. This is counterintuitive to the general assumption that Metros and category-A TCs, which comprises the large cities and metropolis, are characteristic of much greater demand for 4G MCT. Interestingly, such assumptions have led to the neglect of 4G mobile network infrastructures deployment activities in these regions in the past, given the prevalent assumption regarding such regions having very low revenue potential. This belief also shapes the valuation of the base prices in these TCs, and, therefore, could lead to a loss for the government during the spectrum auctions. While these are initial findings from a relatively smaller dataset, nevertheless, these findings need to be further investigated for understanding the changed service usage patterns of 4G MCT subscribers across various markets. Notably, such studies are also scant globally. Future research may cater to this aspect of 4G and 5G diffusion the world over.

We state our final proposition below.

Proposition 5: *In markets where purchasing power is relatively lower, the speed of diffusion of 4G MCTs could be substantially higher than the earlier MCT generations, considering the shift in demand and usage patterns. With the launch of 5G MCT, this trend could continue to persist.*

We hold a strong belief that these propositions could offer valuable avenues for exploration in future research, especially when extended to global data sets. By gathering enough data, such investigations could offer greater understanding of the rural-urban dynamics in the spread of the next generation MCTs, viz., 4G and 5G. This could provide useful perspectives for policymakers and other stakeholders to fine-tune their approaches towards infrastructure implementation, pricing, and other regulatory actions.

7 Conclusion

This research delves into the initial diffusion patterns in the growth of 4G MCT within an emerging economy, namely India, offering valuable insights for the impending 5G MCT diffusion. Utilizing Everett Rogers' Diffusion of Innovations theory and the Heterogeneous Market Hypotheses, the study examines the early 4G MCT diffusion by a "4G only" mobile network operator (MNO) across India's twenty-two telecom circles (TCs). Employing nonlinear regression-based quantitative analysis, the study estimates diffusion model parameters across these TCs. Through a comprehensive exploration of diffusion dynamics amid socio-economic diversity across markets, the study presents several counterintuitive propositions based on its findings.

Annexure A

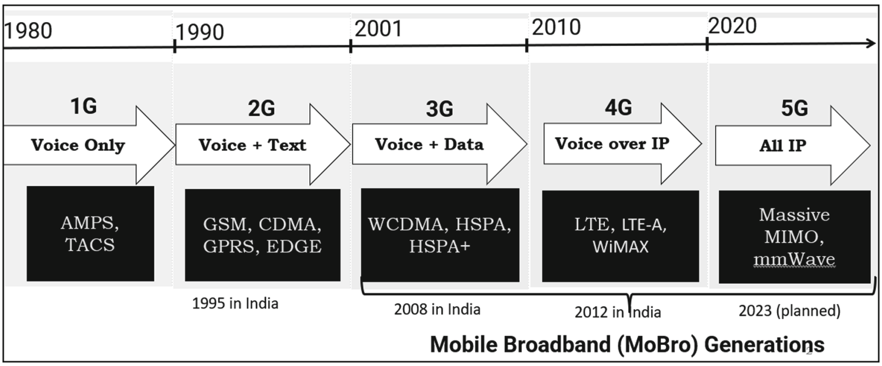

Fig. 3. MCT generation evolution. Source: Authors' own representation

Table 2. Summary of various diffusion model parameters for VOLTE diffusion in Telecom Circles in India

Category	Telecom Circle	Bass parameters				Gompertz parameters				Weibull parameters				Logistic parameters			
		p	q	M	RMSE	K	b_1	b_2	RMSE	A	$\boldsymbol{B}$	$\boldsymbol{L}$	RMSE	$\boldsymbol{K}$	$\boldsymbol{b_1}$	$\boldsymbol{b_2}$	RMSE
Metros	Delhi	0.0054	0.0676	7.63E+08	9.44E+05	7.63E+08	0.1085	7.0516	1.14E+07	2.87E+08	7.17E+07	3.76E+08	1.04E+07	1.70E+07	0.10211	12.33237	5.05E+05
	Mumbai	0.0052	0.0813	4.99E+08	9.28E+05	4.99E+08	0.1019	6.9596	1.59E+07	2.16E+08	5.39E+07	2.82E+08	7.97E+06	1.27E+07	0.124479	12.5714	6.09E+05
	Kolkata	0.0049	0.0751	3.99E+08	1.08E+06	3.99E+08	0.0972	6.5370	1.60E+07	1.54E+08	3.86E+07	2.02E+08	5.69E+06	9.82E+06	0.107198	14.23302	9.92E+04
A category circles	Andhra Pradesh	0.0038	0.0733	1.28E+09	1.04E+06	1.28E+09	0.0969	6.8286	1.88E+07	4.09E+08	1.02E+08	5.36E+08	1.53E+07	3.26E+07	0.092945	19.54577	1.44E+05
	Gujarat	0.0047	0.0749	9.02E+08	1.19E+06	9.02E+08	0.0952	6.4328	1.88E+07	3.42E+08	8.54E+07	4.48E+08	1.26E+07	2.22E+07	0.105807	14.72795	9.79E+04
	Karnataka	0.0039	0.0661	9.67E+08	4.21E+05	9.67E+08	0.0989	6.6399	3.73E+06	2.83E+08	7.08E+07	3.71E+08	1.26E+07	2.23E+07	0.085445	19.48992	8.58E+05
	Maharashtra	0.0031	0.0763	1.26E+09	3.04E+05	1.26E+09	0.0942	6.9824	5.35E+06	3.64E+08	9.09E+07	4.76E+08	1.39E+07	3.45E+07	0.091634	23.21599	9.21E+05
	Tamil Nadu	0.0039	0.0710	1.05E+09	5.67E+05	1.05E+09	0.0977	6.7552	6.83E+06	3.32E+08	8.30E+07	4.35E+08	1.24E+07	2.59E+07	0.091253	19.09864	8.31E+05
B category circles	Haryana	0.0038	0.0717	4.03E+08	7.62E+05	4.03E+08	0.0889	6.2023	1.38E+07	1.26E+08	3.14E+07	1.65E+08	4.69E+06	1.01E+07	0.091195	19.71069	7.06E+05
	Kerala	0.0061	0.0770	3.12E+08	9.81E+05	3.12E+08	0.1011	6.4553	1.45E+07	1.41E+08	3.52E+07	1.85E+08	5.13E+06	7.39E+06	0.135023	9.748355	1.46E+05
	Madhya Pradesh	0.0020	0.0804	1.46E+09	1.09E+06	1.46E+09	0.0873	7.0283	2.16E+07	3.30E+08	8.26E+07	4.33E+08	1.30E+07	4.61E+07	0.089342	30.33435	2.28E+05
	Punjab	0.0047	0.0773	5.45E+08	1.01E+06	5.45E+08	0.0964	6.5898	2.39E+07	2.12E+08	5.31E+07	2.78E+08	7.87E+06	1.37E+07	0.109385	14.66553	1.24E+07
	Rajasthan	0.0018	0.0756	1.51E+09	1.21E+05	1.51E+09	0.0857	6.7879	1.24E+06	2.86E+08	7.15E+07	3.75E+08	1.12E+07	4.63E+07	0.08285	33.73143	9.93E+05
	UP (East)	0.0031	0.0800	1.06E+09	1.19E+05	1.06E+09	0.0922	6.9757	1.57E+06	3.27E+08	8.18E+07	4.29E+08	1.25E+07	3.02E+07	0.096538	22.3765	5.53E+05
	UP (West)	0.0034	0.0708	8.89E+08	1.60E+05	8.89E+08	0.0952	6.7225	2.11E+06	2.54E+08	6.36E+07	3.33E+08	9.56E+06	2.23E+07	0.087818	21.72681	3.89E+05
C category circles	Assam	0.0028	0.0965	2.49E+08	2.27E+05	2.49E+08	0.0842	7.0349	2.18E+06	9.13E+07	2.28E+07	1.20E+08	3.59E+06	8.15E+06	0.117409	21.03983	1.10E+06
	Bihar	0.0027	0.0857	1.08E+09	3.39E+05	1.08E+09	0.0866	6.9127	6.22E+06	3.29E+08	8.23E+07	4.32E+08	1.28E+07	3.30E+07	0.100855	23.73436	2.58E+05
	Himachal Pradesh	0.0043	0.0862	1.20E+08	8.60E+05	1.20E+08	0.0925	6.6647	1.28E+07	4.97E+07	1.24E+07	6.51E+07	1.87E+06	3.31E+06	0.11959	15.3716	8.71E+05
	Jammu & Kashmir	0.0040	0.0838	1.51E+08	4.25E+05	1.51E+08	0.1037	7.6779	5.15E+06	5.81E+07	1.45E+07	7.62E+07	1.70E+06	4.26E+06	0.108486	17.45566	8.98E+05
	North East	0.0033	0.0860	1.28E+08	6.24E+05	1.28E+08	0.0926	7.1226	6.19E+06	4.43E+07	1.11E+07	5.81E+07	5.24E+06	3.82E+06	0.105079	20.79296	1.03E+06
	Orissa	0.0027	0.0791	4.95E+08	1.01E+06	4.95E+08	0.0841	6.5334	1.22E+07	1.36E+08	3.41E+07	1.79E+08	2.57E+07	1.44E+07	0.092327	25.20077	8.09E+05

Notes: RMSE signifies the root-mean-squared error value for the individual estimation scenario. Weibull model parameters, namely A, B and L corresponds to the transformations applied to the original parameters, namely α, β, and K, as explained in (Sharif & Islam, 1980, pp. 251).

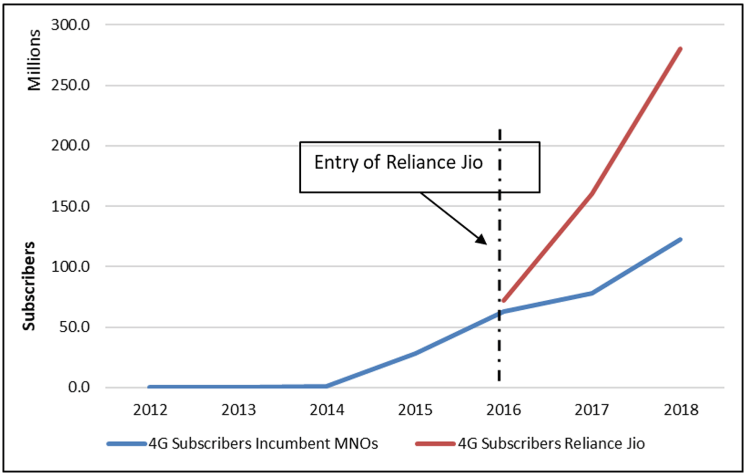

Fig. 4. Comparison of 4G subscribers of the incumbent MNOs (combined) and Reliance Jio, in India. Source: BMI International database

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E-Government Maturity, Gender Inequality and Role of Government Effectiveness: A Longitudinal Study Across Countries

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Abstract. Understanding the role of e-government in driving governments' development agenda has received attention from academicians and policymakers. Despite this, there is a dearth of research focusing on the higher-order impact of e-government at a macro level, such as sustainable development goals. This paper explores the relationship between e-government maturity and gender inequality (SDG 5). Drawing on empowerment theory, we examine how e-government maturity may help reduce gender inequality in the country. Moreover, based on institutional theory, we look at the potential role of government effectiveness in influencing the impact of e-government maturity on gender inequality. The study uses publicly available data from well-known sources. We provide empirical results supporting the proposed relationships using two-way fixed effect regression on a balanced panel dataset of 139 countries from 2003 to 2020. Our findings suggest a significant negative relationship exists between e-government maturity and gender inequality. Additionally, government effectiveness provides a considerable moderation effect between e-government maturity and gender inequality. We also validate our results through robustness checks. This study contributes to the literature on e-government impact and the role of institutional factors in realizing the benefits of e-government. Based on the findings, we provide implications for both research and practice.

Keywords: E-government Maturity · Gender Inequality · Government Effectiveness · Panel Data · Fixed-effects

1 Introduction

The rapid advancement in Information and Communication Technology (ICT) and its use by every individual, business, and government has led to societal progress. E-government, or EGOV in short, is usually defined as the adoption and use of ICT by governments to transform the public delivery systems and improve the efficiency with which government services are provided to all stakeholders [1]. Due to its massive potential in public administration, it has caught the attention of all national and international

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organizations [2]. It is now well accepted that e-government can act as a catalyst for increasing the efficiency of internal governmental processes, improving the delivery of public services, and strengthening government-citizen engagement [2]. This is evident by the fact that all the 193 member states of the United Nations have implemented e-government in some form [3]. Moreover, governments are developing strategic digital initiatives to transform the public services system. Some examples are Digital India, Digital Kazakhstan, Smart Nation Singapore, and many others. At the same time, due to its potential benefits and widespread adoption and use by governments across the globe, e-government has received attention from researchers, too. The extant literature on e-government can be categorized into three broad groups: (i) Factors of e-government adoption, (ii) e-government design and implementation, and (iii) e-government impact on stakeholders. While the first two groups have attracted significant research, there is limited literature on e-government impact [3]. The extant research on the e-government impact has focused on corruption control, better government transparency, and economic prosperity, among others [4]. There is more scarcity of research on higher-order effects of e-government at the macro level. It may be due to “the fuzziness and diversity of the intended goals of e-government projects” ([5], p. 108). Moreover, most of these studies tend to be narrow-focused, i.e., the scope of the study is limited to a particular country or region [4]. As a result, this narrow perspective on e-government impact research limits our ability to fully understand its potential to achieve higher-order goals at the macro level, such as those outlined in the Sustainable Development Goals (SDG) [3].

In 2015, the United Nations adopted the 2030 Agenda comprising seventeen sustainable development goals [6]. One of the core principles of these sustainable development goals is to promote inclusiveness, which broadly means providing equitable access to opportunity for all, irrespective of gender, caste, religion, etc., and ensuring the marginalized groups are not left behind from participating in and gaining from sustainable development. SDG#5 deals explicitly with the issue of gender inequality and aims to promote women’s inclusion in the developmental agenda as they often face various forms of inequality, discrimination, and violence globally [7]. SDG#5B, one of the sub-targets of Goal 5, seeks to promote gender equality and women empowerment using technology [7]. In this context, we believe that e-government may play an essential role in driving the goal of reducing gender inequality and promoting women empowerment. E-government can potentially empower citizens, especially the marginalized population, including women, by enabling easy access to information and services related to education, health, and well-being through online public platforms. This leads us to our first research question:

RQ1: What is the relationship between e-government maturity and gender inequality in a nation?

We also argue that while e-government may help the countries drive their agenda of promoting gender equality, its impact may be even more significant in the presence of other conditions or factors, such as institutional factors. We consider government effectiveness as an institutional factor in this study. Government effectiveness refers to the capacity of the government to formulate and implement policies, provide services, and address the needs of its citizens through robust public administration and bureaucracy [8]. We posit that the complementary role of government effectiveness could further strengthen the effect of e-government maturity on gender inequality. This leads us to our second research question:

RQ2: How does government effectiveness affect the relationship between e-government maturity and gender inequality in the country?

We intend to make several contributions through our research. First, we theorize the relationship between e-government maturity and gender inequality and the role of government effectiveness in influencing this relationship using empowerment theory and institutional theory, respectively. Second, we use publicly available balanced panel data from 139 countries from 2003 to 2020 to analyze the above relationships and provide empirical support. Third, we add to the literature on higher-order impacts of e-government, such as sustainable development goals. The findings of this study would help policymakers in policy formulation and implementation to effectively utilize the potential of e-government in achieving the social and economic objectives of the governments. The rest of the paper is organized as follows. Section 2 provides the theoretical basis for hypothesis development, followed by the research design in Sect. 3. Analysis and Results are provided in Sect. 4, followed by discussion and implication in Sect. 5. Concluding remarks complete the paper in Sect. 6.

2 Theory and Hypotheses

2.1 Relating E-Government Maturity and Gender Inequality

Empowerment Theory: E-government has transformed the public service delivery systems from centralized bureaucratic processes to digitally enabled citizen-oriented channels [9]. This transformation improves the government's connection with various stakeholders. For example, it allows the government to share policy-related information with the citizens and gather feedback [10]. It provides a more transparent public service delivery system to citizens. Past literature has shown that E-government is closely linked to development outcomes, such as economic prosperity [4] and inclusion [11]. Many E-government initiatives may empower the citizens, especially the marginalized population, including women, by enabling easy access to information and services related to health and well-being [3]. E-government has allowed marginalized groups, including women, to avail themselves of various social benefit schemes directly without any intermediary like Direct Benefit Transfer in India. Initiatives such as e-learning portals can reduce barriers for them to access education and training materials. E-government has been recognized as a powerful tool for reducing gender inequality and empowering women through the use of ICT. Digital communication platforms provide new opportunities to break traditional barriers and increase women's participation in governance processes [12]. As public service delivery becomes more sophisticated (i.e., higher e-government maturity), it leads to more significant socioeconomic impacts such as increased citizen engagement, inclusion, and representation of marginalized groups, particularly women, in the public sector. Therefore, based on the above argument, we hypothesize that:

H1. A higher level of E-government maturity in a country is associated with a lesser prevalence of gender inequality in that country.

2.2 Moderating Role of Government Effectiveness

Institutional Theory: According to institutional theory, formal and informal rules, norms, and structures within an organization or society shape behaviour, decision-making, and outcomes [13]. In our context, government effectiveness acts as an institutional factor that moderates the relationship between e-government maturity and gender equality. As we mentioned earlier, government effectiveness relates to the government's capability to formulate and implement policies [8]. An effective government will ensure that policies aimed at promoting gender equality and leveraging e-government initiatives are well-designed, implemented, and monitored regularly. If government agencies responsible for e-government initiatives are effective in planning and execution, it increases the likelihood that the benefits of e-government initiatives will reach women and marginalized groups, enhancing gender equality. An effective government, based on institutional characteristics and norms, is more likely to leverage e-government initiatives as a strategic tool for promoting gender equality. Therefore, based on the above argument, we hypothesize that:

H2. Government effectiveness moderates the relationship between e-government maturity and gender inequality, such that with higher government effectiveness, the negative effect of e-government maturity on gender inequality increases in that country.

Figure 1 represents the research model for the study.

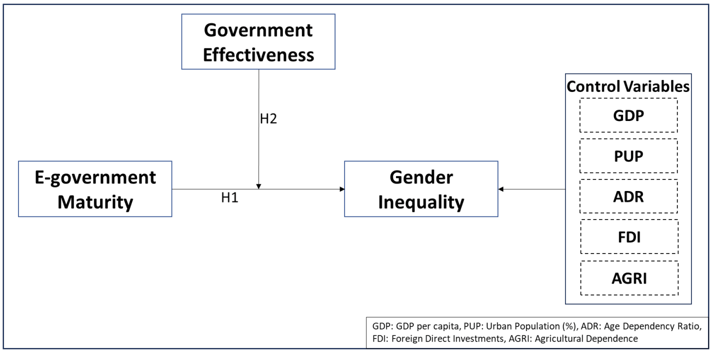

Fig. 1. Research Model

3 Research Design

3.1 Data

We use publicly available archival data from well-known databases such as the United Nations and the World Bank. These are reputed and established sources with robust processes and standardized methodologies for data collection. This ensures the reliability and validity of the data used in the study [4].

The dependent variable in our study is gender inequality (GI), which is operationalized using the Gender Inequality Index. The United Nations Development Program (UNDP) publishes the gender inequality index as a part of the Human Development Report annually. It is a composite index to measure the gender-based differences in achievements in the areas of health, workforce, and empowerment at a country level [14]. The first dimension, health, is based on the maternal mortality ratio and the adolescent fertility rate. The second dimension, the workforce, is based on the labour force participation rate. The third dimension, empowerment, is based on secondary education and the number of seats in parliament occupied by women. The gender inequality index ranges from 0 to 1. Since this index measures inequality, a higher index value represents high gender inequality, indicating a worse outcome. A lower value of the gender inequality index represents low gender inequality, showing promising conditions where women enjoy equal rights and opportunities in the country as men. For example, the values of the gender inequality index for Afghanistan and Austria were 0.678 and 0.053 in 2021, respectively [15].

The independent variable in our study is E-government maturity (EGM), which is operationalized using the Online Service Index. It is one of the three sub-indices of the E-government Development Index in E-government Survey Reports published by the United Nations [16]. The online service index captures the extent of ICT use in public service delivery by various countries and measures their current level of maturity. Its value ranges from 0 to 1, where a higher value indicates a higher level of e-government maturity. The online service index has been widely used in the past literature to measure e-government maturity in cross-country studies [3, 4, 8].

This study uses government effectiveness (GEF) as a moderating variable operationalized using one of the worldwide governance indicators, government effectiveness, published by the World Bank. Government effectiveness captures the quality of policymaking by the government, the credibility of the government's commitment to such policies and their implementation, and the degree of its independence from political pressures [17]. Its value ranges from -2.5 (weak governance) to $+2.5$ (strong governance).

The study uses several control variables to address the issue of omitted variable bias. We have selected control variables based on the existing literature on gender inequality. We control the effect of macroeconomic conditions, urbanization, demography, foreign direct investment, and agriculture dependence on gender inequality. Gross domestic product (GDP) per capita represents the macroeconomic conditions, while for urbanization, we use the percent of the urban population residing in the country. Age dependency ratio is used to control for demography as a more dependent population, i.e., people younger than 15 or older than 64, mean more responsibility on the female member to care for the dependent family members, forcing them to stay indoors. Table 1 presents the summary of variables used in the study.

Table 1. Summary of variables and their sources.

Variable	Notation	Description	Data Source
Dependent Variable			
Gender Inequality Index	GI	GI is a composite index of gender inequality with three dimensions: reproductive health, empowerment, and labour force	Human Development Report
Independent Variable			
E-government Maturity	EGM	Extent to which government has online presence in delivering public services	United Nations E-Government Survey
Moderating Variable			
Government Effectiveness	GEF	Captures the quality of policy formulation and implementation, government's commitment to such policies, and quality of civil service	World Bank World Governance Indicators
Control Variables			
Log of GDP per Capita	GDP	Log transformation of economic output of a country measured as the ratio of the country's GDP to its population	World Bank
Percentage of Urban Population	PUP	Urban population refers to people living in urban areas as defined by national statistical offices	World Bank
Age Dependency Ratio	ADR	Ratio of dependents, i.e., people younger than 15 years or older than 64 years, to the working age population, i.e., between 15–64 years of age	World Bank

(*continued*)

Table 1. (*continued*)

Variable	Notation	Description	Data Source
Foreign Direct Investment	FDI	Net inflows as a percentage of GDP	World Bank
Agricultural Dependence	AGRI	Agriculture value added as a percentage of GDP	World Bank

4 Analysis and Results

Our study used a balanced panel dataset instead of a cross-sectional dataset since it offers several advantages over the latter. Some of them are (i) controlling for issues of endogeneity due to omitted predictor variables, if any, and (ii) examining the dynamic relationship between study variables over time, which is not possible in a cross-sectional dataset [18]. The sample dataset consists of 139 countries covering a period of eighteen years. The data is available for 2003, 2004, 2005, 2008, 2010, 2012, 2014, 2016, 2018 and 2020. The list of countries considered in the study is provided in Table 4 in the Appendix. We excluded the countries having high missing values from our sample dataset. We have used open-source software R for the analysis. The descriptive statistics and pairwise correlations for variables used in the study are provided in Table 5 in the Appendix.

4.1 Hypothesis Testing

We employed a two-way fixed effects panel regression model to test the proposed hypotheses in the research model. The advantage of the two-way fixed effects model is that it addresses endogeneity concerns due to unobserved heterogeneity across the countries as well as unobserved heterogeneity over time [19, 20]. Although multicollinearity is not a significant concern in panel data analysis [21], we have done centering on the independent and moderating variables to address the issue of multicollinearity due to the interaction term in the model [22]. The variance inflation factor (VIF) values lie in the range of 1.01 to 2.84 using the random effects regression model, which is below the threshold of 5 [23]. The Hausman specification test was done to decide between the fixed effects and random effects models [24]. The test results suggest that the fixed effect model performs better than the random effect model. The Augmented Dicky-Fuller test is conducted to check for seasonality (unit root) [25]. The test results confirmed no seasonality in the data. To check for heteroskedasticity and serial correlation in the data, we conducted the Breusch-Pagan test [26] and the Breusch-Godfrey/Wooldridge test [27], respectively. The test results confirmed the presence of both heteroskedasticity and serial correlation in the data. The Pesaran CD test (for $T \leq N$) was performed to test for cross-sectional dependence of the data, i.e., to check whether residuals are correlated across countries [28]. The test confirmed the presence of cross-sectional dependence in the data. We have used robust standard errors to estimate our model based on these diagnostic test results [29].

Table 2 presents the main results of our regression analysis. We can see that e-government maturity is negatively associated with gender inequality, i.e., our hypothesis H1 ($\beta = -0.028$, $p < 0.05$) was supported. The interaction between e-government maturity and government effectiveness is also found to be significant. It means that government effectiveness is moderating the relationship between e-government maturity and gender inequality such that it amplifies the negative effects of e-government maturity on gender inequality, i.e., our hypothesis H2 ($\beta = -0.018$, $p < 0.01$) was supported.

