Unveiling metaverse potential in supply chain management and overcoming implementation challenges: an empirical study

Surajit Bag
Department of Transport and Supply Chain Management, University of Johannesburg, Johannesburg, South Africa and Institute of Management Technology Ghaziabad, Delhi-NCR, India

Muhammad Sabbir Rahman
Department of Marketing and International Business, School of Business and Economics, North South University, Dhaka, Bangladesh

Gautam Srivastava
School of Management, IILM University, Greater Noida, India, and

Santosh Kumar Shrivastav
Department of Business Analytics, Institute of Management Technology Ghaziabad, Delhi-NCR, India

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Abstract

Purpose – The metaverse is a virtual world where users can communicate with each other in a computer-generated environment. The use of metaverse technology has the potential to revolutionize the way businesses operate, interact with customers, and collaborate with employees. However, several obstacles must be addressed and overcome to ensure the successful implementation of metaverse technology. This study aims to examine the implementation of metaverse technology in the management of an organization's supply chain, with a focus on predicting potential barriers to provide suitable strategies.

Design/methodology/approach – Covariance-based structural equation modeling (CB-SEM) was used to test the model. In addition, artificial neural network modeling (ANN) was also performed.

Conflict of interest statement: On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Our guidelines make it clear that the ScholarOne record must accurately include all affiliation details at initial submission.

Surajit Bag's affiliation has been updated to include "Institute of Management Technology Ghaziabad, Delhi-NCR, India".

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Findings – The CB-SEM results revealed that a firm's technological limitations are among the most significant barriers to implementing metaverse technology in the supply chain management (SCM). The ANN results further highlighted that the firm's technological limitations are the most crucial input factors, followed by a lack of governance and standardization, integration challenges, poor diffusion through the network, traditional organizational culture, lack of stakeholder commitment, lack of collaboration and low perception of value by customers.

Practical implications – Because metaverse technology has the potential to provide organizations with a competitive advantage, increase productivity, improve customer experience and stimulate creativity, it is crucial to discuss and develop solutions to implementation challenges in the business world. Companies can position themselves for success in this fascinating and quickly changing technological landscape by conquering these challenges.

Originality/value – This study provides insights to metaverse technology developers and supply chain practitioners for successful implementation in SCM, as well as theoretical contributions for supply chain managers aiming to implement such environments.

Keywords Supply chain management, Metaverse, Barriers, Augmented reality, Virtual reality

Paper type Research paper

1. Introduction

In recent years, the metaverse has emerged as a popular virtual world in which individuals can interact with each other in a digital environment (Wan *et al.*, 2023). With its potential to provide real-time tracking of goods and services, the metaverse has the capability to revolutionize supply chains (SCs). Increased efficiency, lower costs, and better transparency might all result from this shift. In the metaverse, virtual markets might be created to make it easier for buyers and sellers to conduct business. As a consequence, procurement procedures may become more efficient, using less time and money than conventional SC techniques. The capacity to model supply chain instances and test new technologies and tactics is another benefit of the metaverse in supply chain management (SCM). Prior to being put into practice in the real world, this technology might assist anticipate possible problems and optimize supply chain processes.

One of the most significant consequences of the metaverse for operations and SCM is the potential for virtualization (Queiroz *et al.*, 2023). Businesses can simulate production and distribution processes, discover bottlenecks and test various scenarios to improve their operations by building virtual representations of physical products (Queiroz *et al.*, 2023). The metaverse can also provide SC participants with a forum for cooperation and communication. Teams can collaborate, share data and make decisions instantly in a virtual setting, increasing efficiency and reducing lead times (Queiroz *et al.*, 2023). The capacity to follow products through every stage of their lifecycle is another potential advantage of the metaverse. Businesses may monitor a product's location, health and performance by building a digital twin of it. This process allows them to make data-driven decisions regarding upkeep, repairs and replacements (Queiroz *et al.*, 2023).

A wide range of industries and sectors, including marketing, education, healthcare and social medias, could be impacted by the metaverse's capacity to extend the physical world via augmented and virtual reality technologies (Dwivedi *et al.*, 2022). However, important hazards and obstacles connected to the creation of the metaverse must be considered. The lack of infrastructure and technology needed to support a fully functional, cross-platform metaverse is one of the main obstacles (Dwivedi *et al.*, 2022). While immersive video games and virtual worlds can provide some insight into the possible socio-economic effects of the metaverse, substantial infrastructural and technological development is still necessary for the creation of a fully functional metaverse (Dwivedi *et al.*, 2022).

Apart from their benefits, metaverse technologies have some challenges. We thoroughly searched the body of literature regarding this subject but could not locate any studies or research papers that have particularly empirically examined the challenges of the metaverse in SCM. This finding indicates that there is a significant knowledge gap regarding the possible difficulties and constraints of metaverse technologies and emphasizes the need for additional research in this area. Finding the metaverse's barriers is crucial for a number of reasons. First, by ensuring that any potential problems and limitations are handled and minimized to promote widespread adoption and usage, this information may help direct the development and deployment of metaverse technologies. Second, being conscious of the barriers to the metaverse may assist identify problems that may call for more research and innovation to solve and progress the area. Third, by pinpointing the obstacles to the metaverse, policymakers and decision-makers can be better prepared to oversee and regulate the technologies that constitute the metaverse and deploy them in a moral and responsible manner. Identifying the barriers to acceptance of metaverse technology will help to resolve the issues before implementing it. It will also help to understand the need of each one whoever is involved or assumed to be benefited from this technology regardless of their background or resources. Therefore, the aim of this study is to investigate the barriers to incorporating metaverse technology into SCM and the research questions are as follows:

RQ1. What are the barriers to metaverse technology implementation in SCM?

RQ2. What is the effect of the barriers on the implementation of metaverse technology in SCM?

Existing studies regarding metaverse technology implementation in managing SCs have mostly concentrated on the benefits and challenges and have been conceptual and exploratory in nature (Queiroz *et al.*, 2023; Trivedi and Negi, 2023). However, few empirical research studies in this area include: PUICĂ (2022) studied information technology and SCM and explained metaverse business modeling. In addition, Polas *et al.* (2022) applied cross-sectional analysis to investigate the variables influencing the adoption of blockchain technology among SMEs. In another study, De Giovanni (2023) examined the