Table 2. Main results (With no lag)

Variables	Model 1 GI	Model 2 GI	Model 3 GI	Model 4 GI
EGM	−0.033**	−0.025**	−0.030**	−0.028**
	(0.014)	(0.012)	(0.013)	(0.012)
GEF		−0.028***	−0.041***	−0.043***
		(0.004)	(0.007)	(0.007)
EGM * GEF				−0.018***
				(0.006)
GDP			0.146***	0.139***
			(0.031)	(0.030)
PUP			0.118***	0.113***
			(0.031)	(0.029)
ADR			0.127***	0.143***
			(0.027)	(0.027)
FDI			0.013***	0.013***
			(0.005)	(0.005)
AGRI			0.054*	0.065**
			(0.032)	(0.033)
R-squared	0.011	0.037	0.098	0.103
#Observations	1390	1390	1390	1390
#Countries	139	139	139	139
Model	Fixed effect	Fixed effect	Fixed effect	Fixed effect

Robust Standard Error in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

The above findings are also illustrated as an interaction plot in Fig. 2. When the government effectiveness is high, the negative effect of e-government maturity on gender inequality is stronger. In contrast, when the government effectiveness is low, the negative impact of e-government maturity on gender inequality is weaker.

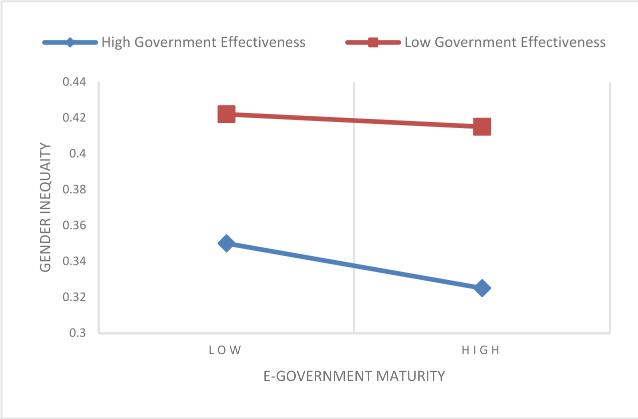

Fig. 2. Interaction Plot

4.2 Robustness Check

We conduct additional analysis to establish the robustness of our findings. First, we provide the results obtained from alternative model specifications. Table 3 provides the regression outputs of pooled OLS and random effects models in Model (5, 6) and Model (7, 8). Both hypotheses were supported, indicating the relationship is not model-dependent, thus increasing the reliability of the findings. Second, as previous research has suggested, to address the concerns of reverse causality, we used lagged variables in our regression model [3, 30]. The results of these models are provided in Table 3 in Model (9, 10). The findings are similar to the main results, and both hypotheses were supported. Past literature has also provided evidence that e-government initiatives may have a delayed impact on developmental outcomes [18, 31].

Table 3. Results of robustness check

Variables	Model 5 GI	Model 6 GI	Model 7 GI	Model 8 GI	Model 9 GI	Model 10 GI
EGM	−0.122***	−0.114***	−0.108***	−0.104***	−0.027**	−0.026**
	(0.016)	(0.018)	(0.021)	(0.021)	(0.011)	(0.011)
GEF	−0.072***	−0.065***	−0.027***	−0.030***	−0.034***	−0.036***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.007)	(0.007)
EGM * GEF		−0.085***		−0.041***		−0.018***
		(0.012)		(0.012)		(0.006)
GDP	−0.119***	−0.104***	−0.063*	−0.064**	0.114***	0.108***
	(0.021)	(0.021)	(0.033)	(0.030)	(0.033)	(0.032)

(*continued*)

Table 3. (*continued*)

Variables	Model 5 GI	Model 6 GI	Model 7 GI	Model 8 GI	Model 9 GI	Model 10 GI
PUP	0.017	0.031*	−0.244***	−0.226***	0.077***	0.073***
	(0.019)	(0.018)	(0.062)	(0.061)	(0.016)	(0.015)
ADR	0.266***	0.325***	0.194***	0.226***	0.095***	0.110***
	(0.046)	(0.049)	(0.051)	(0.048)	(0.028)	(0.029)
FDI	−0.001	−0.002	0.015**	0.016**	0.012**	0.012**
	(0.011)	(0.012)	(0.007)	(0.007)	(0.005)	(0.005)
AGRI	−0.110***	−0.037***	0.068*	0.086**	0.062*	0.072**
	(0.017)	(0.014)	(0.037)	(0.037)	(0.033)	(0.033)
Intercept	0.701***	0.601***	0.647***	0.626***		
	(0.101)	(0.105)	(0.138)	0.126		
R-squared	0.771	0.779	0.450	0.462	0.069	0.074
#Observations	1390	1390	1390	1390	1390	1390
#Countries	139	139	139	139	139	139
Model	pooled OLS	pooled OLS	Random effect	Random effect	Fixed effect	Fixed effect
Lag	Zero-lag	Zero-lag	Zero-lag	Zero-lag	1-year lag	1-year lag

Robust Standard Error in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

5 Discussion and Implications

The main objectives of the study are (1) to explore the potential relationship between a country's e-government maturity and gender inequality over a period of time and (2) the role of government effectiveness in moderating the relationship between e-government maturity and gender inequality. Our two-way fixed effects panel regression analysis on a dataset from 139 countries indicates a negative association between e-government maturity and gender inequality. This finding suggests that e-government can be a powerful empowering tool to achieve development outcomes by enhancing public service delivery and bolstering the connection between government and citizens. The results are also in line with previous research findings [3]. E-government initiatives are equally accessible to all citizens. It also enables people, especially marginalized ones, including women, to be aware and involved in social and political issues due to access to all the information and resources through online platforms. The benefits of various social schemes run by the government can directly reach women through e-government, empowering them economically.

Moreover, government effectiveness was found to be moderating the relationship between e-government maturity and gender inequality such that with higher government effectiveness, the potential of e-government initiatives in achieving developmental goals such as reducing gender inequality is enhanced. This implies that governments should be effective in policymaking and implementation so that the e-government initiatives are well-designed as per the needs of the citizens and the resources are allocated strategically to support these initiatives. For example, governments committed to such policies invest in digital literacy training for women to ensure their accessibility to e-government portals/platforms which can lead to favourable outcomes.

Our study offers several implications for research and practice. First, we establish theoretically the potential relationship between e-government maturity and gender inequality at the macro level and provide empirical support through a longitudinal analysis. Second, we contribute to e-government literature, focusing on its potential to achieve higher-order development goals, such as reducing gender inequality at a global level. Third, we add to the existing literature on gender equality, showing e-government as a potential driver to achieve it. Fourth, we also demonstrate the significance of institutional factors in the country, such as government effectiveness in realizing the full potential of e-government in achieving its objectives.

For policymakers, it becomes essential to modernize the public service delivery systems with the integration of ICT to achieve its social objectives. E-government initiatives can strengthen the government-citizen connect and thus enable the government to reach out to marginalized groups, including women. The policymakers should keep in mind that the full potential of e-government initiatives can't be realized unless government effectiveness is in place. A government can only succeed in e-government initiatives to achieve its developmental goals when its national institutions are effective, civil servants are competent, and the government is committed to such policies.

5.1 Limitations and Future Research

Although we tried to take necessary precautions in conducting this study, our research has few limitations. These limitations should provide new opportunities for future work. First, the study has used secondary data collected from publicly available databases. Thus, it limits the choice of variables used in the study. Since to operationalize our dependent variable, we have used the gender inequality index, which has three dimensions related to health, labour, and empowerment. Future work may consider other dimensions or indices to operationalize gender inequality. Second, we have considered governance effectiveness as an institutional factor. Future research may consider other institutional factors that can be potential moderators in the study. Third, our study is focused on analyzing the relationships at a macro level. Future research may examine these relationships at a micro level in different regions using primary data collection or other approaches. Fourth, even though we have done robustness checks to validate the results, future research may employ more advanced techniques to address the concerns related to endogeneity.

6 Concluding Remarks

Given the dearth of macro-level studies focusing on the potential of e-government maturity in achieving higher-order development goals, the current research is arguably one of the first to investigate the relationship between e-government maturity and gender inequality using panel data covering 139 countries over almost eighteen years. We use empowerment theory and institutional theory to establish the e-government and gender inequality relationship and the moderating role of government effectiveness, respectively. Our findings show that a country's e-government maturity is negatively associated with gender inequality. Also, government effectiveness is found to be playing a significant role in moderating this relationship. With higher government effectiveness, the negative effect of e-government maturity on gender inequality increases, whereas with lower government effectiveness, this relationship becomes weaker. We believe that our research adds to the developmental agenda of e-government and would encourage future research in this direction.

Appendix

Table 4. List of countries used in the study.

Albania, Algeria, Angola, Argentina, Australia, Austria, Azerbaijan, Bahamas, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Chad, Chile, China, Colombia, Congo Rep., Costa Rica, Cote d'Ivoire, Croatia, Cyprus, Czechia, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Eswatini, Ethiopia, Fiji, Finland, France, Gabon, Gambia, Georgia, Germany, Ghana, Greece, Guatemala, Guinea, Guyana, Honduras, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Korea Rep., Kuwait, Kyrgyz Republic, Lao PDR, Latvia, Lesotho, Lithuania, Luxembourg, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Mauritania, Mauritius, Mexico, Moldova, Mongolia, Mozambique, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, North Macedonia, Norway, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Russian Federation, Rwanda, Sao Tome and Principe, Saudi Arabia, Senegal, Sierra Leone, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sri Lanka, Sudan, Sweden, Switzerland, Tanzania, Thailand, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkiye, Turkmenistan, Uganda, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Uzbekistan, Vietnam, Zimbabwe

Table 5. Descriptive statistics

	Variables	M	SD	1	2	3	4	5	6	7	8
1	GI	0.38	0.18	1.00							
2	EGM	0.46	0.26	−0.71	1.00						
3	GEF	0.08	0.96	−0.80	0.70	1.00					
4	GDP	4.05	0.50	−0.83	0.69	0.82	1.00				
5	PUP	0.58	0.23	−0.63	0.60	0.62	0.80	1.00			
6	ADR	0.60	0.18	0.72	−0.56	−0.58	−0.79	−0.57	1.00		
7	FDI	0.05	0.19	−0.08	0.02	0.10	0.09	0.09	−0.10	1.00	
8	AGRI	0.11	0.11	0.68	−0.58	−0.66	−0.84	−0.72	0.71	−0.08	1.00

Note. #Countries = 139; M: Mean; SD: Standard Deviation; GI: Gender Inequality; EGM: E-government Maturity; GEF: Government Effectiveness; GDP: Log of GDP per capita; PUP: Percentage of Urban Population; ADR: Age Dependence Ratio; FDI: Foreign Direct Investments; AGRI: Agriculture Dependence; Correlations greater than |0.02| are significant at $p < 0.05$ (two-tailed).

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Healthcare IT Adoption

Blockchain and Onion Routing-Based Secure Data Management Framework for Healthcare Informatics

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Abstract. Healthcare is undeniably a paramount concern for both individuals and nations alike. Its significance extends beyond just individual well-being, as the state of healthcare plays a pivotal role in the overall growth and stability of a nation's economy. Recognizing this, industry and academics have embarked on various pioneering initiatives aimed at improving the quality of healthcare decisions and services. These efforts have remarkably transitions in healthcare frameworks, progressing from Healthcare 1.0 to Healthcare 5.0. Nowadays, wearable devices make the healthcare analysis of any individual easy. Doctors/hospitals can take the data, analyze it and suggest the diagnosis. But, this is not easy as we think. It is because of security issues where attackers can tamper with the wearable device message before reaching the concerned doctor. The modified message can misguide the doctor with an accurate diagnosis. This leads to a more severe cause for the patent and can endanger the patient's life. Existing frameworks are mainly focusing on traditional cryptographic and blockchain solutions, which offer some level of security but no anonymity. Motivated by this, we proposed an artificial intelligence (AI), blockchain and onion routing-based secure and anonymous healthcare data management framework for wearable devices in this paper. Onion routing offers high security and anonymity with multi-layer encryption, whereas AI is used to distinguish malicious non-messages from malicious ones. Blockchain is used to authenticate the intermediate nodes of the onion network.

Keywords: Artificial Intelligence · Blockchain · Onion Routing · Healthcare · Security · Data Management

1 Introduction

Technological innovations are instrumental in the transformation of the healthcare sector. The manufacturing industry has seen a massive transformation through Industry 4.0. The same is applicable to the healthcare industry, which

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has seen a revolution from Healthcare 1.0 to 4.0 [3]. With Industry 5.0 being the next stage of the revolution, the healthcare segment has simultaneously seen growth with the advent of Healthcare 5.0 [5]. The aim of Healthcare 5.0 is to use technology and improve patient outcomes and the entire system of healthcare management. This also involves the use of technologies like blockchain and artificial intelligence. The healthcare industry has seen a revolution from the period of 1970 to the current situation [7]. Healthcare 1.0 was in the period 1970 to 1990 when the reports of patients were more doctor centric and the emphasis was on physical records or files. Healthcare 2.0 saw the phase of digitalization, which is moving existing processes to digital technologies where electronic records are kept. Here, the data was kept at a central level, which had access to all. This phase was more data-driven and communication was better than in the previous stage. The transit from Healthcare 2.0 to 3.0 (2006–2015) saw a major transit from centralization to decentralization, where the human relationship between the doctor and patient transferred to more human and technology intervention. The advent of Healthcare 3.0 also came with the concept of Web 3.0, enabling user-customization of how patient healthcare records were shared [9]. Humans started having wearable devices, which were quick, cost-efficient and gave immediate outputs. In the phase of Healthcare 4.0 that lasted from 2016 to 2019, the focus was more on real-time data collection and multimedia management. There is a sea change in the healthcare segment from a doctor-centric approach in Healthcare 1.0 to a patient-centric one in Healthcare 5.0, which began in 2020 where the use of wearable devices in the form of a smartwatch, which monitors almost all the levels of the patient and is highly cost-effective also. Thus, Healthcare 5.0 gives a more personalized approach to patients.

Initially, digitalization in healthcare was used for taking appointments or consulting on video calls for ease of use. However, there is an increased demand for better patient outreach and personalization. This needs Internet of Things (IoT) systems that allow the communication of different sensor devices. The recent development in healthcare for real-time patient diagnosis is wearables, which are equipped with multiple healthcare sensors, such as temperature, oxygen saturation, heart rate, etc. The sensor reading of each wearable can be stored in the Electronic Health Record (EHR), which is maintained centrally at the hospital. Today, in the era of computing, all the sectors in Industry 5.0 exchanged data over wireless channels. Wireless channels are highly vulnerable to security attacks. The data is exchanged over the wireless channel, which is susceptible to various security issues/attacks, such as data modification, spoofing, etc.

To overcome the aforementioned issues, cryptography is a plausible solution [8]. Wearable devices exchange individuals' health information on the go. It is important to have enhanced security to safeguard the security and privacy of the patient's health information, including managing who can view the patient's health records. Traditional cryptography offers single-layer encryption, which can be easily broken using quantum computing. This can be taken care of with an advanced security algorithm, such as an onion routing (OR) network. It is a multi-layer encryption algorithm in which multiple keys are used to decrypt each

OR encryption layer. Along with high security, OR also offers anonymity. It is of utmost importance in the case of wearables. Any individual's health information must be anonymous (attackers should not be visible with the origin of the information) to protect privacy. The overall complexity increases when we move from single-layer to multi-layer encryption. Thus there is a need for a mechanism that helps reduce the system's complexity. Also, Malicious messages (temper with the data by hackers) lead to serious conditions for the patient. Malicious messages misguide doctors and hospitals for better and timely diagnosis.

The use of artificial intelligence (AI) is the best practice to minimize the complexity of the system and filter non-malicious messages from malicious ones. In Healthcare, information analysis is important, which helps classify the data messages as malicious or non-malicious [1]. This is called healthcare informatics. We employed AI algorithms to classify wearable device messages as malicious or non-malicious. Motivated by this, we propose an AI and OR-based healthcare informatics framework for secure health data management of wearable devices in this paper. We employed blockchain technology to strengthen further the AI and blockchain-based healthcare informatics framework for data management. Adding blockchain to the ecosystem of healthcare is something that is of utmost importance. A blockchain is a database of sequential blocks, stored in multiple decentralized and independent nodes [6,9]. Thus, Blockchain is a relatively recent trend, which has promises in a number of applications for both civilian and military contexts [2]. Blockchain is a disruptive technology, which has emerged in the last few years in the healthcare sector for security purposes [6]. The Use of blockchain can provide necessary guarantees for the secure processing, sharing, and management of sensitive data. In the proposed framework, we use blockchain technology to store the verifying token for the nodes involved in the OR. Whenever the sender shares the data with multiple encryptions, it stores verifying tokens to blockchain and encryption keys. When any node receives an encrypted packet with the attached verifying token, it first matches the token with the stored token in the blockchain. If both are the same, then the onion node will decrypt only the message. This ensures the authentication of the onion node.

1.1 Research Contributions

The major contributions of the paper are as follows.

- We propose an OR-based secure healthcare data management framework for wearable devices to strengthen data exchange and patient diagnosis. The proposed framework also protects patients' privacy by maintaining the anonymity of healthcare data.
- We integrate AI algorithms to classify data packets exchanged by wearable devices with the doctor/hospital over the OR network as malicious or non-malicious. This minimizes the overall complexity of the proposed framework.
- We collaborate blockchain technology with the OR network to authenticate nodes involved in the network.

1.2 Organization

The rest of the paper is organized as follows. Section 2 discusses the proposed OR-based healthcare data management framework for wearable devices. Section 3 concludes the paper.

2 The Proposed Framework

This section discusses the proposed blockchain and onion routing-based healthcare data management framework. The proposed framework ensures high security, privacy, and anonymity of the wearable device data exchanged between the device and the hospital/doctor. The proposed framework is divided into four diverse layers: data collection layer, intelligence layer, security layer, and EHR layer. The data collection layer has patients with wearable devices, the intelligence layer classifies the health data as malicious or non-malicious, the security layer ensures the safe delivery of data to the hospital, and the EHR layer collects data received from the data collection layer. The detailed description of each layer of the proposed framework is described as follows (Fig. 1).

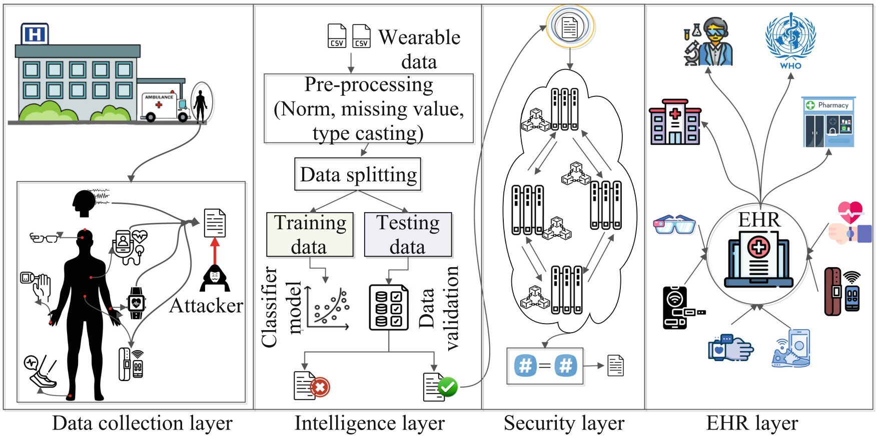

Fig. 1. The proposed secure and anonymous healthcare data management framework for wearable devices.

2.1 Data Collection Layer

This layer comprises p patients and w wearable devices. The patient and wearable sets are defined as $\{1, \ldots, p\} \in \mathbb{P}$ and $\{1, \ldots, w\} \in \mathbb{W}$, respectively. Here, the number of patients and the number of wearable devices are equal, i.e., $p \equiv w$. Each wearable device w is equipped with s sensors, such as temperature, SPo2, heart rate, etc. The sensor set is defined as $\{1, \ldots, s\} \in \mathbb{S}$. The total number of sensors present in the data collection layer is represented as follows.

$$\mathbb{S}_T = n(\mathbb{S}) \times n(\mathbb{W}) \tag{1}$$

where $\mathbb{S}_T$ is the total number of sensors in the data collection layer. $n(\mathbb{S})$ signifies the count to total sensors deployed in a single wearable device $\mathbb{W}_i$. $n(\mathbb{W})$ denotes the count of total wearable devices deployed in the data collection layer. This layer collects data D from all the wearable devices and stores it as a *.csv* file. The destination of data D is the EHR layer, where hospitals/doctors can analyze it and diagnose the disease. As the channel is wireless, we can not think of it as ideal. The wireless channel is open and highly vulnerable to security risks. An attacker $\mathbb{A}$ can forge the data traveling between $\mathbb{W}_i$ and EHR. To protect the same, we need to pass the data D to the EHR layer via intelligence, followed by the security layer. The data D collected from this layer can be passed to the intelligence layer.

2.2 Intelligence Layer

This layer aims to efficiently classify malicious and non-malicious wearable data by training the AI classifiers. Toward this goal, first, we used a standard dataset [4] where researchers have used the IoT-Flock tool to gather healthcare data traffic comprising of both malicious and non-malicious. The dataset (D) comprises of two data, i.e., attack and environment monitoring; we combined both datasets to strengthen the performance of healthcare systems. Here, the D has different sensor data associated with the wearable; formally, it has data of $\mathbb{S}_t$ from the data collection layer.

$$D \xrightarrow{\text{has}} \mathbb{R}^{p \times q} \tag{2}$$

where, p and q are the rows and columns of D. Since the dataset is not preprocessed, we apply standard pre-processing steps, such as filling in missing values and Not a Number (NaN) with central tendency values (mean (μ)). Standardized the dataset with min-max scalar (Ψ), applied explicit type casting (i.e., float $\rightarrow$ int), and label encoded the categorical values into the numerical format.

$$D = \begin{cases} \{\text{NaN}, \phi\} \xrightarrow[\text{by}]{\text{handled}} \mu \\ \left.\begin{array}{l} q_{i,j} >> q'_{i,j} \\ q_{i,j} >> q'_{i,j} \end{array}\right\} \xrightarrow[\text{by}]{\text{handled}} \Psi \\ \Phi \xrightarrow{\zeta} \{0, 1, 2, \ldots\} \\ \text{float} \xrightarrow{\text{type casting}} \text{int(float)} \end{cases} = D' \tag{3}$$

where, ϕ is the missing value, ζ is the label encoder, and D' is the preprocessed dataset. Once the dataset is preprocessed, D' is splitted into the training D'_{TR}

and the testing dataset D'_{TS}. The training dataset is forwarded to the incorporated AI classifiers, such as RF, KNN, NB, and SVM, for classification tasks. Once all the classifiers are trained, it is evaluated with the testing dataset D'_{TS}. From the result analysis, we analyzed that the RF achieves better accuracy in detecting (or classifying) malicious and non-malicious wearable data. Hence, RF is considered the best AI classifier among others. Further, the non-malicious wearable data is forwarded to the security layer, where OR is applied, which offers enhanced security and robust anonymity to the wearable data.

2.3 Security Layer

The non-malicious wearable data is forwarded from the intelligence layer to the security layer, which comprises of an onion routing network denoted with Υ. It consists of multiple onion routers, such as $\{\upsilon_1, \upsilon_2, \ldots, \upsilon_m\} \in \Upsilon$, where each υ_i is an anonymous onion router hidden from the surface (public) Internet. This fact offers anonymity to the OR users. Further, Υ uses multi-layered encryption at each υ_i for securely relaying the encapsulated data from the source to its intended destination. With such essential benefits, we utilized Υ for the proposed work, which provides an end-to-end secure communication pipeline to relay non-malicious wearable data to the EHR. Here, the source sensor $s_i \in \mathbb{S}$ wants to transmit the wearable data (π_i), which belongs to $\{\pi_1, \pi_2, \ldots, \pi_p\} \in \Pi$ to the EHR $(\mathbb{E})$. First, s_i calculates the hash of the π_i, denoted as π_i^h for handling data integrity issues. Then, for encryption, we utilized advanced encryption standard (AES), where s_i has to compute public and private key pairs between s_i and π_i for encrypting and decrypting wearable data. Next, each $\upsilon_i \in \Upsilon$ is associated with two additional information, i.e., profiling parameter (ϱ) and verifying token (ν). The profiling parameter consists of different factors, such as decryption time, bandwidth utilization, memory utilization, and data rates. So based on the aforesaid factors, the Υ selects the best onion routers for relaying π_i. Generally, it provides three onion routers, i.e., guard (υ_i^g), middle (υ_2^m), and exit node (υ_3^e) to establish communication between s_i and $\mathbb{E}$. Further, the verifying token is used to strengthen the security of Υ, wherein each layer, a ν, is generated for υ_i and gets stored in the blockchain immutable ledger. So whenever an incoming multi-layered encrypted message with ν arrives at υ_i, the already stored ν from blockchain and just arrived ν is compared. If both ν are same then, υ_i can decrypt the encrypted message otherwise, we discard υ_i from the Υ.

Source sensor s_i uses AES to apply multi-layered encryption to the hashed wearable data (π_i^h). Then, it selects the three best onion routers based on their profiling parameter ϱ and forwards the triple-encrypted message to Υ.

$$\mathfrak{E}_3(\mathfrak{E}_2(\mathfrak{E}_1(\pi_i^h))) \xrightarrow{\text{forwards}} \Upsilon \tag{4}$$

where, $\mathfrak{E}_3, \mathfrak{E}_2, \mathfrak{E}_1$ is triple-encrypted message. Moreover, each encryption layer is composed of verifying token (ν) for verifying the authenticity of υ_i. So when encrypted message $\mathfrak{E}_3(\mathfrak{E}_2(\mathfrak{E}_1(\pi_i^h)))$ with (ν) reaches to first onion router (υ_i^g), it first check whether the already stored ν from blockchain node is same as the incoming ν.

$$(\mathfrak{E}_3(\mathfrak{E}_2(\mathfrak{E}_1(\pi_i^h)))) \xrightarrow{\text{reaches}} \upsilon_i^g \tag{5}$$

Once, ν is verified, the υ_i^g uses its decryption key δ^g to decrypt first layer encryption $\mathfrak{E}_1$. This decryption key is shared by s_i via Diffie-Hellman key exchange algorithm to the selected onion routers (based on ϱ).

$$(\mathfrak{E}_3(\mathfrak{E}_2(\mathfrak{E}_1(\pi_i^h)))) \xrightarrow{\text{reaches}} \upsilon_i^g \xrightarrow[\delta^g]{\text{decrypt using}} (\mathfrak{E}_2(\mathfrak{E}_1(\pi_i^h))) \tag{6}$$

Once the first layer is peeled off, the rest of the encrypted message, i.e., $(\mathfrak{E}_2(\mathfrak{E}_1(\pi_i^h)))$ is forwarded to the next best onion router υ_i^m (as shown in Eq. (6)). Next, again if ν is matched for the middle onion router, then it can use its decryption key (δ^m) to decrypt second-level encryption.

$$\begin{array}{r} (\mathfrak{E}_3(\mathfrak{E}_2(\mathfrak{E}_1(\pi_i^h)))) \xrightarrow{\text{reaches}} \upsilon_i^g \xrightarrow[\delta^g]{\text{decrypt using}} (\mathfrak{E}_2(\mathfrak{E}_1(\pi_i^h))) \xrightarrow{\text{reaches}} \upsilon_i^m \\ \downarrow \\ (\mathfrak{E}_1(\pi_i^h)) \xleftarrow[\delta^m]{\text{decrypt using}} \end{array} \tag{7}$$

Once the second layer is peeled off, the rest of the encrypted message, i.e., $(\mathfrak{E}_1(\pi_i^h))$ is forwarded to the next best onion router υ_i^e (as shown in Eq. (7)). Similarly, for the last layer, if ν verifies the authenticity of the exit onion router, then it can use its decryption key δ^e to decrypt the last layer of encryption.

$$\begin{array}{r} (\mathfrak{E}_3(\mathfrak{E}_2(\mathfrak{E}_1(\pi_i^h)))) \xrightarrow{\text{reaches}} \upsilon_i^g \xrightarrow[\delta^g]{\text{decrypt using}} (\mathfrak{E}_2(\mathfrak{E}_1(\pi_i^h))) \xrightarrow{\text{reaches}} \upsilon_i^m \\ \downarrow \\ \mathbb{E} \leftarrow \pi_i^h \xleftarrow[\delta^e]{\text{decrypt using}} \upsilon_i^e \xleftarrow{\text{reaches}} (\mathfrak{E}_1(\pi_i^h)) \xleftarrow[\delta^m]{\text{decrypt using}} \end{array} \tag{8}$$

Equation (8) shows the entire decryption and relaying process of the encrypted message from s_i to EHR ($\mathbb{E}$). In Eq. 8 the hashed message π_i^h is securely received to $\mathbb{E}$. Now EHR ($\mathbb{E}$) computes the hash for the received hashed message π_i^h. If both the hash are the same, $\mathbb{E}$ can trust the message and allow it to store in their repository; otherwise, discard it. The security layer provides robust encryption, anonymity, and secure passage between source s_i to $\mathbb{E}$ for smart healthcare systems. We want to highlight that the proposed OR network (Υ) is computationally inexpensive due to the incorporation of AI technology. This is because, prior to Υ, AI classifiers classify the malicious and non-malicious wearable data and only allow non-malicious data to pass from the OR network. The intelligence layer discards the malicious data; hence, the OR network has to process only non-malicious wearable data π_i, thus reducing the computational overhead of the Υ. It is also worth to be noted that the proposed OR network is reliable and efficient due to the incorporation of two additional information, i.e., profiling parameter (ϱ) and verifying token (ν). In the Υ, ϱ selects the best onion routers (υ_i) based on their performance factors. Further, ν verifies the authenticity of each υ_i, i.e., whether the onion router is a rogue router or not. These aforesaid enhancements improve the performance of the proposed framework and offer concrete security and privacy solutions to the data management framework for healthcare informatics.

2.4 EHR Layer

The secured wearable data is forwarded to the EHR layer from the security layer. This layer has a storage server that stores the patient's wearable data to automate administrative tasks, provide reporting and analytics, provide clinical decision support, and store and manage patients' health records. The EHR is shared among different hospitals, research laboratories, and healthcare organizations (e.g., World Health Organization) for health information exchange (HIE). It allows healthcare providers to share patient information electronically, which can improve the quality of care and reduce the risk of medical error.

3 Conclusion

In this paper, we proposed a blockchain and onion routing-based intelligent healthcare data management framework for wearable devices. AI performs healthcare informatics by analyzing exchanged data packets as malicious or non-malicious. The proposed framework can offer high security with a high anonymity rate. The anonymity of the message keeps the sender's identity private. This restricts attackers from targeting a particular individual's health data. Overall, the proposed framework can allow doctors to diagnose correctly with high precision for patients' safety.

The proposed work uses blockchain and onion routing as a security mechanism for smart healthcare systems; however, utilizing them increases the latency in the operational performance of the proposed work. Therefore, in future work, we will employ a 5G network to enhance the communication channel and reduce the latency in the proposed framework.

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Detecting and Characterizing Mental Health Using Social Media Analytics

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Abstract. This paper aims to characterize and detect mental health from Twitter users' posts and how the language, user attributes, and tweet attributes are associated with one of the most prevalent mental illnesses, depression. In this study, the social media analytics CUP framework and the Twitter API are used for the data collection of 27408 unique users. Data analysis uses expert input, natural language processing, and statistical methods. The empirical result from the statistical test confirms that linguistic features can represent the social media user's mental illness conditions and attributes of social media posts, and users are significantly associated with mental illness and depression. Mental health is a widespread issue worsened by the pandemic. There's still a stigma attached to it, which discourages open discussions. Digital technology, including social media, can significantly impact our mental health. Hence, the passive mechanism of mental illness characterization and detection from social media can help in timely intervention and provide the necessary support.

Keywords: Twitter analytics · social media · Mental health · Sentiment Analysis

1 Introduction

We are living in the digital era, and none of the aspects of life is untouched by digital technologies, be it entertainment, education, health, or even our daily conversation, which is being mediated by technological platforms. This the digital age is dominated by social media, which is now an integral part of our life. Social networking sites such as Twitter, Facebook, and Instagram enable us to get hyper-connected with our friends and family and the world at large [1]. People use social media for various purposes, such as exchanging information and sharing opinions, thoughts, and emotions; hence, social media platforms like Twitter is considered a public town square [2]. The conversation on social media takes place in a naturalistic environment, and user-generated content post interaction provides valuable insights into individual behavior [3]. By leveraging user-generated content from social media, we can model and predict the various dynamics of human behavior, which can be helpful in tackling issues like mental illness [4]. Mental health is a global epidemic and the recent COVID-19 pandemic amplified it [5]. Mental

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illnesses such as depression and anxiety are considered a social stigma, so people do not talk about it openly; hence, social media plays a critical role in such diseases [6]. Social media can provide real-time insight into the mental health of individuals as well as the population at large [7]. The present paper uses Twitter data to explore whether mental depression can be identified in light of the following questions: RQ1: What linguistic feature characterizes depression in mental health disclosures shared on social media? RQ2: What is the association between user attributes and tweet attributes with depression?

The remaining paper is structured into a brief literature review, research methods, findings, and conclusions.

2 Social Media Use and Mental Health

Mental disease is a leading cause of impairment worldwide. According to the WHO, mental illness is more prevalent than the covid crisis. Anxiety and depression is the most common mental health illness [8]. Unlike physical health, mental health is not easily visible, and due to the stigma attached to it, people hesitate to open up about any mental health-related issue [9]. People on social media express their feelings and emotions with others without the fear of being judged [10]. Social media user communicates over various social platform by exchanging text, photos, and video depending on the nature of the media supported. Social media data contains rich sources of signals about mental illness conditions. While text such as tweets on Twitter, when analyzed using linguistically, reveals the sentiment and depth [11], images shared on Instagram are examined through the lens of visual sociology, such as color, themes provide a deeper understanding of one's mental status [12]. Several studies [4, 10, 13, 14] highlight that social media users' user-generated content depicts their mental health conditions. Social media has also been widely researched for various aspects of mental illnesses such as Alzheimer's [15] and schizophrenia [16]; eating disorders [17]; and various other diseases such as diabetes, and cancer [18]. People with mental illness often use social media platforms like Twitter to seek information and support [1]. Social media facilitates interaction and peer support for mental illness issues [19, 20].

3 Social Media Analytical Framework

In today's digital world, social media has become an integral part of our lives and is present in every sphere of our existence. Social media can be accessed through social networking sites as well as mobile apps such as Facebook, Twitter, Instagram, and Snapchat, through which people connect with each other. by sharing text messages, photos, and videos [21, 22]. Social media analytics refers to the process of collecting, analyzing, and visualizing data by employing a specific framework such as CUP [23] and SPIN [24]. In this study, we have used the CUP framework as depicted in Fig. 1(a). The initial stage of social media data collection involves the acquisition of relevant data from social media platforms using specific criteria like keywords, hashtags, etc., and this is achieved by employing a range of techniques, such as utilizing platform-specific APIs using or web scraping using tools as well as programming language R and Python.

The data extracted from social media is not readily available for analysis hence pre-processing of data is required before any meaningful analysis can be done through a series of tasks, as shown in Fig. 1(b). The understanding phase involves analyzing the data using various analytical methods, such as sentiment analysis and text mining, for pattern identification for obtaining insights. Analytical methods allow us to delve deeper into the data and uncover meaningful insights that may not be immediately apparent. The last stage is a presentation where the insights uncovered in the previous stage are summarized in a meaningful way to communicate the findings for decision-making or expand the understanding of the phenomenon under study [25]. Social media analytics is used in various domains, such as in healthcare, to understand the socio-technical perspective [18] and in business for new product development [26].

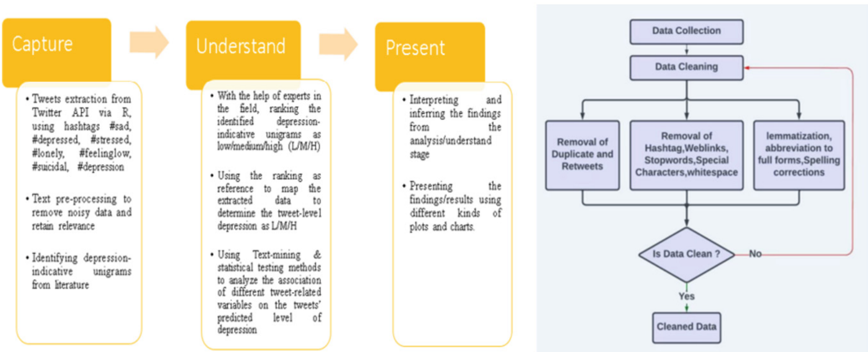

Fig. 1. (a) CUP Framework for Social Media Analytics (b) Steps for pre-processing of the social media data

4 Method and Data Sources

Among the social media platforms available, such as Facebook and Reddit, we chose Twitter because of its unrivaled popularity as a micro-blogging site, with over 275 million people worldwide [27, 28]. For this study, we collected a total of 52,375 tweets related to depression from 27,408 users via Twitter's API using R based on at least one of these or a combination of hashtags: #depressed, #stressed, #lonely, #feeling-low, #suicidal, #depression, and #sad. After the pre-processing of the data, analysis was performed in two stages, as described in a further section. Social media analytics using Twitter is broadly classified into various categories: descriptive analytics, content analytics, network analyses, and space-time analytics, and is applied depending on the content and nature of the phenomenon being studied [29]. Social media is one main source of big data, and through the exploration of big data, health practitioners and researchers are uncovering a promising avenue to detect linguistic markers or patterns that may be associated with mental health disorders such as depression, schizophrenia, or suicidal behavior [30, 31]. Big data extracted, when analyzed with state-of-the-art method natural language processing, machine learning uncovers the insight for causal inferences [32, 33]. The social media analytics-driven method gives a competitive advantage over the traditional method because of its veracity, velocity, and volume [34].

4.1 Characterizing Depression Based on Unigram

Twitter allows people to post on its platform, called tweets, where text is a major element and another user can interact with tweets by liking, commenting on, or retweeting them. In the first phase, our unit of analysis is tweet-text to understand the depression level. The tweet is a sentence of 140 characters or more in length, and to analyze the tweet text, the natural language processing the method is used as we are using linguistic features to characterize depression. The natural language processing tool kit (nltk) converts the tweets from sentences to n-grams, the smallest units of a sentence, to understand the pattern and frequency of the words used. In the current study, we converted tweets into unigrams after applying nltk, which refers to a single word or token in a sequence of text. The unigram, being the smallest unit in the sentence, helps to identify the structure and understanding of the usage of words in the tweet text. Further, to characterize the depression level from the unigram obtained from the tweet text of the user and with the help of experts, each tweet is mapped with popular depression-indicative unigrams identified from the literature [35, 36] as shown in Table 1 after that experts ranked this indicative unigram into the low, high and medium depression level as depicted in Fig. 2 and its distribution shown in Fig. 3

Table 1. Depression-indicative unigrams identified from the literature

Loser	Depress	Lonely	Sad	Alone	Unsuccessful
Useless	Life	Imbalance	Blame	Problems	Intimidate
Suicidal	Safe	Escape	Kill	Nobody	Conversation
Uncomfortable	Therapy	Medication	Shit	Worry	Mine
Hurts	Myself	Worth	Break	Pressure	
Painful	Hate	Suck	Torture	Weak	

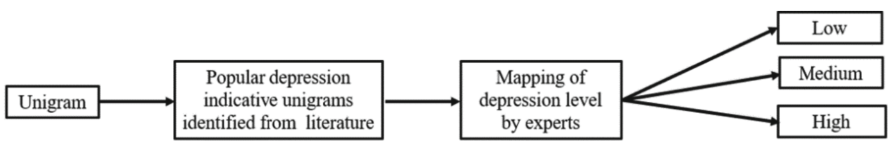

Fig. 2. Mapping of depression indicative unigram.

After the characterization of popular depression indicative unigram by the expert to perform the detection of the level of depression, the depression score for each tweet was determined by mapping it against each of the expert-ranked unigrams list. The presence of words from these lists was used to calculate a collective score, providing insight into

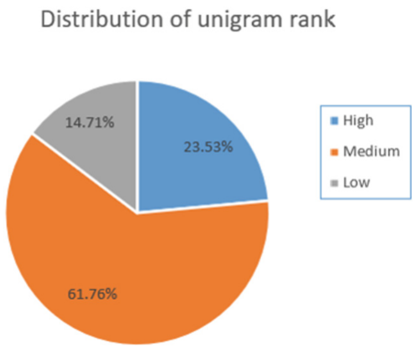

Fig. 3. Distribution of unigram based on ranking by expert.

the level of depression expressed in each tweet. Each tweet was assigned a depression score ranging from 0 to 9. This score was then used to categorize the tweets as having a low, medium, or high level of depression. Tweets with a depression score in the range of 0 to 3 were classified. as low, those with a score of 3 to 6 were considered medium, and tweets with a score of 6 to 9 were marked as high in terms of their tweet-level depression, as depicted in Fig. 4.

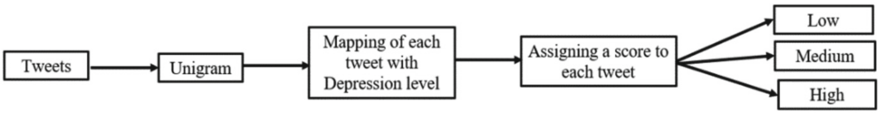

Fig. 4. Assignment of score to each tweet by expert

4.2 Association of Depression Level with User Attributes and Tweet Attributes

In the previous section, we characterized and detected the depression level based on tweet text which is one of the major mental health challenges faced by billions of people across the globe, as per the world health organization report. In this the phase of analysis, we analyzed various attributes of user posts. While the tweet text is a major element, each tweet has various attributes, too, as depicted in Fig. 5. Literature indicated that tweet attributes like time and length exhibit the user's mental illness propensity and, similarly, user interaction with their own network, such as followers can be a proxy for depression measurement. The hashtag plays a key role in magnifying the user post on social media across the user network. People with mental illness use several hashtags, such as #selflove #selfcare and #mentalhealthmatters, to garner social support. The frequency of tweets indicates active self-disclosure and engagement as a coping strategy for mental illness [37].

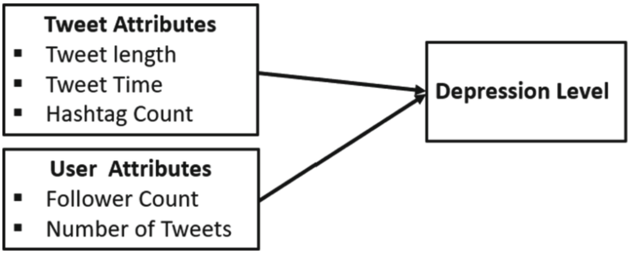

Fig. 5. Various attributes of Tweets and their association with depression level

5 Results

5.1 Descriptive Analysis

A visual depiction of word frequency is known as a "word cloud." The size of each word in the generated image indicates its frequency in the analyzed text; the larger the word, the more frequently it appears. The word cloud is widely used across the domain of politics, business, etc., to find the focus of discourse [38, 39]. As shown in Fig. 6 depression is emerging as the center of discourse among users' tweets, while sadness and stress also appear as other factors.

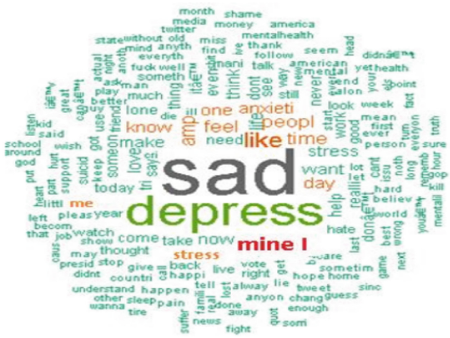

Fig. 6. Word cloud after pre-processing of tweets

Social media is often viewed as a type of laboratory for understanding social behavior. This is because as people exchange thoughts and opinions, they also exhibit emotions through their posts, whether that be in the form of text, photos, or videos. Social media has become invaluable for navigating human behavior's complex and ever-changing landscape [40]. The process of extracting the emotions from the is called sentiment analysis, which is broadly represented as positive, negative, and neutral based on the text of user posts. It's evident from Fig. 7 that negative sentiment is very high, indicating the presence of mental illness among users.

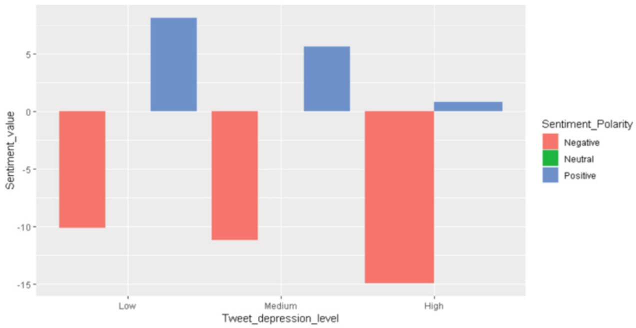

Fig. 7. Sentiment analysis of tweets

Social media is a valuable tool for studying human emotions' complex and multidimensional characteristics and mental illness are highly related to emotions users express through their posts. Emotion valence analyzes the data based on the key emotions of joy, sadness, surprise, anger, fear, disgust, trust, anticipation, and polarity. For this, a score for each emotion per tweet was calculated. Also, a result of an overall analysis of emotions depicted by the tweets is shown below in Fig. 8 and 9. It's very much self-explanatory that negative emotion is very high, followed by sadness among users' posts and reflects their mental illness conditions such as depression.

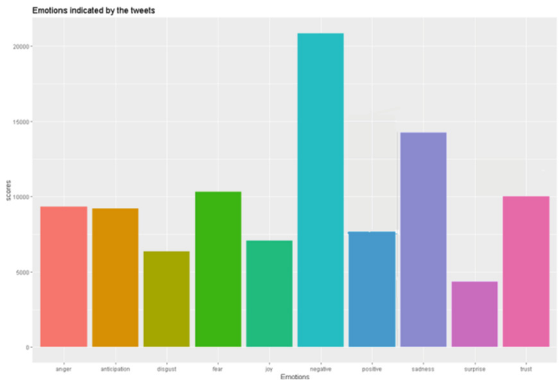

Fig. 8. Emotions valence analysis of tweet

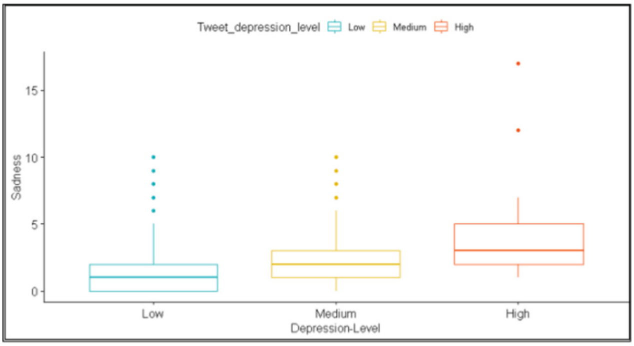

Fig. 9. Association of depression level with emotion of tweet

6 Statistical Analysis

In the preceding section, we highlighted the significant role of sentiment and emotional valence when characterizing depression through user-generated content on social media platforms such as Twitter. These descriptive findings provide valuable insights into the nature of depression and its manifestation in online discourse. This section explains the association of tweet attribute and user attribute with depression level.

6.1 Tweet Length

Literature indicates [11] that the length of the text posted by the user plays a crucial role in obtaining various support on social media platforms. The length of a tweet is determined by the number of characters used, with a maximum of 280 characters allowed. To distinguish between short and long tweets, those with less than 140 characters are labeled as short, while those exceeding that limit are categorized as long. A chi-square test of independence was conducted to examine the relationship between tweet length and the depression level indicated in the tweet. The p-value obtained from this test was 0.00000000000000022, demonstrating the significant impact of tweet length on the identified depression level. The frequency of the size of the tweet is shown in Fig. 10.

6.2 Tweet Time

The temporality of the user post is very critical and can be significant when it comes to the characterization of mental illness among users from social media posts [3]. To understand the temporal association of user tweets we divided them into four categories: Early Morning, Daytime, Evening, and Late Night. The tweets posted between 4:00 am to 9:00 am were categorized as Early Morning, the ones from 9:00 am to 16:00 were marked as Daytime, from 16:00 to 21:00 as Evening, and from 21:00 to 04:00 am as Late Night. The tweet time frequency is shown in Fig. 11. Further, we performed a chi-square test of independence between the time of day a tweet is posted and the level of depression indicated by the tweet. Under the test, the null hypothesis assumes that both the time the tweet was published and the corresponding identified depression level are independent.

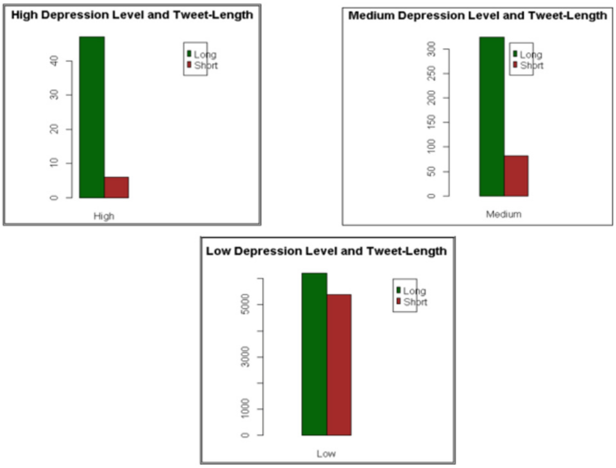

Fig. 10. Tweet Length Type frequency for High, Medium and Low Depression Level Tweets

However, based on the results of the conducted chi-square test, the p-value obtained was 0.000158, which is less than the significance value of 0.05. Hence, the null hypothesis is rejected, indicating an association between the tweet time and its indicated depression level.

Based on previous research, individuals who suffer from depression tend to post most of their tweets during late-night hours. This finding supports the potential link between tweet times and mental health. Late-night tweeting may indicate sleep disturbances or insomnia, commonly associated with stress and anxiety—both factors related to depression. Additionally, the increased engagement in tweeting during late-night hours might suggest a sense of social withdrawal or heightened emotional vulnerability experienced by those facing mental health challenges. Although this analysis does not provide a definitive diagnosis, it emphasizes the importance of tweet timing in comprehending people's mental well-being and the potential for utilizing social media data to recognize patterns that may require further support or intervention.

6.3 Hashtag Count

User, while posting on social media people incorporates hashtags as it helps facilitate visibility and engagement of user post content [41]. Further, we performed a correlation test between the number of hashtags used and the depression score calculated for a tweet, which was conducted using Pearson's correlation method. The p-value obtained from the test was less than the significance level of alpha = 0.05, indicating a significant correlation between the hashtag count and the depression score of the tweet. The negative value of the correlation coefficient of −0.234102 emphasizes a negative association between the two attributes as shown in Fig. 12.

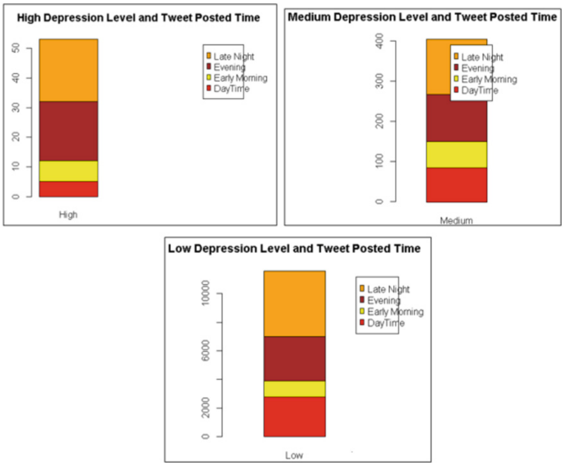

Fig. 11. Tweet Posted Time-frequency for High, Medium, and Low Depression Level Tweets

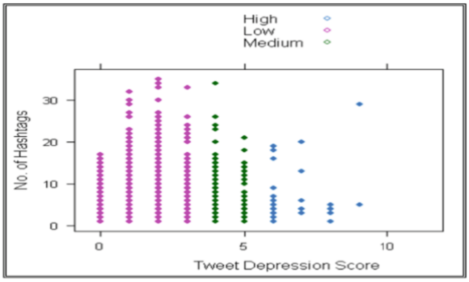

Fig. 12. Depression score of tweets and the hashtags-count used in the tweet

6.4 Number of Tweets

The number of tweets is a user-level attribute, which indicates their activity level on Twitter. To determine if this attribute is related to the depression level indicated by a tweet, a correlation test was conducted. The examination revealed a p-value below the significance level of 5%, indicating an association between the two variables. However, the correlation coefficient obtained was -08731, suggesting a negative association between the user's tweet count and the depression level indicated in their tweet, as shown in Fig. 13.

6.5 Follower Count

Follower count indicates the in-degree connection of the user on the social media platform, which also represents the strength of the social relationship [21]. Based on the results of a correlation test, it has been determined that there is a negative correlation

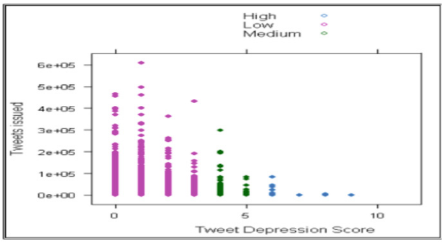

Fig. 13. Depression score of tweets and the tweets count

between the level of depression expressed in a tweet and the number of friends an individual has, as shown in Fig. 14. While the p-value suggests an association below the significance level, the value of Pearson's correlation coefficient is −0.03401133.

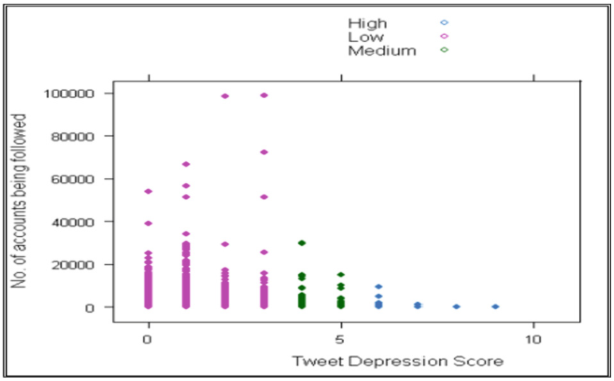

Fig. 14. Depression score of tweets and the follower count

The statistical analysis summary in Table 2 shows how the various attributes are significantly associated with depression among social media users and how each feature is important while characterizing and detecting mental health on social media.

Table 2. Summary of statistical analysis of the association with user & tweet attribute

Attribute	Attribute type	Association with depression level
Tweet Length	Tweet Attribute	Yes (p-value < 0.05)
Tweet Time	Tweet Attribute	Yes (p-value < 0.05)
Hashtag Count	Tweet Attribute	Yes (p-value < 0.05)
Number of Tweets	User attributes	Yes (p-value < 0.05)
Follower counts	User attributes	Yes (p-value < 0.05)

7 Discussion

Mental health is the leading cause of disability globally and a major challenge for society. Unlike physical health, mental health is much more complex as it's a highly stigmatized issue [9], therefore passive characterization & detection mechanisms for mental illness become very important to individuals and the population at large [6]. Social media contains various clues about human behaviour such as communication taking place in real time. In this research work, we demonstrated how user interaction and user-generated content can be leveraged for mental health-related issues such as depression and anxiety. Our research also highlights how attributes of users' posts such as length, time, and the kind of word are associated with mental health conditions and can be a significant passive proxy for mental illness characterization. The user attributes like the number of followers and the following count portray users' social interaction and activity, which is one of the key indicators of mental health. People with severe mental illness conditions tend to withdraw from social interaction hence the user attribute can help in the timely detection of mental health conditions. Based on the results of this research, it is important to note that depression levels were determined solely based on tweets and not at the user level. The sample size of 12,039 pre-processed tweets from 9,544 unique users would not be sufficient to draw conclusions about depression levels at the user level. Data is collected using Twitter API by following all the ethical considerations and in accordance with Twitter API terms & and conditions for research. In this study, only Twitter was used hence the finding may not hold for other social platforms. The current analysis is only descriptive in nature however an inferential or econometric model can be developed for better understanding.

8 Conclusion

In this digital age social media data is considered one of the best proxies to understand behavior and get a sneak peek at how people think, feel, and react to events or situations. Employing state-of-the-art technology for social media data analysis can complement existing methods and significantly enrich our understanding of mental illness. The organic nature of social media conversations provides an authentic backdrop for this expanded exploration. Social media can be used for real-time monitoring of mental illness for the population at large during the pandemic-like situation by exchanging informational and social support with each other. Future research, work can explore why people post about their mental health on social media and how it leads to various consequences. Since social media data is comparatively easy and faster and can provide diverse viewpoints hence insight derived from social media is valuable for decision-making and forecasting future behavior in business, healthcare politics, and government policymaking.

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Smart IoT-Enabled Cloud-Fuzzy System for Remote Monitoring of Infected Patients

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Abstract. Health is the cornerstone for overall well-being, influencing various aspects of life. With the emergence of pandemic-prone diseases, physical and mental health have also been affected. Covid-19, the recent global emergency has devastated the entire world and even today people's physical and psychological well-being has deteriorated by this pandemic. In these tough times, technology and its innovations have contributed to the management of pandemic-prone diseases. In light of this, the current work concentrates on Internet of Things (IoT) enabled cloud-fuzzy expert systems to assess the severity levels of the infected patients. These severity levels can vary from mild, to moderate, severe, and critical. The vital data is acquired from the patients through wearable healthcare devices every five-minute intervals. If the patient's health worsens, the doctors and the patient's family will be notified. This severity level identification system can be a solution to precisely monitor the patient's health conditions during pandemic-prone diseases like covid-19.

Keywords: fuzzy logic · IoT · cloud computing · covid-19 · smart healthcare · severity · pandemic-prone disease

1 Introduction

Over the years, the healthcare industry is one such sector that has witnessed extensive growth mainly due to advancement in the field of science and technology (Pradhan et al., 2021). However, the global healthcare system was paralyzed when an unknown virus named covid-19 spread across the globe (Brahmi et al. 2020; Singh et al. 2020).

The entire medical fraternity was under tremendous pressure, since, they had to care for the patients while simultaneously preventing themselves from the exposure to this deadly virus. Patients have to wait long hours for their turns, as there was a shortage of oxygen cylinders, ventilators, and even hospital beds for critically ill individuals (Ghosh

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et al., 2022). Due to the extreme rushing of the emergency rooms of the hospitals, many patients succumbed to death without receiving adequate care (Alharthi et al., 2021). Therefore, in order to overcome this shortage, many people who were either recovering from this virus or were recently in contact with an infected person were advised home quarantine, in order to check the spread of this deadly virus. However, this was another major challenge for the healthcare workers as well as the government to keep a check on them. This has opened doors for researchers to find an appropriate solution to the above problem, in order to keep us prepared to fight any such global pandemic in the future.

The Internet of Things (IoT), fuzzy logic-based smart systems, artificial intelligence (AI), telemedicine, etc. have been significantly used in disease protection, prevention, and control. These technologies can be used in real-time remote health monitoring of patients suffering from the disease and will enable a real-time consultation between a doctor and a patient. Even though AI and machine learning (ML) have been used extensively to tackle the epidemic, the availability of data is still their main prerequisite (Dwivedi et al., 2023; Mishra & Tyagi, 2022; Richey et al., 2023). Fuzzy logic can handle murky and imprecise data, which is particularly common in real-life situations (McNeill & Thro, 1994), hence in the current research, fuzzy based decision models are employed. These models can effectively incorporate expert knowledge and even manage complicated systems with numerous input variables (Pham & Pham, 1999).

Drawing motivation from the above, this research proposes a system that will be used to detect the severity level of covid-19 in patients who were either recovering from this virus or were recently in contact with an infected person and were advised home quarantine. There are different severity levels of covid-19 which include mild, moderate, severe or critical as per WHO criteria (WHO, 2023). For this process, data related to given biomedical parameters will be acquired from the patient through wearable healthcare sensor-based devices which will be connected to a smart device. This device will be connected to the cloud through internet connectivity established via an IoT gateway. At the cloud, this fuzzy system will check for the severity levels of the disease based on given inputs received at a regular intervals of five minutes. After the detection of two consecutive readings of severe or critical, an alert message will be generated and sent to doctors, paramedical staff, and family members of the patients. Thus, continuous monitoring and prompt reading recording are essential elements of patient care since this can help medical personnel in spotting possible issues earlier and can save patients' lives. The main advantage of inculcating this model into real-time use is that it does not require any manual intervention. Therefore, the physical presence of doctors is also not mandatory for monitoring purposes, which will help reduce the doctors' stress levels and will focus on those patients much which require urgent care. The rest of the paper is structured as follows: The theories and ideas given by well-known experts in the same field are covered in Sect. 2. Section 3 describes the suggested IoT enabled cloud-fuzzy inference method for the severity detection of patients. The results and findings of this study are demonstrated in Sect. 4. At last, the conclusions are presented in Sect. 5.

2 Literature Review

The last few decades have seen an upsurge in patient care, an increase in operational efficiency, and an overall improvement in healthcare delivery due to the incorporation of cutting-edge technologies and digital solutions. Therefore, this section has been divided into two sub-sections (a) fuzzy logic-based smart healthcare monitoring systems, (b) IoT and cloud-based smart alert generation systems, that can be utilized for the effective handling of pandemic-prone diseases.

2.1 Fuzzy Logic-Based Smart Healthcare Monitoring Systems

In this regard, Şahin et al. (2023) created an interval type-2 fuzzy logic-based smart system with an accuracy of 86.6%. The suggested model consisted of three fuzzy components with distinct input parameters. The cumulative results from the three fuzzy units were amalgamated to determine the severity of the disease. Similarly, Jayalakshmi et al. (2021) generated a ubiquitous system to analyze the health conditions of covid-19 patients by constructing fuzzy activity-based semantic rules to determine whether the patient's health is normal or abnormal. In addition, Rahman et al. (2023) proposed an intelligent health monitoring and diagnosis system that made use of IoT and fuzzy logic-based artificial intelligence tools. In this study, critical covid-19 patients or those isolated in remote regions were provided with intelligent diagnoses of serious problems. Similarly, an IoT and fuzzy-logic-based risk identification system had been designed by Şimşek & Yangın (2022) to assist healthcare professionals in accurately and promptly identifying the danger of covid-19 infection among patients.

In the same regard, Panja et al. (2023) proposed a real-time remote health monitoring of patients based on the Internet of medical things and fuzzy logic-based smart approaches. Similarly, for remote patient monitoring of covid patients, Shabbir et al. (2023) designed a telemonitoring-based model to determine the level of severity among patients. Compared to other ML methods, the boosted tree performed the best, with a precision rate of 72.3%. In the similar manner, Ershadi & Rise (2023) suggested a hierarchical model based on the fuzzy C-mean clustering approach and the ANFIS classifiers to determine the severity status of the covid-19 hospitalized patients. Several ML models were applied to the considered datasets based on image data and clinical feature data, with 94%, 92%, and 90% accuracy achieved.

2.2 IoT and Cloud-Based Smart Alert Generation System

Over recent years, there have been substantial growth and transformation in the healthcare industry with the inculcation of Mobile healthcare (mHealth) applications and cloud computing technologies (Bhatia & Sood, 2017; Verma & Sood, 2018). In this context, Shahed et al. (2023) devised a smart and secure system for remote monitoring of covid-19 patients, in which various vital indicators were collected from the patients using an accessible smart device, which was then saved on the cloud and retrieved when needed. This study prioritized patients' data and privacy while coping with the most recent devastating pandemic. Similarly, Bhardwaj et al. (2022) designed the covid-19 smart health monitoring system, which has specifically targeted the rural or underserved areas where clinics and hospitals can keep track of the patient's symptoms. Various IoT sensors were mounted to the patient's body in the envisioned system, in which the readings were collected and delivered to the cloud via an IoT-based communication channel. As a result, the recorded data was accessible to doctors at city hospitals, allowing them to monitor sick patients. According to Verma et al. (2018) and Verma & Sood (2018), the convergence of IoT and cloud computing technologies has become increasingly important in providing efficient, patient-centered care, particularly for real-time decision-making in remote patient monitoring during pandemic-prone diseases, providing clinicians, patients, and their families with regular updates.

From the above literature survey, it is clear that the integration of fuzzy logic and IoT-based expert system is crucial for the diagnosis of patients suffering from different pandemic-prone diseases. These systems can detect the severity or risk levels of disease in patients through continuous health monitoring. However, most of these studies do not consider all important biomedical parameters as recommended by WHO. Moreover, some studies rely on blood tests related inputs which do not provide automated detection of disease severity. Keeping all these facts in mind, the present study takes motivation from the above studies and suggests an automated solution for the detection of severity levels in patients. This study takes into account only those biomedical parameters which can be acquired from the patient's body through wearable sensory devices in a non-invasive way.

3 Research Methodology

The main objective of this study is to develop a smart IoT-enabled cloud-fuzzy system for remote monitoring of patients. Figure 1 shows the proposed system. The proposed system is divided into three major phases (a) Data acquisition phase, (b) Data storage phase and (c) Detection and Alert generation phase.

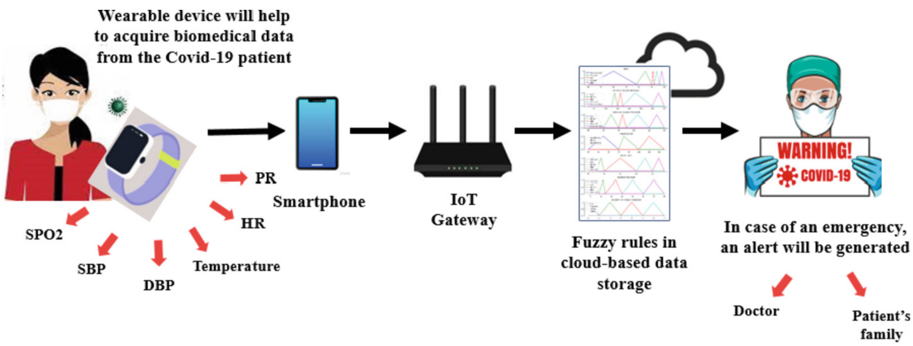


Fig. 1. IoT and Fuzzy logic-based severity identification system

(a) **Data Acquisition Phase:** The data acquisition or the data collection phase is the initial step in which biomedical data in the form of oxygen saturation (SpO2), systolic blood pressure (SBP), diastolic blood pressure (DBP), body temperature (temp), pulse rate (PR), and respiratory rate (RR) will be collected from the patients using a smart wearable device (like smartwatches or IoT sensor patch). This data is acquired from the patients at regular intervals. In this study, we have considered the time interval of five minutes.

(b) **Data Storage Phase:** Once the required data is acquired from the patient, it is necessary to store the data, so that it can be analyzed. Hence, the data storage phase comes into play. In this phase, the acquired data is stored on the cloud using the IoT gateway. For this study, we have used Microsoft Azure cloud for storing and analyzing data with the following specifications and resources (PremiumV3 [P1v3]; Compute Type: Dedicated; Disk Space: 250 GB and expandable).

(c) **Detection and Alert Phase:** This is the final phase of the proposed system. In this phase, risk assessment in terms of the covid severity of the patients (i.e. mild, moderate, severe or critical) will be checked using a fuzzy inference system. Fuzzy rules are applied to the data stored in the cloud. The doctors will have access to the patient data that is stored on the cloud. If consecutive two outputs show the same severity (severe or critical), an alert will be sent to the doctors, paramedical staff, and the patient's families. Additionally, this developed system will alert the doctors if the patient's health deteriorates further.

4 Results and Experimentation

This section incorporates the clinical examination of covid-19 infected patients from all angles (input parameters) to show the findings of the suggested study. Based on their health circumstances, it is decided if the patients are in a mild, moderate, severe, or critical state. To determine this, the recommended model was tested on patients who already had covid-19 infections, by incorporating various types of IoT sensors.

4.1 Data Acquisition Phase

In the present study, we have used a smartwatch (See Fig. 1) equipped with various sensors (See Table 1) to retrieve data in an authentic manner. These sensors have been connected altogether for the data retrieval purpose to continuously monitor the vitals of the infected covid patient. Sensors that have been used to check the values of the vitals for the proposed methodology are described in Table 1. Different healthcare smart watches available in the market include X-WRIST X2, Charge 4, Charge 5, Luxe, Sense series, and Versa Series etc.

4.2 Data Storage Phase

Once the required vital data has been retrieved from the human body using the wearable device (smartwatch in our case), these values will be transferred in real-time to the connected smartphone, and from the smartphone, this vital data is saved on the cloud using application programming interface (API) via IoT gateways in form of json blocks. Every json block contains the value of the six body vitals (See Table 1). After every five minutes, the data acquired from sensors is stored on the cloud using the IoT gateway in the form of json blocks. The working of this process is depicted pictorially in Fig. 2.

Table 1: Sensors used to monitor vitals with specified biological reference range

Sensor	Purpose	Range
SpO2 Sensor	To measure the oxygen saturation level in a person's blood (measured in per cent)	(40–100)%
SBP Sensor	To measure the higher number in a blood pressure reading (measured in millimeters of mercury or mmHg)	(70–200) mmHg
DBP Sensor	To measure the lower number in a blood pressure reading (measured in millimeters of mercury or mmHg)	(40–140) mmHg
Temp. Sensor	To measure the human body temperature (measured in degree Fahrenheit)	(90–105) °F
PR Sensor	To measure a person's heart rate in beats each minute (bpm)	(40–135) bpm
RR Sensor	To measure the rate of a person's breathing (measured in breaths per minute or bpm)	(4–40) bpm

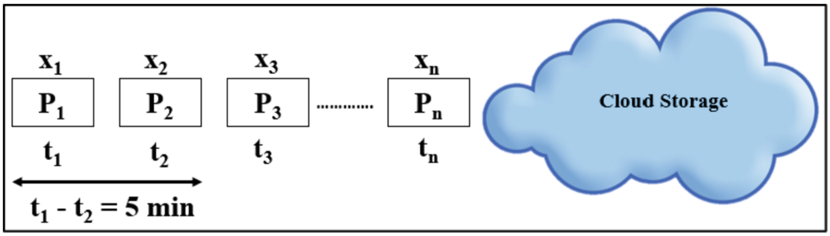


Fig. 2. Health-related data transformation of patients in the form of packets

Assume P_1, P_2,… P_n is the total number of packets used to transmit patient health information, to the doctors. Let x_1, x_2,…. x_n be the number of input samples that take time t_1, t_2, up to t_n. A screenshot of json blocks stored in the cloud is shown in Fig. 3.

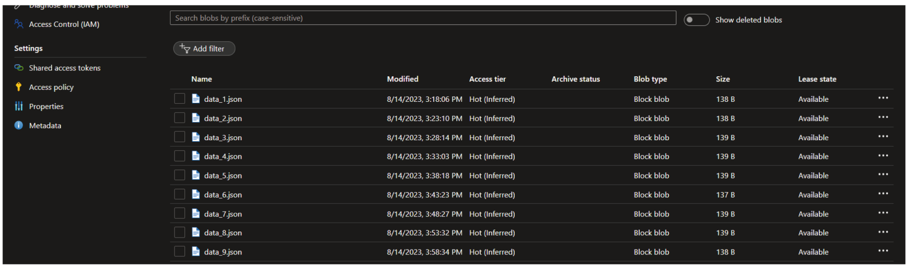


Fig. 3. Screenshot of json blocks stored in the cloud

4.3 Decision-Making and Alert Generation

Following the cloud-based storage of the values, a fuzzy rule-based decision support system will be activated to categorize the patients' severity as either Mild, Moderate, Severe, or Critical. Every five minutes, the same procedure will be carried out. The membership plots for the several input parameters utilized in the present study are shown in Fig. 4. Overall, there are six input parameters also called Antecedents: pulse oximetry (SpO2), systolic blood pressure (SBP), diastolic blood pressure (DBP), temperature (Temp.), pulse rate (PR), and respiratory rate (RR). The input parameters are further divided into several ranges; for instance, SpO2 can be represented as Extremely Low, Very Low, Low, Average, and High. A brief description of all these vital signs is described in Table 2.

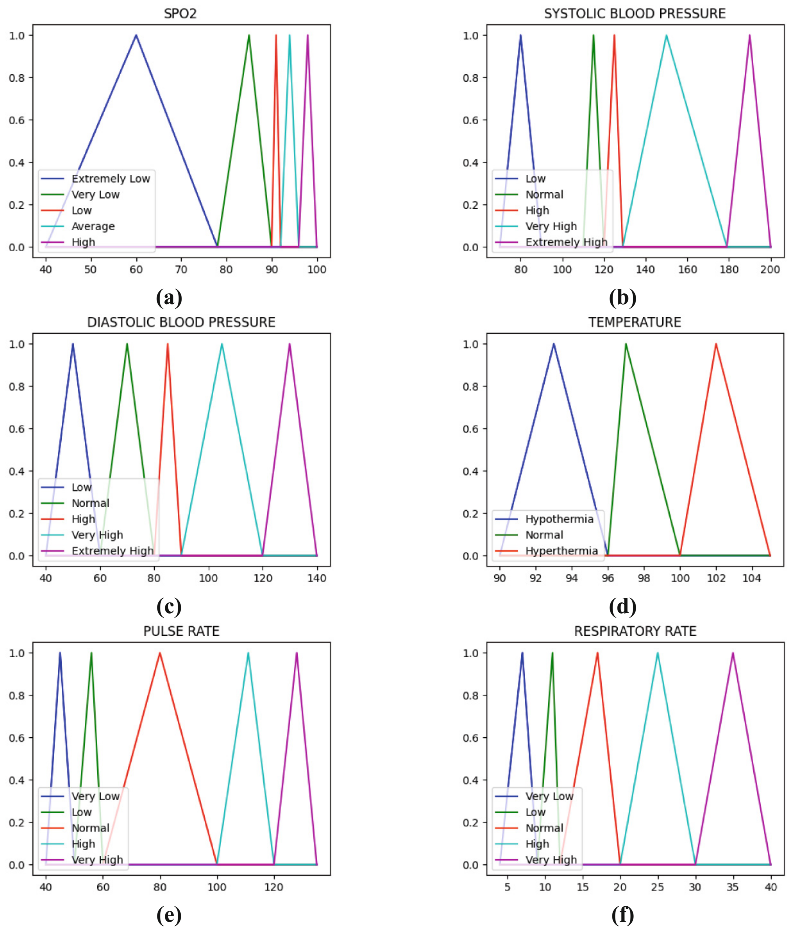


Fig. 4. Membership plots for the input parameters (a) SpO2 (b) SBP (c) DBP (d) TEMP. (e) PR (f) RR

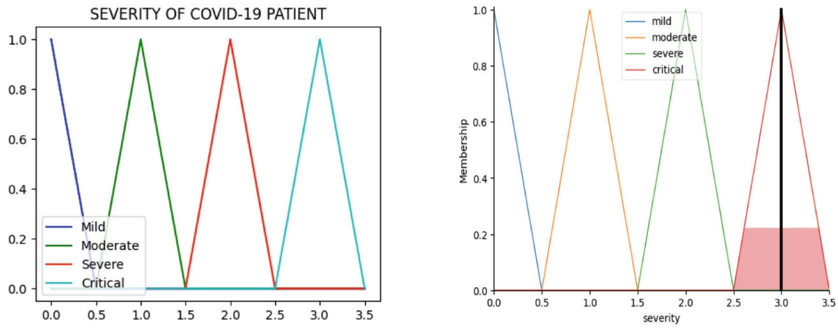
Table 2. Input parameters or Antecedents and their respective ranges

SpO2 (40–100) %	Extremely Low	Very Low	Low	Average	High
Range	$\leq$ 78 (40–78)	< 90 (78.1–90)	$\geq$ 90 (90.1–92)	(92–96) (92.1–96)	> 96 (96.1–100)
SBP (70–200) mmHg	**Low**	**Normal**	**High**	**Very High**	**Extremely High**
Range	< 90 (70–90)	120 (110–120)	(120.1–129)	$\geq$ 130 (129.1–179)	$\geq$ 180 (179.1–200)
DBP (40–140) mmHg	**Low**	**Normal**	**High**	**Very High**	**Extremely High**
Range	< 60 (40–60)	80 (60.1–80)	(80.1–90)	> 90 (90.1–120)	< 120 (120.1–140)
TEMP (90–105) °F	**Hypothermia**		**Normal**	**Hyperthermia**	
Range	(90–96)		(96.1–100)	(100.1–105)	
PR (40–135) bpm	**Very Low**	**Low**	**Normal**	**High**	**Very High**
Range	< 50 (40–50)	< 60 (50.1–60)	(60.1–100)	> 100 (100.1–120)	> 120 (120.1–135)
RR (4–40) bpm	**Very Low**	**Low**	**Normal**	**High**	**Very High**
Range	< 10 (4–9)	< 12 (9.1–12)	(12.1–20)	(20.1–30)	> 30

Severity: The output variable by which the condition of the covid-19 individual is identified is called severity. It is decided whether an infected person is Mild, Moderate, Severe, or Critical based on their health status and the measurements of the aforementioned factors. Patients with mild severity can be treated at home; however, patients with moderate severity need to be properly attended to and, depending on their health, should either be isolated at home or in a hospital. People in severe or critical situations should be admitted to the hospital, where they can access an ICU or a ventilator in an emergency. It is important to periodically monitor them to ensure that their health is not deteriorating. Figure 5(a) displays the membership plot for the output parameter (consequent) severity and Fig. 5(b) depicts the severity of the patient as Critical obtained while applying certain rules.

A triangular membership function, just like a triangle, has three parameters: the lower boundary, the centre, and the upper boundary with degrees of membership ranging from 0 to 1 (Jayalakshmi et al., 2021; Singh & Lone, 2020). A proper study has been done to determine the ranges of the above-mentioned parameters.

Severity, the output function, is the AND (&) of each of the aforementioned input parameters. The term “ctrl” refers to the control module from the control systems library.



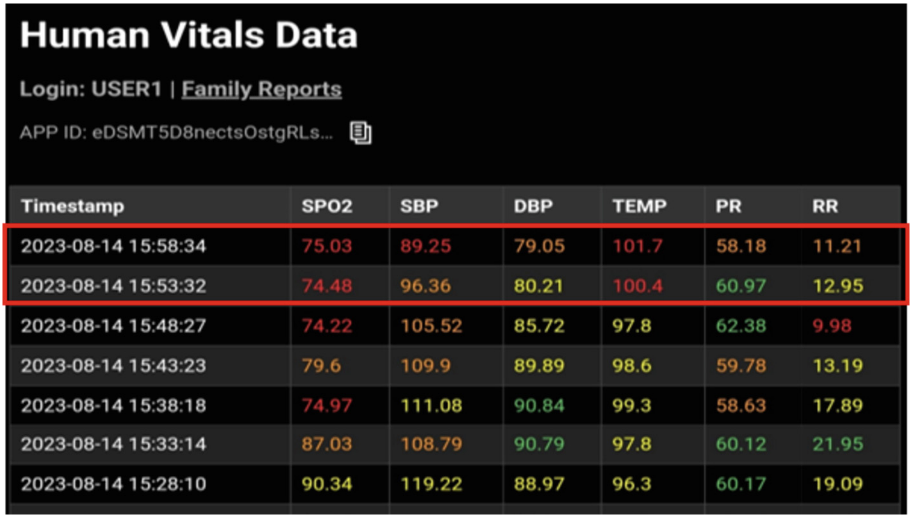
(a) **(b)**

Fig. 5. (a) Membership plot for the output parameter Severity having sub-categories as Mild, Moderate, Severe, and Critical; (b) Output graph showing the severity of the patient as Critical

The basic syntax they follow is shown in Eq. 1:

RuleX = ctrl.Rule (INPUT1 ['sub-type'] & INPUT2 ['sub-type'] & INPUT3 ['sub-type'] & INPUT4 ['sub-type'] & INPUT5 ['sub-type'] & INPUT6 ['sub-type'], severity ['sub-type']) (1)

When a patient reports two constant values of severe or/and critical, it will generate warning signals, which will be visible to the doctor in the form of a dashboard, as shown in Fig. 6. Further, it will generate mobile notifications for the doctor and family members of the patients as shown in Fig. 7(a) and 7(b). This will enable earlier detection and notification if the patient's condition worsens.



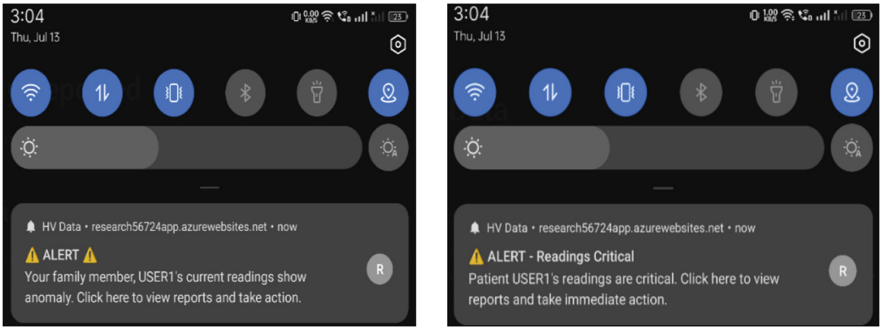
Human Vitals Data

Login: USER1 | Family Reports

APP ID: eDSMT5D8nectsOstgRLs...

Timestamp	SPO2	SBP	DBP	TEMP	PR	RR
2023-08-14 15:58:34	75.03	89.25	79.05	101.7	58.18	11.21
2023-08-14 15:53:32	74.48	96.36	80.21	100.4	60.97	12.95
2023-08-14 15:48:27	74.22	105.52	85.72	97.8	62.38	9.98
2023-08-14 15:43:23	79.6	109.9	89.89	98.6	59.78	13.19
2023-08-14 15:38:18	74.97	111.08	90.84	99.3	58.63	17.89
2023-08-14 15:33:14	87.03	108.79	90.79	97.8	60.12	21.95
2023-08-14 15:28:10	90.34	119.22	88.97	96.3	60.17	19.09

Fig. 6. Storage of biomedical parameters of patients at different time intervals (Note: Red represents Critical, Orange represents Severe, Yellow represents Moderate and Green represents Mild condition of the patient) (Color figure online)



(a) **(b)**

Fig. 7. Mobile screenshot showing (a) when an alert is generated to patient's family; (b) alert generation to Doctor

5 Conclusions

Human lives have been drastically altered after the emergence of the recently occurred outbreak called covid-19. Along with the patients, the mental and physical health of the doctors has also been impacted. The entire healthcare industry has been rattled, which has led to a lack of surgical and human resources. This led to the involvement of cutting-edge technologies to timely monitor the patient's health conditions and analyze their performance. Therefore, the current work inculcates the adoption of healthcare 4.0-based tools and technologies like intelligent fuzzy systems and the IoT. This study is only applicable to patients that have tested positive and now they are under isolation. Thus, there is a need to continuously track their health to determine whether their severity levels could not deteriorate further. Patients' basic real-time biomedical indicators are gathered regularly at the interval of five minutes and stored on the cloud so that clinicians can access them. An alert will be generated in the event of any emergency. The results of this study can be used by doctors to assess the health of their patients and determine which ones need urgent care. Other high-tech innovations, such as machine learning algorithms and statistical analysis, can be employed in the future to determine the accuracy and other performance indicators of the proposed system.

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Exploring Managers' Effective Use of Health Management Information Systems Dashboard: A Value-Focused Thinking Perspective

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Abstract. In low-resource settings, effective and impactful decision-making within healthcare systems is essential due to limited resources. Extracting meaningful information from Health Management Systems like the District Health Information System(DHIS2) dashboard has significant implications in improving healthcare planning, and resource allocation. In this study, we investigate values that govern managers' effective use of DHIS2 Dashboard. We conducted a total of fourteen interviews, which yielded six fundamental objectives (data accuracy, resource optimization, scalability, interactivity, data silos, stakeholder engagement) and thirteen means-ends objectives assessed by managers when operating the dashboard effectively. The developed means-ends objectives network will provide an information springboard for researchers as it uncovers key drivers of effective use of health information systems. Moreover, this research will assist both practitioners and implementers in enhancing features of comparable platforms, to be rolled out in similar contexts.

Keywords: Dashboard · Effective Use Theory · Value-Focused Thinking · DHIS2

1 Introduction

District Health Information Software 2 (DHIS2) has become a transformative force in African healthcare, ushering in a new era in healthcare data management [1, 2]. The DHIS2 has gained a strong foothold in Africa through its dynamic data collection, aggregation, analysis and visualization features. The versatility of the system stretches beyond mere data processing; it acts as a gateway to evidence-based decision-making, enabling improved healthcare policies and performance [3].

In response to Africa's growing health emergencies and catastrophes, governments and health organizations are increasingly relying on dashboards as a means of decision-making. Dashboards are defined as visual illustrations of core information, laid out in a logical structure for improved monitoring of data, with the aim of reaching accurate objectives and taking informed decisions [4]. The dashboard's impact on disease surveillance initiatives is evidenced by statistics from Nigeria, where the use of the technology

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has shortened the time required for timely, informed detection and response to outbreaks [5, 6]. However, recent research has uncovered a number of dashboard-related concerns, notably issues surrounding data interpretation and deriving useful information out of it [6, 7]. Dashboard users often find it challenging to cope with limited mental capacity while processing displayed information, making effective use of dashboards a significant hurdle [8, 9]. From a managerial perspective, transitioning to a data-driven decision-making mindset requires a change in organizational culture and practices. Research has indicated that users are hesitant to switch to a dashboard-based approach to decision-making, leaning on traditional decision-making routines. Therefore, we seek to address the following research question:

RQ: What are the values that managers strive to capture through the effective use of DHIS2 dashboard?

To answer the research question, we applied the Value-Focused Thinking(VFT) approach [10]. Moreover, we used the concept of Effective Use Theory(EUT) so as to generate values that contribute solely to the effective use of the functionality [11]. The aim is to leap beyond data visualization (adoption) and explore underlying mechanisms behind patterns and trends, and thus uncover correlations between factors. By looking at values through the lens of effective use, our focus is on turning data into pertinent, actionable intelligence for informed decision-making within the African healthcare sector.

2 Background

2.1 Effective Use of Information System

Organizations reap maximum value from an information system based on how effective the users are in exploiting the system [12, 13]. Effective use of a system refers to *"using a system in a way that helps attain the goals for using the system"* [11]. Within the scope of this research, we define effective use of the DHIS2 dashboard as making strategic use of the feature, to unlock full benefits of available data for improved healthcare decision making and management. The concept has received particular attention in the emerging information systems (IS) literature due to its fundamental reliance on promoting data-driven decision making [12]. It extends well beyond merely using dashboard functionalities and encapsulates leveraging the platform to drive value, derive actionable intelligence and optimize programme outcomes.

The emerging literature emphasizes that effective use of a system is consistent with wider tenets of efficient IS deployment [14]. It covers a combination of technical, human and organizational considerations [15]. The Theory comprises three inter-related and interfering facets: (1*) transparent interaction*, in which a user can interact with the system representation; (2) *representational fidelity*, whereby a user derives an accurate picture of the domain; and (3) *informed action. Transparent interaction* denotes the unimpeded engagement of users with the dashboard, guaranteeing its accessibility, visibility and ease of use. In the context of using the DHIS2 dashboard, this means empowering healthcare managers to intuitively engage with the dashboard in a way that enables seamless data exploration. *Representational fidelity* stresses the accurate depiction of data using visualizations and illustrations. It highlights the importance of enabling information shown in graphs, tables and other visualizations to faithfully mirror underlying data that they represent. *Informed action*, suggests that dashboard information drives evidence-based decision-making and positive outcomes. It means equipping healthcare managers with actionable evidence derived from data.

2.2 Means-End Chain Theory

Means-End Chain (MEC) theory suggests that users and stakeholders link specific system features to desired organizational or personal outcomes [16]. At the base of this hierarchical framework are the tangible system features and functionalities. These lead to intermediate benefits, often in the form of operational efficiencies or improved capabilities [17]. At the apex of the chain are the higher-order goals or end-states, such as strategic advantages or fulfillment of organizational missions. Essentially, users and stakeholders perceive and adopt information systems based on how well they believe these systems will aid in realizing their overarching objectives [17].

System functionalities and features can be perceived as the means to achieve certain ends or organizational goals. These goals, ranging from improved operational efficiency to strategic competitive advantage, form the *"end"* of the chain [18]. EUT which emphasizes not just the adoption but the optimal utilization of a system, aligns closely with this perspective. For a system to be effectively used, users and stakeholders must perceive a clear pathway from system features (means) to the realization of desired outcomes (ends). If this chain is not apparent or is deemed weak, even a technically superior system may remain underutilized, as users fail to see its potential in fulfilling their objectives. The theory underpins the assumption that individuals perceive products as a medium for fulfilling important goals and seeks to articulate how choosing a product or service promotes the fulfilment of intended goals [19].

The convergence of MEC and EUT highlights the imperative of harmonizing system functionalities with articulated goals of users and organizations. The presence of sophisticated features in an information system is not inherently valuable; rather, their effectiveness is contingent upon their alignment with and contribution towards the desired outcomes of the organization. For instance, if an enterprise values collaborative decision-making, a system's collaborative tools (means) should lead to enhanced teamwork and better collective decisions (ends). When designing, implementing, or promoting information systems, recognizing and acting upon these means-end connections can significantly boost user buy-in, optimize system utilization, and ultimately ensure that the technology genuinely benefits the organization.

3 Methodology

This research employs Value Focused Thinking(VFT) approach to design and structure user values, drawing upon theoretical foundations of the MEC Theory [10]. VFT emphasizes starting with a clear understanding of desired values and outcomes before considering possible solutions or alternatives [10]. Instead of beginning with the constraints of available technologies or existing system specifications, VFT encourages stakeholders and to first articulate what they truly value be it enhanced data security, improved user experience, operational efficiency, or any other overarching goal. This value-centric approach ensures that system designs and decisions inherently align with the strategic objectives and core values of an organization [20].

The traditional approach to decision thinking is backward-looking, as individuals tend to concentrate on identifying options for decisions instead of engaging in values formulation [21]. As situations emerge, people tend to reflect on fixed patterns and options, as opposed to focusing on objectives that make sense when decisions are made [10]. The main idea behind VFT is to uncover fundamental values that shape the use of a given technological artefact, along with mechanisms for reaching those values. Each value is driven by objectives at different degrees of maturity: for instance, mean objectives cover characteristics that are specific to lower and higher tiers, while having an impact on other objectives [10]. In turn, fundamental objectives serve both to define personal tenets for users and the core rationales underlying their decision-making processes. However, there is mutual co-dependence between objectives, although means objectives contribute to the fulfilment of fundamental objectives. Thus, these correlatives are revealed within a network of means-ends objectives.

Within the IS literature, VFT approach has been extensively applied. Most recently, Rzepka used the approach to evaluate the use of Voice Assistants [22]. The approach has also been utilized within the security industry to explore the strategic incentives that drive the improvement of information security policy compliance [23]. As regards the use of cutting-edge technologies, VFT has demonstrated its effectiveness in assessing security implications for governments' use of blockchain [24]. Given that VFT has proved its relevance in unmasking underlying core values and offering a consistent process for clarifying interrelated objectives, we therefore draw on it in this research to explore management's intent in using the DHIS2 Dashboard. Thus, Fig. 1 and Table 1 illustrate the methodological process used.

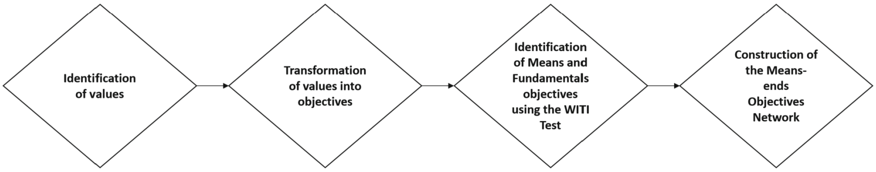

Fig. 1. Value-focused Thinking Process [20, 25]

3.1 Data Collection

Our focus is on users (managers) with proven hands-on experience in using DHIS2 Dashboard for decision-making, in line with the research question. By proven experience, we refer to managers with at least 10 years' decision-making experience using health data, with at least 05 years' experience using the DHIS2 Dashboard. These specifications served to establish a detailed picture of our needs and expectations, and thus circumscribe key areas of discussion. In accordance with Keeney's recommendations on VFT, we carried out one-to-one physical interviews with 14 DHIS2 managers between January 2023 and March 2023. Interviews lasted an average of 53 min. The resulting sample consisted of 9 men and 5 women, ranging in age from 39 to 61.

Table 1. Description of the VFT process [10, 20]

Step	Procedure
1	To draw up an exhaustive list of values within this specific decision-making scenario, we asked participants a series of questions. Firstly, we posed the question *"What would you like to achieve with the dashboard?"* to identify the value of effective use of the feature. Next, we raised questions about the objectives, potential benefits and challenges of using the dashboard effectively. Afterwards, they were also invited to generate unranked and unprioritised wish lists. Additional probing questions were asked: *"If the Dashboard had no boundaries, what value could be gained from it?"* We kept raising questions until no further value emerged. Then the values that were identified in this stage were converted into a common form of actionable objectives
2	In this second step, for each actionable objective we first identified, participants were asked *"Why is this objective important?"* within the context of deriving maximum value from the feature, so as to draw a clear delineation between means and fundamental objectives. Where the response stated that the purpose was important because it constituted *"the essential reasons to care about the situation",* it was classed as a fundamental objective. Where the response indicates that the objective is relevant to achieving other means or a fundamental objective, then it was considered to be a means objective. This cycle was repeated until we identified other means or fundamental objectives
3	The final stage comprises building a means-ends objectives network upon what was achieved in the previous stage. It represents the means and the fundamental objectives, and the relationships between them

3.2 Data Analysis

The author coded the verbatim transcripts of the interviews in vivo so as to build up a list of means and fundamental objectives derived from the users' utterances [26, 27]. This first step served to calibrate emerging patterns, uncover any instances of inconsistency and define concepts. In coding the rest of the interviews, redundancies were easily filtered out, while common objectives were clustered into themes. In this way, each objective was shaped into a common pattern, comprising a decision context, an object and a preferential orientation. For the purpose of this research, the decision context is expressed as the effective use of the DHIS2 Dashboard, presenting the object as a noun and preferential orientation as a verb. For instance, statements like *"it's more convenient to browse"* were turned into *"maximize interactivity"*. Further on, related objectives were clustered into global themes, with relationships between means-ends chain derived from the interviews. As a result, we deliver a means-ends network that depicts in a structured sense the values of managers' effective use of the DHIS2 Dashboard, along with their related links.

4 Results

Following data analysis, we draw up a list of fundamental and mean objectives, as shown in Table 2 below: ***Data Accuracy, Resource Optimization, Scalability, Interactivity, Data Silos, Stakeholder Engagement*** are the fundamental objectives that maximize the effective use of the DHIS2 Dashboard. These fundamental objectives are driven primarily by 13 means objectives, supplying information on how the core values can be attained. The items as depicted in the table below exemplify these objectives, and the network is presented in Fig. 2.

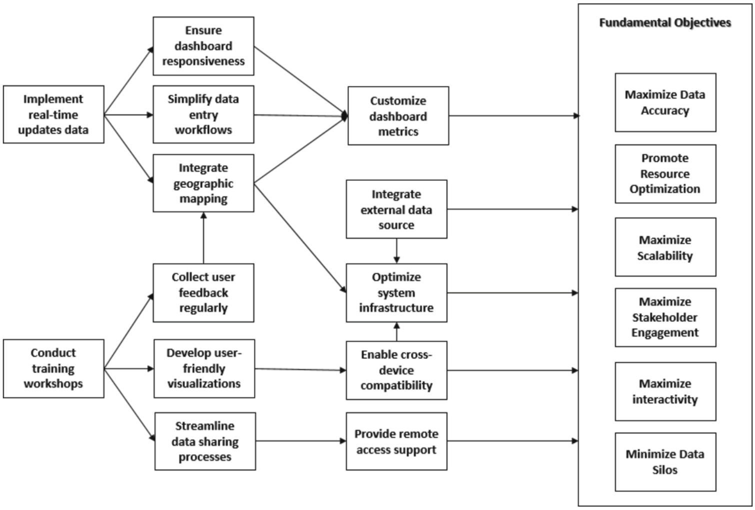

Fig. 2. Means-Ends Objectives Network for DHIS2 Dashboard Effective Use

Data accuracy is at the core of DHIS2's dashboard for effective use, providing a key input for informed decision-making. Evidence of its importance emerged strongly from in-depth interviews with healthcare managers. Nine of them highlighted that accurate figures on patient numbers and disease outbreak had a decisive bearing on resource deployment towards targeted health interventions: *"Inaccurate data on vaccine supplies had previously led to shortages in remote health facilities. We couldn't immunize children as planned, which put their health at risk." [P7].* In addition, targeted actions are also dependent on accurate data: *"During the cholera outbreak, we managed to map out epidemic hot spots, thereby dispatching medical teams and curbing propagation of the disease"* [P4].

Another fundamental objective widely raised was ***resource optimization***. It's is an important aspect in strengthening health systems in low-resource areas. Regarding health system management in Cameroon, optimizing resources implies leveraging data to improve the use of limited resource: *"Since data on malaria became readily available, we identified a pattern that resulted from observed cases"* [P5]. Other managers explained the economic considerations involved, such as budget allocation and staffing

"Since visualizing malaria data on the dashboard, we have been able to identify a pattern that resulted from cases being observed in certain regions" [P2].

Table 2. Fundamentals objectives of DHIS2 Dashboard Effective Use

Fundamental Objectives	Evidence from the interviews
Maximize Data Accuracy	• *My maternal care efforts improved as DHIS2 tracked antenatal visits precisely* • *DHIS2's accurate records empower my unit to plan and execute vaccination drives effectively*
Promote resource optimization	• *I used DHIS2's insights to allocate vaccines strategically* • *Using DHIS2, I identified areas needing health services expansion due to population growth*
Maximize scalability	• *Expanding our health services was hassle-free, as our system managed increased data flow* • *Data tracking across district went smoothly, even as our operations expanded* • *As our health facilities increased, data accuracy and analysis speed were maintained*
Maximize Interactivity	• *The intuitive interface made it simple for me to explore various data views* • *I could personalize my dashboard layout, enhancing my workflow efficiency* • *Quick data exports allowed me to analyze data offline for in-depth assessments*
Minimize Data Silos	• *We act faster with diverse data sources; it's a game-changer in our response strategies* • *I used to struggle to find information from other programme*
Maximize Stakeholder Engagement	• *I reached out to partners using shared data, making our health campaigns more focused* • *Engaging data narratives led to open conversations with stakeholders, aligning our actions and goals*

Scalability, a fundamental objective in numerous digital solutions, is critical when it comes to using DHIS2 dashboard effectively, especially in diverse and dynamic environments such as Cameroon. It is not just about processing an increasing amount of health data, but also adapting to shifting health metrics, changing user skill sets and addressing unique healthcare challenges in different regions. Seven of them cited the need for the system to support different national programme demands, all of which dictate that the data input format architecture should be maintained: *"The system had to be an almost exact replica of the monthly printed health forms that we fill in, so that we could monitor our indicators. we want to ensure uniformity of data collection and communication across the region, which facilitates monitoring, evaluation and the development of strategies for our interventions"* [P6] Others pointed out the existing urban-rural dichotomy:

"Urban areas, with more health facilities, place greater demand on a wider range of medicines, leading to complex inventory data. In rural areas, the focus is on specific prevalent ailments" [P1].

Stakeholder engagement refers to active participation, consultation and collaboration with all parties who either interact with or are affected by the system. These range from healthcare professionals, to healthcare administrators, community leaders and even regional health data analysts. Their comments, views and needs play an essential role in adapting the DHIS2 dashboard to make it more relevant, user-friendly and effective. Several managers mentioned the need to involve first-tier stakeholders such as national health programmes, along with international bodies, to align agendas and pinpoint common areas for collaboration: *"Districts have expressed concern about monitoring vaccine storage temperatures. As a result, a real-time temperature monitoring function has been added to the dashboard, which ensures that vaccines are properly stored throughout the country" [P12].*

Interactivity has emerged repeatedly as a fundamental driver behind the effective use of the functionality. The respondents pointed out a new sense of excitement in manipulating and displaying data: *"I no longer sift through pages of static data. Instead, by interacting with the dashboard, I can quickly pinpoint trends, anomalies, or specific data points, allowing for more timely and informed decisions"* [P8] (Table 3).

Reducing **data silos** is an important consideration for managers in the decision-making and informed action cycle. To prevent waste of resources and coordinated decision-making, a number of managers indicated that a game-changer for them and their teams was limiting the time it took to aggregate data from different sources for a quick insight and timely response: *"for national programs like HIV and Malaria, fragmented data is a roadblock. We need a complete picture to allocate resources or launch health campaigns" [P10].*

Table 3. Means-ends objectives of DHIS2 Dashboard Effective Use

Means objectives	Evidences from Interviews
Conduct training workshops	• *Helping teammates navigate data complexities improved our strategic thinking and cohesion* • *I mentored colleagues in data interpretation* • *Nurturing data champions within the team enhanced our collective potential for impactful actions*
Implement real-time updates data	• *I preserved data relevancy, aiding our prompt adaptation to evolving situations* • *I ensured the dashboard data reflected ongoing field operations, aiding immediate adjustments* • *Emergency responses were enhanced through my data refreshes*
Customize dashboard metrics	• *I fine-tuned data representations, aligning them with our decision-making needs* • *My job was tweaking what we see, making data relevant and clear* • *I adjusted the visuals for smarter choices*

(*continued*)

Table 3. (*continued*)

Means objectives	Evidences from Interviews
Provide remote access support	• *I assisted epidemiologists in reviewing disease trends on their computers, aiding timely interventions* • *I enabled health supervisors to access staff training records on their tablets, ensuring continuous skill development* • *I supported supervisors in analyzing outbreak data on tablets, allowing them to coordinate response efforts effectively.*
Develop user-friendly visualizations	• *The refinements to the dashboard's graphics facilitated prompt decision-making by managers* • *I upgraded the dashboard's design for researchers, enhancing data analysis* • *I customized visuals to help me, as a pharmacist, track medicine inventory at a glance*
Optimize system infrastructure	• *I improved our tech setup, facilitating better data utilization for strategic planning* • *I fine-tuned our technology structure, supporting efficient data-driven program management*
Streamline data sharing processes	• *Our interconnected data approach strengthened cross-functional insights for smarter strategies* • *Efficient information flow improved our collective understanding and decision-making*
Collect user feedback regularly	• *Active participation informed dashboard improvements* • *Consistent input helped tailor the dashboard to our needs*
Simplify data entry workflows	• *We streamlined how we update, which boosted overall efficiency* • *Data input became straightforward, allowing more focus on analysis*
Enable cross-device compatibility	• *Using it on various gadgets ensures flexibility and convenience* • *The system's adaptability across devices is a huge advantage* • *The convenience of using it on any gadget is a game-changer*
Integrate geographic mapping capabilities	• *The system displays data in a spatial context* • *Information is presented with location context*
Integrate external data sources	• *Our dashboard reflects insights from diverse origins* • *Data is unified for a holistic view*
Ensure dashboard responsiveness	• *Changes are promptly displayed* • *Our system reacts promptly to interactions*

5 Conclusion

The study provides an insight on dashboard values within healthcare systems, from a managerial perspective. Value Focused-thinking approach was applied to this research. Results revealed that data accuracy of feature, Resource Optimization, Scalability, Stakeholder Engagement, Interactivity, Data Silos constitute the fundamental values of to maximize values of DHIS2 dashboard.

While we have carefully adhered to the steps of the VFT methodology, this study presents a number of limitations that provide avenues for future research. Firstly, our sample scope could have been expanded to cover younger managers in districts and regions, who have daily hands-on access to the dashboards and direct interaction with data entry officers. Expanding the sample to this group would also enable us to investigate sub-groups based on user characteristics such as age, gender and experience. Secondly, we have focused on mature, experienced managers. Although this approach yielded in-depth information from experienced users, gathering information from non-adopters and users of traditional approaches would provide a better understanding of their perceptions of the feature.

In resource-constrained setting, the VFT approach can help optimize HMIS design and implementation. By prioritizing local healthcare values and constraints, the approach ensures that HMIS aligns with unique requirements of these environments, promoting systems that are both technologically competent and contextually relevant.

For the researchers, embedding VFT into their methodology provides a deeper understanding of challenges associated with HMIS adoption in underserved areas. Furthermore, a focus on stakeholder values enables researchers to unfold nuanced socio-cultural information, resulting in actionable strategies that enhance the relevance and effectiveness of HMIS deployments.

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The Effect of AI-Powered Cloud Computing on the Resilience of Healthcare Systems: A Governance Perspective

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Abstract. Healthcare systems, beyond delivering health services, play a pivotal role in shaping national identities. Their resilience is thus crucial. This paper, anchored on the World Health Organization's resilience framework, investigated the role of AI-powered cloud computing in enhancing the resilience of healthcare systems, specifically focusing on governance within the systems. A qualitative study was conducted using the interpretivism paradigm. Data was collected through interviews with healthcare information technology (IT) experts knowledgeable in healthcare IT. Preliminary findings from the participants reveal that AI-cloud solutions promote participatory leadership by facilitating an integrated system and improved decision-making. Furthermore, these technological solutions foster coordination among healthcare entities, ensuring data security and performance monitoring. AI's capability in cloud computing helps in top-tier data management and the prediction of potential risks, thereby emphasizing its importance in healthcare. This paper underscores the role of AI-powered cloud computing in reinforcing healthcare governance and overall system resilience.

Keywords: AI-powered cloud computing · detection of shocks · governance · healthcare · information systems and flows · participatory leadership · resilience

1 Introduction

Information systems play a crucial role in modern-day economies [1]. Notably, organizations have become overly reliant on these systems, emphasizing the importance of both resilient organizations and the information technology (IT) systems that support them to ensure operational continuity in the face of unexpected disruptions [2]. Despite the importance of resilience, several organizations, including healthcare institutions, continue to rely on non-resilient systems. This is also despite the advent of cutting-edge technologies such as cloud computing and artificial intelligence (AI) [3]. This poses a significant concern, especially because healthcare systems play a crucial role in providing social and economic benefits to patients, families, and healthcare providers.

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This study sought to investigate the contribution of AI-powered cloud computing towards improving the governance of healthcare systems in the context of healthcare systems resilience. To achieve this objective, the study leveraged the World Health Organization's (WHO) resilience framework [4] which served as the conceptual framework underpinning this research. The study explored how AI-powered cloud computing can enhance healthcare system resilience by focusing on the framework's four tenets related to the governance of healthcare systems, namely, participatory leadership, coordination of activities between government and stakeholders, effective information systems and flows and lastly, surveillance, enabling the timely detection of shocks and their impact [4].

Thus, the guiding main research question (RQ) was: How does AI-powered cloud computing enhance governance in healthcare organizations? The corresponding sub-questions were as follows: (RQ1) How does AI-powered cloud computing enable participatory leadership in healthcare systems? (RQ2) How does AI-powered cloud computing enhance the coordination of activities across government and key stakeholders of a healthcare system? (RQ3) How does AI-powered cloud computing enhance healthcare information systems and flows? And (RQ4) How does AI-powered cloud computing enable timely detection of shocks (disruptive events) and their impact?

According to [5] governance is an essential and important building block for healthcare systems. Effective governance and leadership contribute to improved health, responsiveness, social and financial risk protection, and improved efficiency [5].

The rest of the paper is structured as follows: Sect. 2 presents the literature review, Sect. 3 presents the guiding theoretical framework and the resulting conceptual framework, Sect. 4 presents the methodology, Sect. 5 discusses the results, and lastly, Sect. 6 presents the conclusions and limitations of the study.

2 Literature Review

This section portrays the need for resilience in healthcare systems. Thereafter, the concept of AI-powered cloud computing is unpacked.

2.1 The Need for Resilience in Healthcare Systems

The concept of resilience is prominent in many scientific fields as well as in many organizations [6]. As resilience research is present in a wide range of fields such as psychology, ecology, healthcare, engineering and computer science [6], it is not surprising that "resilience" has many connotations across disciplines. The Oxford Dictionary defines resilience as "the capacity to withstand or to recover quickly from difficulties". After reviewing various definitions of resilience from various disciplines, [7] concluded that the definitions of resilience almost always contain the basic idea of the ability to recover from unexpected challenges or bounce forward through adaptation and transformation.

The obvious function of a healthcare system is to deliver a variety of services and interventions, and these can be personal or non-personal [8]. Healthcare systems do not simply deliver healthcare services to maintain or improve health, but they perform multiple functions for society, for example, they also play a role in protecting households from financial impacts associated with illnesses hence influencing the economic productivity of societies [8].

The importance of healthcare systems clearly shows why they need to be resilient. The World Bank states that for a healthcare system to be considered resilient, it needs to be aware of threats and risks, be agile in responding to evolving needs, and be shock-absorbent and adaptive to minimize disruptions [9]. Many scholars agree that the need for resilience within healthcare systems emerged as a significant concern, particularly in the wake of the COVID-19 pandemic. This crisis exposed underlying structural vulnerabilities that had detrimental effects on economies, individuals, and societies at large [4].

2.2 AI-Powered Cloud Computing

There is no single definition of AI-powered cloud computing, and the term can be interpreted in a variety of ways. AI-powered cloud computing refers to the integration AI technologies and cloud computing services to enhance and optimize various aspects of computing and data processing. The term refers to the integration of two distinct technologies: *artificial intelligence* and *cloud computing*, which are briefly discussed below:

Cloud computing entails the delivery of information systems and IT infrastructure and resources such as file storage, servers, email, and applications via the internet, allowing businesses to avoid the burden of hosting their technology infrastructure on-site [10]. Cloud computing has five essential characteristics: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service [10]. The popularity of cloud computing is mainly credited to its numerous advantages which include considerable cost savings, ease of management, flexibility and scalability, improved mobility and enhanced collaboration, rapid development and deployments, improved security, business continuity and disaster recovery [10].

On the other hand, there is ***artificial intelligence*** which can be interpreted as the process of enabling machines to mimic intelligence [11]. Combining various technologies and frameworks, AI enables machines to reason and make decisions that have the best chance of achieving a particular goal [12]. According to [12] at its foundation is machine learning and its more complex sibling, deep learning. They bring to life various AI applications such as computer vision, natural language processing, and the ability to harness huge volumes of data to make accurate predictions and discover hidden insights.

When considering AI-powered cloud computing, the two technologies are integrated. To enable the development and maintenance of robust systems, these two technologies work in conjunction with one another [13]. One could argue that there is a two-way relationship between AI and the cloud: firstly, AI can be used to make the cloud more efficient and effective, and secondly, cloud computing technology can be used as an enabler for the deployment of powerful AI systems.

3 Theoretical and Conceptual Framework

This section discusses the theoretical framework that underpins the study as well as the conceptual framework adopted.

3.1 Theoretical Framework for Healthcare Resilience

The WHO published a framework [4] to promote the development of resilient healthcare systems. The complete framework is described in detail in [4]. The framework compiles a list of strategies aimed at strengthening healthcare systems and increasing their resilience. It also provides a list of areas of assessment for those strategies. According to the WHO [4], there are four healthcare-strengthening building blocks that can be used to develop strategies for healthcare resilience: (i) governance, (ii) financing, (iii) resources, and (iv) service delivery. In the framework, these strategies are mapped against four stages of a shock cycle, namely, (stage 1) preparedness, (stage 2) shock onset and alert, (stage 3) shock impact and management, and (stage 4) recovery and learning.

This paper focuses on the strategies related to governance. [4] proposes five strategies under the governance building block which need to be considered to increase resilience. These strategies are: (1) effective and participatory leadership with strong vision and communication, (2) coordination of activities across government and key stakeholders, (3) organizational learning culture that is responsive to crises, (4) effective information systems and flows, and (5) surveillance enabling timely detection of shocks and their impact [4].

3.2 Conceptual Framework of the Study

The healthcare resilience framework developed by [4], more specifically its strategies pertaining to governance, serves as an underpinning foundation for the study's conceptual framework. Although there are more building blocks outlined by the WHO [4], this study only focuses on one of them as it has been identified (in the existing literature and emerging evidence from shocks such as the COVID-19 pandemic) to be a key healthcare system function that needs to be considered to ensure healthcare systems resilience [4].

Figure 1 presents the conceptual framework guiding the research. This framework has been developed by the researchers and is based on the underpinning theoretical framework [4].

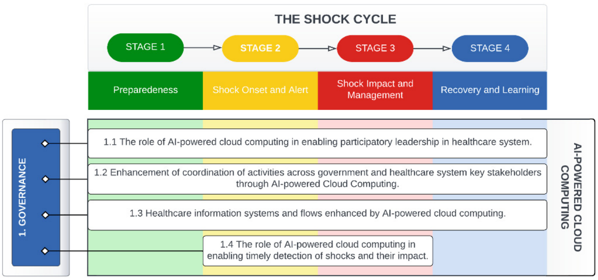

Fig. 1. Conceptual framework. Source: developed by the researchers based on theoretical framework [4]

This study investigated how AI-powered cloud computing can be mapped in relation to the governance of healthcare systems. Hence, as seen in Fig. 1, point 1.1 is derived from strategy 1 of the theoretical framework; point 1.2 is derived from strategy 2; point 1.3 is derived from strategy 4; and point 1.4 is derived from Strategy 5.

4 Research Design and Methods

The interpretivism paradigm was used in the study to gain in-depth insights into how AI-powered cloud computing contributes to healthcare system resilience from a governance perspective. The study employed a qualitative research methodology, and a cross-sectional exploratory design was applied. The data was gathered through interviews with participants who have knowledge of the implementation of information systems in healthcare. An interview guide with a set of 9 open-ended questions was used to conduct the interviews.

Purposive sampling was used in the study, with participants chosen based on their knowledge or experience with AI-powered cloud computing in healthcare systems. The initial sample size was 12 participants. However, at the time this paper was written, only five participants had responded. The findings are thus based on the themes that emerged from the interviews with the five respondents.

Prior to approaching the potential participants for data collection, the researchers first applied for ethical clearance to the College of Business and Economics Research Ethics Committee at the University of Johannesburg. The request for ethical clearance was approved (Ethical Clearance Code -2023AIS005). To ensure the anonymity of the research participants, each of the five interviewees was assigned a unique code ([P1] to [P5]).

5 Results and Discussion

This section presents and discusses the study's findings in light of the research questions. To begin with, the demographics of the participants are presented.

5.1 Participants' Demographics

Respondent's demographics comprised their profession, industry sector employed, years of working experience, and geographical location (country). All the participants were knowledgeable about the implementation of information systems in healthcare and had at least eight or more years of working experience. Except for one participant from Kenya, all the participants were from South Africa (SA). The demographics of the participants are summarized in Table 1 below.

5.2 Findings and Discussion

The findings are organized according to the research questions and grouped according to the emerging themes. The themes that emerged from the responses of the participants were identified within each point of the conceptual framework The emerging themes are italicized wherever they are mentioned.

Table 1. Participants' details and demographics

Participant Ref Code	Profession	Industry Sector	Experience (in years)	Country
P1	CEO of a tech-centered healthcare & wellness center	Healthcare	8 years	SA
P2	Technology executive	Healthcare	20 years	SA
P3	Lecturer in healthcare informatics	Higher Education	22 years	SA
P4	Medical data analyst	Healthcare	11 years	Kenya
P5	Cardiologist	Healthcare	30 years	SA

RQ 1: How does AI-powered cloud computing enable participatory leadership in healthcare systems?

According to [4], to achieve resilience through participatory leadership, various areas need to be investigated. These are: the establishment of a strategic direction, effective communication, functional management capacity, and the establishment of protocols and emergency legislation [4]. These areas are significant as they affect the other spheres within the healthcare resilience framework [4].

There were 3 themes generated from the responses to RQ1 (how does AI-powered cloud computing enable participatory leadership in healthcare systems?). These themes are not entirely distinct, and many relate to one another.

Accessibility into an integrated healthcare system:

The findings found that participants believe that AI-powered cloud computing can give leaders *accessibility into an integrated system* and *consolidate various systems*. P5 and P4 believed that AI-powered cloud computing can make systems faster, smarter, and easier to use. P1 believed that AI-powered cloud computing's features could perhaps be leveraged to consolidate different information systems in healthcare. For P5, government and policymakers could leverage the use of a cloud-based AI solution that consolidates the health records of patients in the entire country. P5 stated that "Having a unified solution in the country [South Africa] that both public and private divisions of the system can use would allow for a single medical record for every citizen, that healthcare providers and government and policymakers can have access." P4 added that the features of AI-powered cloud computing can integrate all systems across provinces in the country into just one system. These findings are quite relevant in the context of South Africa. P1 and P5 believed that South Africa's current healthcare system is siloed, with each key stakeholder in the public and private sectors doing their own thing. P5 continued, "While we have good doctors, hospitals, laboratories, and so on, there is no integration that allows the various parties to collaborate in order to achieve efficiency and effectiveness."

Furthermore, it was believed that when it came to health information systems, the systems in use lacked consolidation, making interaction with them cumbersome and ineffective. P1 cited the South African Department of Health, which has around 14 different types of systems to interact with. [14] also mentions that the healthcare system in South Africa is two-tiered with the public and private sectors operating largely in silos. The South African healthcare scenario could be similar to other developing countries. Thus, AI-powered cloud computing, as alluded to by P5 and P4, can assist in building a "unified healthcare solution" in that scenario.

Enhanced collaboration:
AI-powered cloud computing has the potential to support collaboration, leading to the effective participation of leaders in the healthcare system. According to [15], one of the advantages of cloud computing is *accessibility-* referring to cloud computing's ability to provide always-accessible data as well as allowing mobility [16], meaning consumers can access their resources from any geographical location via an internet-connected device. For participant P4, the accessibility advantage of cloud computing can be used to enhance collaboration with leaders as resources can be accessed over a network from any geographic location.

"It enhances and supports collaboration, because it can be available over a network, and it can be accessed from anywhere at any time… the leaders could be in diverse geographical locations, wherever they are, but they could still participate to support the project that they're working on." (P4)

P2 believed that it allows doctors to share data with each other deriving value from *data integration.* It may also foster better communication between the private sector and government, ultimately breaking the silos created. "So once again it comes down to the value of AI from data integration and data sharing perspectives. Obviously, then we didn't look at things like real-time collaboration and communication… Obviously, with that, you get better communication, you get better collaboration, you get private sector and government sector coming together, working together to manage the shocks." (P2)

Empowered decision-making:
AI-powered cloud computing *empowers the leader's decision-making* process by providing them with quality *data analytics*, an efficient way to access information and the ability to *personalize risks* within certain areas and individuals that require access to healthcare. All these lead to the development of evidence-based solutions. For P2, AI-powered cloud computing provides advanced tools and capabilities that empower leaders to participate in decision-making and contributes to the improvement of healthcare outcomes. P3 agreed with P2, believing that leaders are faced with different competing priorities and by leveraging AI-powered cloud computing and its powerful capabilities, they would be able to prioritize effectively as they would have data to support them.

"The technology helps by providing advanced tools and capabilities to empower both leaders and individuals to actively participate in decision making and to help contribute to the improvement of healthcare outcomes and results" (P2).

AI-powered cloud computing fosters the ability to process vast amounts of data and information efficiently and this gives leaders the ability to make evidence-based decisions. P4 (data analyst) stated that "The fact is that with AI-powered cloud computing, you are able to synthesize a lot of information, really, that would take a while to get synthesized using internal computing capabilities."

In essence, to answer RQ1, the findings show that AI-powered cloud computing can assist in integrating the healthcare system. An integrated healthcare system is defined by [17] as "coordinated care that addresses all aspects of patient health, focuses on a patient's individual needs, and involves a multidisciplinary team of healthcare professionals." An integrated healthcare system can provide numerous benefits, including improved quality of care, patient satisfaction, access to treatment, and cost savings. Access to treatment is critical to the resilience of healthcare systems because it ensures that patients receive the appropriate treatment when they require it. According to the findings, AI-powered cloud computing also helps to improve the resilience of healthcare systems through collaboration. [18] investigated collaborative processes in relation to resilient healthcare and discovered that across levels and contexts, healthcare workers collaborate to adapt and respond to changes in order to maintain processes and functions that improve quality and safety. The authors concluded that such collaborations are critical to healthcare resilience.

RQ 2: How does AI-powered cloud computing enhance the coordination of activities across government and key stakeholders of a healthcare system?

The second research question sought to ascertain participants' perceptions of how AI-powered cloud computing may enhance the coordination of activities across key stakeholders in government and healthcare systems. There were 3 themes generated from RQ 2 as portrayed below.

AI-powered cloud computing enhances collaboration.

Participants believed that AI-powered cloud computing would solve the problem of *siloed operations* thus improving the coordination of activities between government and key stakeholders. P1 and P2 were of the view that a deployed AI cloud computing technology could provide the private and public healthcare sectors the ability to collaborate, and the public sector could leverage from the investments the private sector has already been making towards AI and cloud computing technology. P2 stated, "And then obviously with that you get better communication, you get better collaboration, you get private sector and government sector coming together, working together to manage the shock". P1 said, "So again, to come back to how AI facilitate communication in that aspect. It hasn't yet had an impact, especially because you're dealing with the private and the public sector. In the private sector, each player appears to be working, as I said in silos, each one developing their own internal AI capabilities that enable seamless communication between different platforms. But if you go into the public setting public sector, this is where the masses are. This is where the consumers of health are – that (the communication) is non-existent." AI-powered cloud computing's impact on collaboration has also been discussed in RQ1 above.

AI-powered cloud computing enhances systems security

For P4, AI-powered cloud computing's security advantage [*Increased security* [19]] can give stakeholders the confidence of having secure systems that will enhance their coordination of activities at a *reduced cost*. According to P4, "The security of the platform they're working on is guaranteed because cloud computing organizations actually have the financial muscle to get the best experts in terms of security of the system. So, their security will be guaranteed. So even if they're engaging virtually, they will not be concerned about the security of their systems."

AI-powered cloud computing assists in managing patients records
AI-powered cloud computing can also assist in the management of patient records through electronic health records (EHR). EHR is of extreme importance to healthcare organisations [20]. As pointed out by P5, "It creates greater efficiency and management of patient records within the healthcare system". This effective management of patient records can be considered an essential activity that needs to be coordinated to ensure resilience.

RQ 3: How does AI-powered cloud computing enhance healthcare information systems and flows?

[4] recognizes that health information systems are at the core of decision-making throughout any policy process. Having poor information systems, and interrupted flows can undermine the effective management of a shock in healthcare [4]. Assessment areas for effective information systems and flows include communication infrastructure, the flow of data to stakeholders and the existence of data collection systems [4].

The findings pertaining to RQ3 (How does AI-powered cloud computing enhance healthcare information systems and flows?) yielded the themes discussed below.
Improved quality of information:
P3 believed that there are currently many challenges regarding the quality of information gathered in healthcare to enable leaders, policymakers, and even doctors to make decisions efficiently and effectively. The information faces difficulties in terms of completeness and a variety of other factors. As noted by P3, "Now, AI will definitely have potential in the, let's call it, quality of healthcare information… You know, AI systems could help to improve the quality of information in a system like the DHIS [District Health Information System], for instance, in terms of completeness and many other factors."

Improved data management:
P2 believed that with AI-powered cloud computing, healthcare systems can leverage data integration and interoperability among various stakeholders, as well as improve data management and storage overall, which is advantageous because of the need to manage data efficiently to make informed decisions. With AI-powered cloud computing would come the ability to process vast amounts of data and have powerful data analytics creating valuable insights. "And you've got data integration and interoperability between the different players in the healthcare system. You got data analytics and insights that come out of this." (P2).

In summary, raising the quality of information provided and received from systems, as well as improving data management, results in more efficient and effective information systems and flows in the healthcare system. Doing so is crucial and should not be disregarded, according to [4]. Improved information and data management also allow for the development of predictive models in healthcare, which is covered in the next section.

RQ 4: How does AI-powered cloud computing enable timely detection of shocks (disruptive events) and their impact?

RQ4 looked at how AI-powered cloud computing enables the timely detection of shocks (disruptive events) and their impact. The resilience of healthcare systems largely depends on the availability of systems with the capacity to detect and track events as they happen in real-time or as soon as possible [4]. There is a need for surveillance systems that provide early warnings to leaders about possible shocks. An important area of assessment is mechanisms to identify change in need and access to healthcare services [4]. Respondents believed that AI-powered cloud computing can indeed enable the timely detection of shocks in the healthcare system, and the themes that emerged focus heavily on the use of *predictive models, personalizing risk areas.*

Personalizing risk areas:
P1, P3 and P5 shared the belief that AI-powered cloud computing can bring about systems that categorize the health risks of not only individuals but also populations and this in turn can help leaders to identify what the impact of shocks may be. This personalized risk can be based on various factors, such as prevalent health conditions in an area, and that can be loaded into AI-powered cloud computing systems. P5 pointed to the complexity of the issue,

"But, you know, the stresses or the environmental factors that determine disease are different in different populations, based on different types of food being consumed by different cultures … different diets, alcohol consumption, smoking, finances, living conditions, climate, all of these factors, you know, work-related stress, family stress, relationship issues, all of these types of factors are different in a country like South Africa, with disparate incomes, in the way we live in communities... All these factors would determine disease patterns that are very different across the country in different communities. So, any AI solution, that's a unified solution that's able to measure, identify and track individual and population risk would allow for better preparedness".

Predictive modelling:
For P2, AI-powered cloud computing can use vast amounts of data not only to predict the impact of shocks but also to predict when shocks may be just about to happen through the use of *proactive data.* According to P1, "AI would disrupt that environment by being able to detect the shocks before they happen … So, so it helps to enable the detection of shocks and then it helps to leverage advanced analytics, machine learning, algorithms real-time monitoring systems kick in and, you know, you then have the opportunity to collect data in real-time. Share this data in real time integrate this data and contextualize it from an impact perspective and build a story on this on this shock that has now happened".

P3 exemplified how climate change has impacted health and how AI-powered cloud computing systems could aid in predicting the impact of climate change on particular groups of the population. P3 continued, "AI could then be able to predict if there's flooding, or there's this geographic, you know, there's this weather event that is happening, this is how we can prepare ourselves in terms of responding….".

6 Limitations

This study relied on a smaller sample size than initially intended, with interviews being conducted with only five experts in the healthcare and IT sectors. This reduced number might limit the comprehensiveness and diversity of insights acquired. However, the researchers aim to address this in a subsequent version of this paper once all 12 interviews have been conducted.

7 Conclusion

This paper explored how AI-powered cloud computing can enable healthcare systems resilience focusing primarily on healthcare systems governance. Using the WHO's resilience framework, the study examined the nexus between AI-powered cloud computing and key aspects of healthcare governance: participatory leadership, coordination of government and key stakeholders, effective information systems and flows, and the timely detection of shocks and their impact.

The findings highlight the potentially positive impact of AI-powered cloud computing in healthcare. It encourages collaborative leadership by providing leaders access to an integrated healthcare system, breaking down silos. It not only improves collaboration but also helps leaders in making well-informed decisions. The technology also improves the coordination among various healthcare groups. It ensures security and monitors performance, which are important for smooth healthcare operations.

Additionally, applying AI in cloud computing greatly enhances data management, ensuring high-quality and accessible healthcare information. Lastly, in a time where unexpected events can disrupt healthcare, AI-powered cloud computing becomes a valuable tool. It has the potential to predict risks/shocks and encourage collaboration to reduce potential problems.

The study's findings offer policymakers, healthcare providers, and technology developers insights into the role of AI-powered cloud computing in improving healthcare system resilience. As architects of healthcare frameworks, policymakers can use the findings to make informed decisions that facilitate the integration of AI-powered cloud computing. Recognizing the potential for AI-powered cloud computing to improve healthcare system governance, policymakers can foster an environment that promotes the development and use of AI-powered cloud computing in healthcare. The study may serve as motivation for technology developers to continue developing AI-powered cloud computing solutions for the healthcare sector. Developers can fine-tune their technology to align with the healthcare resilience framework by understanding the specific governance dimensions highlighted in this research. This can lead to a stronger connection between technology and healthcare, paving the way for innovative solutions that improve healthcare resilience.

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Fostering Youth Wellbeing Through mHealth Apps: Embracing Physical Activity for a Healthier Lifestyle

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Abstract. In recent years, the World Health Organisation (WHO) has noted an increase in the number of young individuals suffering from Non-Communicable Diseases (NCDs). In addition, NCDs are becoming more common among South African young people. The high rate of smartphone usage in South Africa provides an opportunity to develop mobile applications to encourage young people to embrace healthier lives. This study explored the possible use of mobile health applications to encourage youth to engage in healthy physical activity using the Unified Theory of Acceptance and Use of Technology (UTAUT) model as the theoretical lens. A survey questionnaire was used to collect data from 320 participants using convenient sampling. The findings revealed that the factors influencing youth's adoption of mobile health applications that encourage healthy physical activity are facilitating conditions, social influence (SI), performance expectancy (PE), and effort expectancy (EE). Thus, mobile application-driven interventions that aim to encourage young people to be active should consider the constructs identified in this study that have a higher effect size.

Keywords: Non-Communicable Diseases · healthy lifestyles · physical activity · mobile applications · Unified Theory of Acceptance and Use of Technology

1 Introduction and Background

The World Health Organisation (WHO) defines non-communicable diseases (NCDs) as chronic diseases that cannot be transferred from one person to another [1]. According to [2], NCDs include cardiovascular diseases as well as chronic respiratory diseases, diabetes, and cancer. There is an increasing burden of NCDs in developing countries [3], and this has caused the World Health Organization to declare that NCDs are a global health crisis that needs to be prioritized [1]. Several studies show that a high number

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of people affected by these diseases are from low- to middle-income countries where effective prevention and management of these diseases are lacking [1]. Some factors that contribute to developing NCDs, include smoking tobacco, harmful use of alcohol, adopting an unhealthy diet, and lack of body/physical activity [3].

Forouzanfar *et al.* argue that the major cause of NCDs is living an unhealthy lifestyle [4]. World Health Organisation reported a high rate of young people who suffer from and succumb to non-communicable diseases [1]. Studies have shown that most people, including the youth, own smartphones through which they can stay informed on issues related to the NCDs [5, 6]. Moreover, [7] states that mobile technologies could be used as part of healthcare interventions to raise awareness about NCDs, thereby promoting healthy living. Several studies have investigated the use of mobile technologies to encourage physical activity and exercise [8, 9]. In the context of this study, adopting a healthy lifestyle includes adopting a physical exercise routine. There has been little evidence that people use mobile technologies to induce a healthier lifestyle in previous studies [10, 11]. In addition, [12] and [13] have found that people view healthy lifestyles as just eating healthy rather than adopting physical activity/exercise routines (such as jogging and other exercises).

In South Africa, there is evidence of an increase in diseases related to unhealthy lifestyles, especially among the youth [14]. In light of the current adoption of mobile applications by the youth in South Africa, which was estimated to be 72% a decade ago [15], there is a potential for using mobile applications to induce healthy lifestyles amongst the youth. However, in the context of South Africa, factors that may contribute to the adoption of such mobile applications have not been widely investigated from the youth perspective. This means that the potential adoption of mobile applications that may induce healthy lifestyles by the youth remains largely unknown in the South African context. Identifying such factors may assist in devising adequate mHealth interventions that are specifically targeted to the youth. Moreover, it is anticipated that findings from this study will assist in the design of such mobile health applications taking into consideration the determinants of the adoption of such applications based on the study's findings. Such a user-centred design may contribute to the acceptance of the applications, which could lead to a reduction of health risks associated with the lack of a healthy lifestyle. In the context of this research, the term youth represent people between the age of 14 and 35 as defined by South Africa's National Youth Commission Act of 1996 [16].

The remainder of this paper is structured as follows: Sect. 2 provides a summary of the underlying theory. Section 3 presents the applied research method and the study design. This is followed by the results, discussion, limitations, recommendations and, finally, the conclusion.

2 Theoretical Framework

The study is underpinned by the Unified Theory of Acceptance and Use of Technology (UTAUT) model developed by Ventakesh *et al.* [17]. According to the theory, the constructs: performance expectancy (PE), effort expectancy (EE), and social influence (SI) are likely to have an impact on behavioural intention (BI), while, facilitating conditions (FC) as a construct, is more likely to have an impact on use behaviour. Venkatesh et al. [17] explains the constructs as follows:

Performance Expectancy (PE) measures how much users believe a system will improve their ability to accomplish their jobs.

Effort expectancy (EE) is a term used to describe a person's assessment of how simple or complicated a system is to use and learn.

Social influence (SI) measures whether those who have the power to shape a person's behaviour think that person should adopt a certain system.

Facilitating conditions (FC) refers to people's perceptions that a new system may be used with support (from both a technical and organisational infrastructure) in place.

In addition, the UTAUT model suggests that the moderating elements for the model are gender, age, experience, and voluntariness of use. The UTAUT constructs are shown in Fig. 1. To identify factors influencing the potential acceptance and use of mHealth applications to promote healthy lifestyles, the UTAUT model was used as the theory lens. UTAUT combines the other widely used frameworks. As a result, the UTAUT model can assist in identifying a variety of variables that influence the adoption of information systems [18].

The study was guided by the following research questions:

i. What is the effect of performance expectancy on the behavioural intent to use mobile applications that encourage healthy physical activity?
ii. What is the effect of effort expectancy on a person's inclination to use mobile applications that encourage healthy physical activity?
iii. To what extent is the effect of social influence on the decision to use mobile applications that encourage healthy physical activity?
iv. What is the effect of facilitating factors on users' inclination to use mobile applications that encourage healthy physical activity?
v. What is the effect of behavioural intention on the use of mobile applications that encourage healthy physical activity?

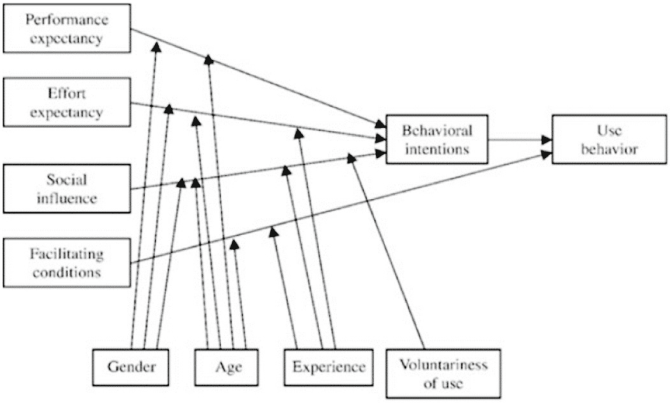

Fig. 1. UTAUT framework [17].

3 Methodology

3.1 Method

The study used a deductive approach coupled with the quantitative method. The study's population comprised young people between the ages of 18 and 35 who were registered students at an institution of higher learning in South Africa, which at the time the study was conducted had 9500 registered students. The sample size was established using De Morgan's sampling table [19], resulting in 370 students constituting the sample for this study. The choice of the student population was mainly because most of the students in institutions of higher learning fall within the age range of 18–35 years.

The principal method of collecting data for this study was the questionnaire survey. Data analysis tools included SMARTPLS 3.0 and the Statistical Package for Social Sciences (SPSS) version 25. Using SPSS version 25, a descriptive analysis was performed to determine how the youth perceived mobile health applications that encourage physical exercise. Additionally, the UTAUT model was assessed using SMARTPLS 3.0's Partial Least Square (PLS) Structural Equation Modelling (SEM) in the context of answering the study's research questions. Models for the Structural Equation Model (SEM) can be divided into two categories: measurement models and structural models [20]. To ascertain the validity and reliability of the constructs for the measurement model, tests for internal consistency reliability, indicator reliability, convergent validity, and discriminant validity were conducted. The Coefficient of Determination (R^2), Standardised Root Mean Square Residual (SRMR), Predictive Relevance (Q^2), and Path Coefficients were used to demonstrate the model's validity. The structural model forecasts how the endogenous constructs will match the model.

4 Results

4.1 Response Rate and Demographic Distribution

Out of the 370 responses, 190 (51.4%) of respondents were female, 178 (48.1%) were male respondents, and 2 (0.5%) did not declare their gender. Additionally, most respondents were under 30 years old, with ages 18 to 23 accounting for 51.9% and ages 24 to 29 accounting for 40.3%. According to South Africa's categorisation of youth, that is, people within the age range of between 18 and 35, it is inferable that all respondents can be classified as young people [16].

The results also revealed that 94.4% of respondents owned a smartphone, while only 4.3% did not. This was expected given the rise in the young people's usage of mobile phones in South Africa [14]. It can be inferred that most respondents were familiar with mobile applications and could thus respond to the research questionnaire based on that experience. In South Africa, the percentage of people who own smartphones has climbed from 45% in 2016 to 90% in 2019 [16].

The results show that 22.2% of respondents frequently (Often% + Very often%) use fitness applications, 21.1% of respondents rarely use these applications, and almost a third (30.8%) of the respondents use them occasionally. It can therefore be inferred that 74.1% of participants have previously used these applications, implying that they were aware of physical fitness applications.

4.2 Construct Validity Test

Convergent and discriminant validity tests in PLS-SEM assist in establishing if a construct belongs in the final model [21]. Regarding the present study, the constructs that passed the convergent and discriminant validity tests can be the factors that influence whether a mobile application that promotes physical activity is adopted.

4.2.1 Convergent Validity

Convergent validity, according to [22] determines the intercorrelation of variables that belong to the same construct. [23] posits that a moderate or strong correlation provides proof of convergent validity. PLS-SEM measures convergent validity using Cronbach's Alpha coefficient, Composite Reliability (CR), and Average Variance Extracted (AVE). As depicted in Table 1, the AVE was greater than 0.6, the Cronbach's alpha value was greater than 0.8, and the CR for each UTAUT construct with items related to the use of mobile applications that promote physical activity was greater than 0.8. As a result, convergent validity was established.

Table 1. Convergent validity

	Cronbach's Alpha	CR	(AVE
Behavioural Intention (BI)	0.912	0.944	0.850
Effort Expectancy (EE)	0.907	0.935	0.781
Facilitating Conditions (FC)	0.816	0.878	0.645
Performance Expectancy (PE)	0.852	0.910	0.772
Social Influence (SI)	0.838	0.902	0.755
Use Behaviour (UB)	1.000	1.000	1.000

4.2.2 Discriminant Validity

According to [24], the degree to which a construct is empirically unique from other constructs i.e., whether a construct measures only what it is designed to measure, is represented by its discriminant validity. The Heterotrait-Monotrait Ratio (HTMT) was employed in this study to evaluate discriminant validity [25]. According to [24], the HTMT ratio for the Covariance-Based Structural Equation Modelling (CB-SEM) should be smaller than 0.85. The HTMT ratio should, however, be smaller than 1.0 for PLS-SEM [25]. The HTMT for each construct relating to the adoption of mobile applications that encourage physical activity is less than 1.0, as shown in Table 2. All items in the UTAUT framework that assessed the effect of mobile applications that encourage physical activity therefore passed the discriminant validity test.

Table 2. Discriminant validity for physical activity

	BI	EE	FC	PE	SI	UB
BI						
EE	0.520					
FC	0.412	0.624				
PE	0.564	0.678	0.425			
SI	0.603	0.512	0.381	0.614		
UB	0.520	0.386	0.409	0.375	0.452	

4.2.3 Factor Loadings

To confirm the reliability of all the variables and to identify those that are essential to measuring factors related to the adoption of mobile health applications that encourage physical activity, factor analysis was utilised. The scores of square factor loadings are used to assess factor loading, which looks at the relationships between each variable in a construct [26]. Variables with factor loadings of less than 0.7 were removed from this study since they did not have a statistically significant effect [26]. Table 3 shows the findings of the factor analysis for the constructs of behavioural intention, social influence, performance expectancy, and effort expectancy.

Since all factor loading values are greater than 0.7, it can be concluded that each construct's items measure just one construct. However, two variables for the facilitating conditions construct had values that were less than 0.7: FC3 (access to a mobile device that allows you to download programmes: 0.51) and FC4 (access to people who can help with difficulties when using mobile applications:0.55). These were removed from further consideration.

4.3 Path Coefficients (Beta)

The path coefficients were calculated using SMARTPLS v3's bootstrapping feature. According to [32], the path coefficient aids in determining how an exogenous variable affects an endogenous variable. The UTAUT constructs' influence on the adoption of mobile health applications that encourage physical activity is also determined by the path coefficient, which also establishes the validity of the latent variables (UTAUT variables) employed in this study. The following hypotheses were proposed to determine the path coefficients:

H_1: Performance expectancy (PE) influences the behavioural intention to use mobile applications that promote physical activity.

H_2: Effort expectancy (EE) influences the behavioural intention to use mobile applications that promote physical activity.

H_3: Social influence (SI) influences the behavioural intention to use mobile applications that promote physical activity.

H_4: Facilitating conditions (FC) influence the use of mobile applications that promote physical activity.

Table 3. Factor loadings

	Items	BI	Factor loadings
BI	BI1	0.92	0.85
	BI2	0.917	0.84
	BI3	0.929	0.86
EE	EE1	0.89	0.79
	EE2	0.879	0.77
	EE3	0.91	0.83
	EE4	0.856	0.73
FC	FC1	0.853	0.73
	FC2	0.894	0.80
	FC3	0.711	0.51
	FC4	0.74	0.55
PE	PE1	0.888	0.79
	PE2	0.914	0.84
	PE3	0.832	0.69
SI	SI1	0.87	0.76
	SI2	0.879	0.77
	SI3	0.858	0.74
UB	UB1	1	1

H_5: Behavioural intention (BI) influences the use of mobile applications that promote physical activity.

Behavioural intention to use mobile applications that encourage physical activity is most strongly influenced by social influence (0.330), performance expectancy (0.208), and effort expectancy (0202), as shown in Table 4. Additionally, facilitating conditions (0.247) and behavioural intention (0.425) strongly influence use behaviour. All the model's constructs had path coefficients that were higher than 0.1. Consequently, all the hypotheses concerning the impact of the UTAUT constructs (variables) on the adoption of mobile applications that encourage physical activity were found to be valid.

4.4 Coefficient of Determination (R^2)

The Coefficient of Determination (R^2), which ranges in value from 0 to 1, measures how well the linear model fits the data. According to [28], R^2 is deemed strong if it is at least 0.67, moderate if it is around 0.33, and weak if it is around 0.19. R^2 was utilised in this study to establish the relationship among the variables used to assess the effect of the UTAUT constructs on the adoption of mobile health apps that promote physical activity. Figure 2 presents the resulting model regarding youth's adoption of mobile applications that encourage physical activity.

Table 4. Path coefficients for physical activity

	Beta	T Statistics (|O/STDEV|)	Comment
BI - > UB	0.425	10.666***	Supported
EE - > BI	0.202	3.516***	Supported
FC - > UB	0.247	5.489***	Supported
PE - > BI	0.208	3.457***	Supported
SI - > BI	0.330	6.288***	Supported

Critical t-values for two tailed tests are 1.65* (significance level = 10 percent), 1.96** (significance level = 5 percent), 2.58*** (significance level = 1 percent).

As depicted in Fig. 2, the three exogenous factors (performance expectancy, social influence, and effort expectancy) account for 37.5% of the variation in the behaviour intention to use mobile health applications that encourage physical activity. Furthermore, behavioural intention and facilitating factors account for 30.3% of the variation in the use of mobile applications that encourage activity.

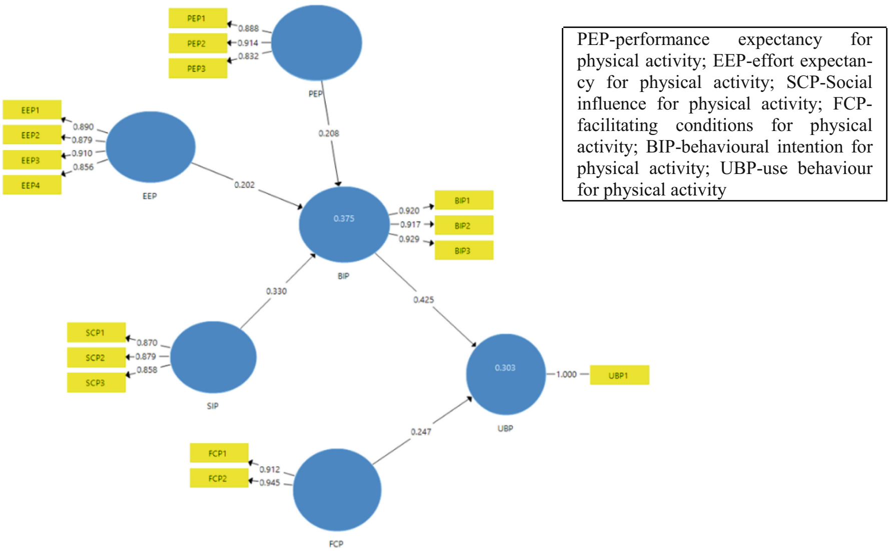

Fig. 2. Model result for physical activity

4.5 Model Fit

The model fit is employed as a tool to determine whether a model is valid and whether it fits the data, [29]. Using SMARTPLS version 3's Standardised Root Means Squared Residual (SRMR), the model's fit was evaluated. If the SRMR value is less than 0.08, then the model is considered acceptable [27]. In this study, the SRMR value is 0.044. Therefore, (Table 5.) the proposed model as depicted in Fig. 2, can be deemed acceptable.

Table 5. Model fit for physical activity.

	Saturated Model	Estimated Model
SRMR	0.044	0.048
d_ULS	0.265	0.313
d_G	0.235	0.241
Chi-Square	548.660	558.257
NFI	0.857	0.855

5 Discussion

The following section discusses the findings in light of the guiding research questions.

a. What is the effect of performance expectancy on the behavioural intent to use mobile applications that promote physical exercise?

The path coefficient helps analyse the relationship between an endogenous variable (in this case, the adoption of mobile applications that promote physical activity) and an exogenous variable (performance expectancy in this case) [27]. This study established that performance expectancy has a significant positive effect on behavioural intention to use mobile health applications that encourage physical activity (effect size = 0.208 at 99% confidence level). The study's findings are consistent with those of earlier studies [8, 30, 31] that discovered a substantial relationship between performance expectancy and behaviour intention towards the adoption of mobile health applications.

b. What is the effect of effort expectancy on a person's inclination to use mobile applications that promote physical activity?

The bootstrapping feature of the SMARTPLS software version 3 was used to examine the effect of effort expectancy on behavioural intention. According to the findings, effort expectancy has an effect size of 0.202 at a 99% confidence level on mobile applications that encourage physical activity, which is consistent with earlier research [8, 32]. According to [31], the uptake of mHealth services is most strongly influenced by effort expectancy in Bangladesh.

c. To what extent is the effect of social influence on the use of mobile applications that promote physical activity?

This study established that social influence has a significant positive effect on the adoption of mobile health applications that encourage physical activity (effect size = 0.330 at 99% confidence level). Additionally, it was discovered that among the UTAUT constructs, social influence is the best predictor of behavioural intention. According to [33], social influence plays a significant role in determining mobile phone use intention. According to a related study by [8], social influence had the greatest effect on individuals' behavioural intentions to use mobile health apps that encourage physical activity. This is understandable given that youth often exhibit higher levels of peer influence than any other population category [34].

d. What is the effect of facilitating conditions on the use of mobile applications that promote physical activity?

The findings show that facilitating conditions influence the behavioural intention to use mobile health applications that encourage physical activity with an effect size of 0.247 (at 99% confidence level). The findings are consistent with those of another study [8], which discovered that in South Africa, enabling environments, as a construct, had a strong effect on the use behaviour of mobile health applications that promote physical activity. Furthermore, [35] discovered that facilitating conditions affected the uptake of mHealth applications.

e. What is the effect of behavioural intention on the usage of mobile apps that promote physical activity?

The behavioural intention construct is used in the UTAUT framework to assess the actual use behaviour. According to the study's findings, behavioural intention towards adopting mobile applications that encourage physical activity has an effect size of 0.425 (at 99% confidence level).

6 Limitations

While the study sampled young individuals aged 18 to 35, the results might not fully represent the broader South African youth, as it focused primarily on those with formal education. Notwithstanding the relatively limited sample, this work offers valuable insights into the use of mHealth applications among young individuals.

7 Recommendations and Future Work

It is recommended that further research be undertaken in the following areas:

Further research is required to understand the adoption of mHealth applications promoting healthy lifestyles among a more diverse sample that also includes youth who are not engaged in formal education. This study does not imply that a healthy lifestyle consists solely of physical activity. Consequently, other aspects of healthy lifestyles that were not covered in this study should be investigated.

On a practical basis, this study suggests that any interventions aimed at encouraging young people to lead healthy lifestyles should consider the constructs (discovered via this study) that have a significant effect on the adoption of mHealth applications that encourage healthy lifestyles.

8 Conclusion

The study sought to determine the factors that contribute to the use of mHealth applications to encourage healthy lifestyles among young people. The results indicated that with varying effect sizes, each of the UTAUT constructs significantly influences behaviour intention towards the adoption of mobile applications that promote physical activity. The most significant effect size across all the constructs is related to social influence. Hence, social influence is the strongest predictor of the adoption of mobile applications that encourage physical exercise.

Social influence (SI), effort expectancy (EE), and performance expectancy (PE) together account for 37.5% of the variation in behavioural intention (BI) towards mHealth applications that encourage young people's physical activity. Facilitating conditions influence the use of mobile applications that promote physical activity. Facilitating conditions explain 30.3% of the variation in the use of behaviour of mobile applications that promote physical activity. An important implication of these findings is that social media should be used in interventions that seek to promote mHealth applications that encourage healthy lifestyles among young people due to the impact of peer influence. This study is a pioneering effort in using structural equation modelling to assess the adoption of mobile applications advocating healthy habits among the sampled South African youth.

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Healthcare AI: A Bibliometric Review

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Abstract. Artificial Intelligence (AI) is transforming various industries, and healthcare is no exception. AI is assisting practitioners in making more accurate diagnoses, improving patient outcomes, and enhancing the overall quality of care. In recent years, scientific publications on healthcare AI have reached unprecedented heights. However, a holistic view of how AI impacts healthcare is scant. Therefore, we rely on a bibliometric approach to explore the interplay between AI and healthcare. This study offers a dynamic, longitudinal analysis of healthcare AI publications, shedding light on the field's expansion, attributes, and core themes: AI technology, healthcare applications, and human-technology interactions. These insights are of significant value to researchers, policymakers, and healthcare providers, aiding the development and adoption of AI into clinical practice and improving global patient outcomes. Furthermore, the study outlines future research directions that help scholars and practitioners understand and contribute to advancing healthcare.

Keywords: Artificial Intelligence · AI · AI applications · Healthcare · Bibliometric Analysis · Healthcare Professionals · Healthcare Practice

1 Introduction

Artificial intelligence (AI) is transforming various industries, and healthcare is no exception. AI can process and learn from large volumes of data and capture patterns otherwise hard for humans. The vast amount of healthcare data, coupled with advances in computational power, has contributed to the exponential growth of research and publications in healthcare AI [1]. Extensive research is emerging in disease diagnosis, automatic skin cancer detection, robotic surgery, oncology, psychiatry, and clinical decision support [2]. Collaboration with AI could help us improve patient outcomes, health system optimization, error reduction, cost reductions, and increased value [3].

Adoption in clinical practice is slower. Several challenges should be addressed before AI is widely accepted by practitioners and patients equally. Previous IS studies have yet to comprehensively map the status of AI and its implications in healthcare adoptions. Previous studies have mainly focused on specific applications of AI or minor aspects of the process of AI, including implementation frameworks, economic impact, patient outcomes, and ethics. For example, Higaki et al. studied the application of machine

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learning in cardiovascular disease [4]. Liang et al. performed a review analysis on the emergence and evolution of big data science in HIV/AIDS applications [5]. Responsible AI, which refers to ethical aspects of AI usage, enabling more transparency and privacy in AI applications, is still a nascent topic [6] applied in healthcare. Overall, little is known about the key AI technologies, their applications, benefits, and barriers in the healthcare systems.

Some medical providers are only willing to use AI in their clinics once its performance is proven in clinical settings. A lack of familiarity among medical practitioners about how AI would fit within and enhance their workflow and gaps in regulatory guidance and requirements also limit its adoption and use. By addressing these gaps, we can accelerate the development of AI solutions to improve patients' lives worldwide. Therefore, a longitudinal exploration of the AI literature on healthcare domains is fundamental to understanding in-depth nuances of AI in healthcare. This study aims to evaluate research outcomes and the impact of AI in healthcare practice, covering the technology, applications, and adaptability by identifying key trends and gaps in the literature; thus, we investigate the below research questions,

RQ1 - What are the patterns of publications in healthcare AI?
RQ2 - How is AI being used in healthcare systems?
RQ3 - What are the prominent themes of AI evolving in healthcare?

We study these topics through bibliometrics analysis of the Scopus database and selected articles that address these questions. This study brings unique insights and makes significant theoretical and practical contributions by identifying AI's main dynamics applied in healthcare. It then reports the main trends, the most popular AI approaches, barriers, and benefits related to the healthcare [7]. The findings of this study provide valuable insights for academic researchers and healthcare practitioners. By assessing the impact and identifying the most promising technologies, this study helps to accelerate the translation of healthcare AI research into clinical practice. It also helps policymakers develop guidelines for the responsible and ethical use of healthcare AI technologies.

2 Research Methodology

Bibliometrics is a common approach that uses mathematical and statistical methods to analyze research journals systematically [8]. We followed the best practices suggested by a reliable bibliometric analysis [9] of the AI approach in healthcare contexts. We selected Scopus since it is the world's largest abstract and citation database, covering a wider range of journals and records than the Web of Science [10].

To get a broader perspective of the topic, keywords such as 'Artificial Intelligence,' 'AI,' 'healthcare,' and 'healthcare industry' were used using 'OR' and 'AND' string commands in the title, abstract, and keywords section. Although no filter was used for the time frame, considering the discussed keywords and limitations, the study's time frame was limited to 1965 to Feb 2023.

To ensure high-quality search results, peer-reviewed articles, journals, and conference papers were included in the selection criteria [11]. Furthermore, only documents published in the English language were considered. The total records downloaded from

Scopus were 19431 entries. We filtered 639 articles published in the A* and A journals from ABDC 2019 ratings from this list. We excluded B and C-category journals considering low occurrences (on average, two articles per journal) of healthcare AI articles in these journals (432/1835). We then removed 17 duplicate and 22 unrelated articles.

Further, we included only those healthcare domain-specific articles focusing on artificial intelligence. Finally, 600 documents were selected for this study. The detailed selection criteria are presented in Fig. 1.

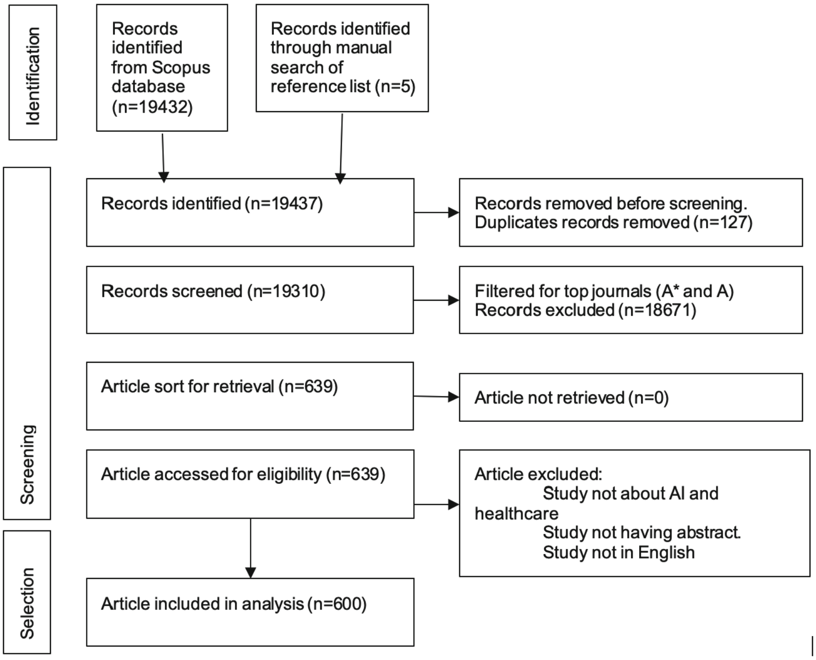

Fig. 1. Research Methodology

Finally, the extracted data relating to research questions 1 and 2 were mapped and summarized. For research question 3, we have used the author's keyword, title, and abstract co-occurrence to analyze and categorize documents into clusters of different themes.

3 Results

3.1 Trend Analysis

In this section, we conduct a trend analysis of articles using indicators such as the number of publications, number of citations, and productive countries to answer RQ1, what are the patterns of publications in healthcare AI.

3.2 Annual Scientific Production

Figure 1 shows the annual distribution of 600 articles which met the research criteria. From one article (0.16%) in 1985 to 130 articles (20.90%) in 2022, the use of AI in healthcare shows an exponential growth (R2 = 0.465). The research publication exhibits three distinct phases: an initial phase (1985–2009) with less than ten articles published annually, a developmental phase (2010–2016) seeing an annual range of 18 to 33 articles, and an expansion phase (2017–2022) featuring an annual range of 43 to 130 articles (Fig. 2).

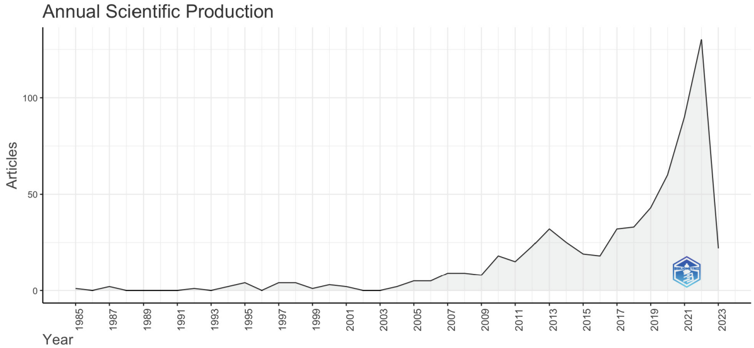

Fig. 2. Annual Scientific Production

3.3 Analysis of Key Journals

In total, 600 articles were published in 90 journals. Table 1 presents the top ten journals ranked based on total publications (TP). If it ties in total publications, we ranked journals according to their total number of citations (TC).

Table 1 reveals that ten journals published 67% of the articles in the field. Top two journals, "International Journal of Medical Informatics" and "Journal of The American Medical Informatics Association" published the most, contributing to 27.67% and 19.83% of the total articles. It indicates that medical-focused journals have more publications compared to general management journals.

3.4 Analysis of Important Articles

The most influential articles can be identified by analyzing the number of citations received by the article [12]. Table 2 shows the 5 most frequently cited articles, of which the top two received more than 500 citations threshold. The most cited among them is the work by Burke et al., which reviews the application of AI in the nurse rostering [13]. The articles published by [14, 15], and [16] are the three most frequently cited articles in terms of annual citations. All three articles are related to health studies using AI. Among these, the article published by Dwivedi et al. [14] is the latest and has the top two total citations.

Table 1. Annual Scientific Production

#	Sources	Articles
1	International Journal of Medical Informatics	166
2	Journal of the American Medical Informatics Association	119
3	Decision Support Systems	24
4	Safety Science	20
5	Information System Frontiers	19
6	Journal of Cleaner Production	14
7	Knowledge Based Systems	13
8	Computer in Human Behavior	12
9	Technological Forecasting and Social Change	11
10	Bioinformatics	9

Table 2. The most cited articles on AI in healthcare.

Author (s)	Title	Year	Journal	TC	TC/Y
Burke E.K et al	The state of the art of nurse rostering	2004	Journal of Scheduling	682	34.1
Dwivedi Y.K. et al	Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice, and policy	2021	International Journal of Information Management	536	178.7
Laranjo L. et al	Conversational agents in healthcare: A systematic review	2018	Journal of the American Medical Informatics Association	393	65.5
Jiang Y., Wen J	Effects of COVID-19 on hotel marketing and management: a perspective article	2020	International Journal of Contemporary Hospitality Management	373	93.2
Nikfarjam A. et al	Pharmacovigilance from social media: Mining adverse drug reaction mentions using sequence labeling with word embedding cluster features	2015	Journal of the American Medical Informatics Association	365	40.6

3.5 Analysis of Most Productive Countries

This section aims to analyze the country-wise distribution of healthcare AI articles. The analysis of the authors' countries is based on the country to which the authors belonged at the time of publication [12]. Figure 3 shows the top 10 countries with the highest number of publications. The USA was the most published and influential country, with 191 papers, which might be linked to the size of the country, the R&D investments, the number of researchers, and the research facilities [17]. China occupies the second position with 55 publications; the United Kingdom closely follows China with 43 publications at third, and Australia at fourth with 29 publications.

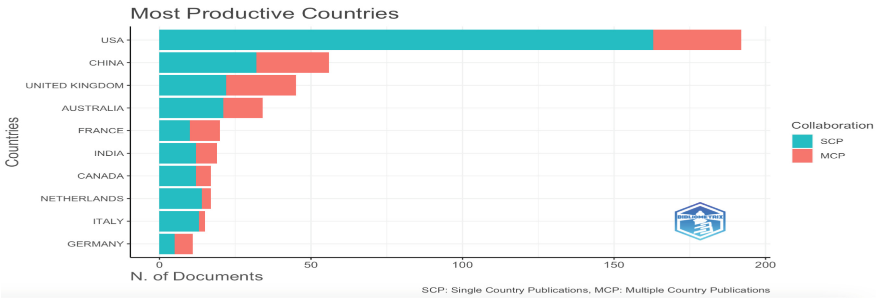

Fig. 3. Annual Scientific Production

3.6 Conceptual Structure Analysis

The keywords that authors list in a publication reflect the topical coverage of that publication, and their co-occurrence reflects the topical trends prevalent in the research field [18]. We perform a keyword co-occurrence analysis of author keywords listed in the 600 articles to answer the most prominent themes of AI for healthcare practice. The keyword occurrence and network are presented in Tables 3 and Fig. 4, respectively.

The top 10 keywords based on their occurrences are presented in Table 3. "Artificial Intelligence" is the most prominent keyword in the list with 183 occurrences, followed by Clinical decision support system (123), electronic health record (43), healthcare (34), health informatics (29), natural language processing (21), health and safety (15), predictive modeling (10). All these keywords reflect the scope of publications in the dataset. More importantly, the keywords are consistent with the line of inquiry of the present study as they reflect the healthcare informatics and related core technologies that can be employed for the automation and optimization of healthcare practice.

The network among keywords is presented in Fig. 4. The node's size represents the occurrence of the keyword, whereas the link between nodes and the thickness of that link represents the co-occurrence between keywords and the degree of that co-occurrence. Here, the topic network illustrates that artificial intelligence, clinical decision support systems, electronic health records, and health informatics are the most prominent nodes in the network that occur and co-occur most frequently with other topical keywords, thus highlighting their relative importance in the field.

Table 3. Authors keyword occurrence

Keyword	Occurrences
Artificial Intelligence	183
Clinical Decision support system	123
Electronics health records	43
healthcare	34
Health informatics	29
Covid-19	31
Natural language processing	21
Automation	16
Health and safety	15
Clinical	8
Knowledge structure	9
Responsible AI	8
Simulation	9
Decision making	9
Data mining	8

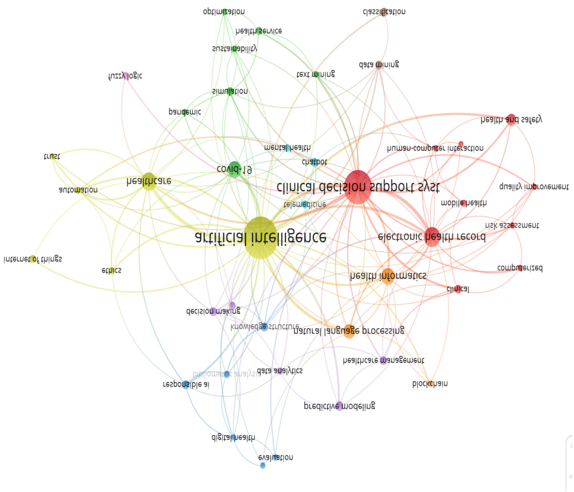

Fig. 4. Authors keyword co-occurrence

The term co-occurrence map on the review corpus results in the formation of three major thematic clusters. The thematic clusters are presented in Fig. 5, highlighting each cluster in a different color. Cluster 1, 2, and 3 are highlighted with red, green, and blue nodes.

Cluster 1 comprises 34 items that have a total frequency occurrence of 1870. The concepts of algorithms, accuracy, performance, feature, and task appear prominently in the cluster's words, which signify the importance of AI algorithms and quality measures for healthcare. AI algorithms such as decision trees, random forests, Bayesian networks, neural networks, deep learning, and natural language processing are predominantly used

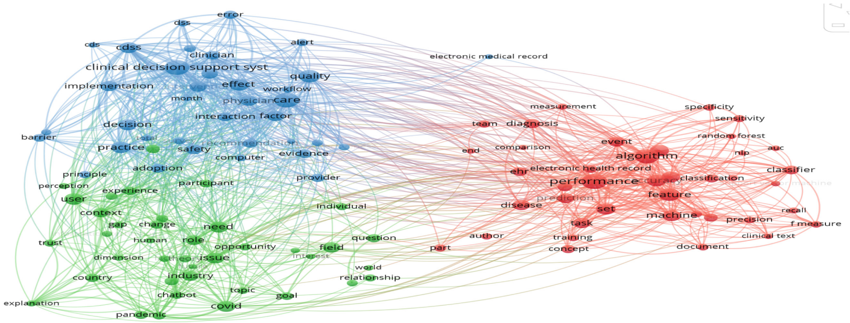

Fig. 5. Title and Abstract's topic co-occurrence analysis

in healthcare domains. AI algorithms can analyze patient data and provide insights into patient risk factors, which can help healthcare practitioners develop more effective prevention and treatment strategies.

Cluster 2 comprises 30 items with a total word frequency occurrence of 1485. The concepts of healthcare practice, literature, decision-making, clinical decision support system, recommendation, implementation, and physician appear prominently in this cluster's words, which signify the applications of AI in healthcare practice.

Cluster 3 comprises 22 items with a total word frequency occurrence of 1535. The concepts of artificial intelligence, technology, health, management, impact, healthcare, need, and issue appear prominently in this cluster's words, which signify the importance of AI and human interaction and the adoption of the technology. AI systems are being used to complement healthcare providers' skills, enhancing their ability to make accurate diagnoses, develop tailored treatment plans, and deliver personalized care. By allowing AI to handle time-consuming, repetitive mechanical tasks such as data analysis, documentation, and administrative processes, healthcare professionals can devote more time to communicating with patients and addressing their emotional needs.

4 Discussion

In this study, we explored how AI is transforming the healthcare industry. We provided a comprehensive analysis of publications from the Scopus database (the world's largest database on scientific research) on AI in healthcare.

A bibliometric study presented the relevant analysis of healthcare AI publications to answer our first research questions. We can characterize the last five years (2017–2022) as an extraordinary growth period in healthcare AI publications. The surge in healthcare AI publications is valuable information for researchers and practitioners. Researchers could target the leading journals as optimal locations to publish their AI articles on healthcare.

Our paper discusses how AI is used in healthcare systems [19]. Top cited articles not only measure the article's quality or importance but also indicate the originality of the research and the significance of the findings [2]. For example, the most cited article, “State-of-the-art nurse rostering,” indicates how AI improves hospital administration. The author’s keyword co-occurrence analysis reveals that AI is crucial in clinical decision-making. AI-driven clinical decision support systems (DSS) can assist physicians in diagnosing by providing support based on vital signs, clinical information, and test results. AI applications that have successfully implemented in DDS systems include neonatal seizure detection, risk stratification for cardiac chest pain patients, predicting hospitalization for hemodialysis patients, estimating the length of hospital stay for burn patients, prioritizing public health measures for foodborne and zoonotic pathogens, and analyzing factors contributing to COVID-19 mortality [20]. AI systems help clinicians manage medications for patients. They provide decision support for drug dosing, drug interactions, allergies, and medication reconciliation. Chronic disease management systems help clinicians manage patients with chronic diseases like diabetes, hypertension, asthma, etc.

AI is used to provide more personalized treatment for patients [21]. AI algorithms can analyze a patient’s genetic makeup and medical history to identify the most effective treatment options for their specific condition. AI has shown immense promise in service quality assurance. AI can automatically validate clinical rules, reduce the number of drug interaction alerts in primary care by false positive alerts, and improve the safety and quality of therapeutic anticoagulation. AI can enhance the safety and quality of inpatient diabetes management by providing real-time monitoring and alerts.

AI is revolutionizing clinical writing by streamlining processes and enhancing the quality of content produced. These AI-powered tools and techniques enable more efficient, accurate, and accessible clinical documentation, ultimately benefiting healthcare professionals and patients [22]. AI is transforming the healthcare industry by increasing efficiency, improving patient outcomes, streamlining operations, and reducing costs.

The ‘Titles’ and ‘Abstract’ term co-occurrence analysis gives us insights into prominent themes evolving in healthcare AI; these are AI techniques, AI applications, and human-AI interaction. Based on our research goal, we deep dive and analyze each cluster to identify their relevance in healthcare practice. In Cluster 1, the focus is on the significance of AI algorithms and quality measures in healthcare. The performance and accuracy of AI systems play a vital role in improving service quality assurance and patient care. For example, deep learning models achieve state-of-the-art results on many healthcare tasks, such as medical image analysis and gene pattern recognition. Large language models used in generative AI can generate text which are indistinguishable from human. System simulation and optimization algorithms determine the optimal number of staff required for inventory management to minimize waste and costs. AI systems allow physicians and service providers to work more efficiently by making data accessible immediately when needed, which helps nurses ensure better patient safety while administering medication [1].

Cluster 2 sheds light on the practical applications of AI in healthcare practice. Key applications include data analysis [23], automated content generation, data visualization, quality control [24], translation, personalized content creation, predictive analytics [21], real-time collaboration, time and resource optimization, and customized training for clinical writers [25]. AI has the potential to enhance decision-making processes, improve patient safety, and optimize treatment outcomes. Additionally, AI-powered tools can assist physicians in drug discovery, benefiting healthcare professionals and patients.

Cluster 3 highlights the need for a balanced approach between AI and human interaction in healthcare. AI should complement healthcare professionals' skills rather than replace them. It is crucial to recognize that the purpose of AI is to augment and empower healthcare professionals in their practice. Successful AI adoption in healthcare heavily relies on the acceptance and engagement of healthcare providers and patients. Introducing AI-driven solutions requires effective communication, education, and training to ensure stakeholders understand these technologies' potential benefits and limitations. Patients should be informed how AI is integrated into their care, ensuring transparency and trust in the technology. Collaborative efforts involving healthcare professionals, data scientists, and engineers can facilitate the development of user-friendly AI systems that align with the needs and preferences of patients.

Moreover, the integration of AI in healthcare must address ethical considerations and data privacy concerns. Adhering to robust security measures and complying with regulatory frameworks such as HIPPA can help build trust among patients and healthcare professionals, ensuring that the benefits of AI are harnessed responsibly and ethically.

5 Implications

Our analysis also has multiple theoretical and practical implications. This review study contributes to the literature on healthcare AI to facilitate a better understanding of its development and adoption. Our study identifies three major themes of healthcare AI: AI technologies, AI applications, and human-ai interaction. Healthcare practitioners can look into this study to identify new AI-powered tools and solutions to improve patient care. By knowing the latest advances in healthcare AI, policymakers can develop policies that support responsible AI development and adoption in the healthcare domain. While AI has the potential to revolutionize healthcare, it also raises many ethical and legal challenges. AI could automate many healthcare tasks, reducing the cost of care. AI-powered chatbots could provide primary medical advice to people who do not have access to a physician. However, there is a potential risk of avoiding physicians for critical health issues and risking their lives. Unlike others, AI systems work based on probabilities; they heavily depend on training data. Healthcare data acquisition and preparation of data for model training are very time-consuming and costly. It requires specialized skills to develop and maintain AI systems in production. There are concerns about AI systems being biased against certain groups of people. AI should be used as a supportive tool rather than a replacement for healthcare providers. The ultimate responsibility for clinical decision-making remains with the healthcare professionals, who utilize AI-driven recommendations as additional information and insights to support their expertise and judgment. The paper encourages healthcare professionals and administrative staff to have constructive conversations about how AI can enhance the quality of work in healthcare settings. It is crucial to consider healthcare AI's potential benefits and risks before widely deploying these technologies.

6 Future Research Direction

AI can offer great opportunities for improving healthcare services and patient care. However, AI models, especially deep-learning models, are very complex, making it difficult for clinicians to understand how they make decisions [26]. This interpretability can be a barrier to trust and adoption of AI in healthcare. Future researchers could investigate new methods to make AI more interpretable and explainable in a way that reveals the causes and effects of changes within a model.

AI systems learn to make decisions based on training data, which may include biased human decisions or reflect historical or social inequities, even if biases such as gender, race, or sexual orientation are removed [27]. Bias in medical data leads to AI models that are only fair to some patients. Future research could focus on identifying and mitigating bias and unfairness in AI models [28].

To adopt AI solutions in clinical practice, a clear governance framework is required to protect people from harm occurring from unethical conduct or data privacy issues. Researchers should proactively address security and ethical risks to avoid social rejection and distorted legislation [20].

Researchers could focus on developing applications to address physician fatigue to mitigate human error in clinical decision-making. Researchers could investigate the use of AI in medication management, explore methods to integrate AI-driven decision support tools seamlessly into medication workflows and assess their impact on medication safety and adherence.

Researchers could explore methods to design user-friendly interfaces with AI while maintaining patient trust and satisfaction. Researchers could develop frameworks and guidelines to ensure responsible and ethical AI implementation. Investigate potential biases in AI algorithms and develop approaches to mitigate them, ensuring fairness and inclusivity in healthcare AI applications.

7 Limitations

As with any study, our research has limitations that could be addressed through more comprehensive future studies. For instance, using a single database such as Scopus may have limited our findings. Future analyses could investigate the health-related sections of PubMed and Web of Science databases individually or collectively. Moreover, the search terms we used, such as “Artificial Intelligence,” “AI,” and “Healthcare,” may have been too broad and potentially excluded relevant studies. Additionally, while we analyzed 600 scientific papers from top-tier journals (A* and A category from ABCD), other journals may contain valuable insights for future researchers as the research topic is still emerging. Since AI in healthcare is still developing, our analysis may need to be updated as new research appears.

8 Conclusions

In this work, we relied on bibliometric analysis to investigate the role of AI in the healthcare system. By exploring three complementary research questions, we identified the pattern of publication in healthcare AI, how AI is being used in healthcare, and the prominent themes of AI evolution in healthcare settings. We noticed that the last five years (2017–2022) was an extraordinary growth period in healthcare AI publications, signaling growing interest and investment in the area. We recognized that AI, clinical decision support and electronic health records were the three most popular topics discussed in healthcare AI. Also, we identified three significant themes under which AI is being developed in healthcare: AI technologies, AI applications, and human-ai interaction.

Our work contributes to the emerging literature on healthcare AI and the development of healthcare systems. We also proposed future research steps that could advance the field, address critical challenges, and maximize the benefits of AI in improving patient care and healthcare practice. Overall, our study provides valuable insights into the current state of AI in healthcare research, highlighting the gaps and suggesting future research directions in this field.

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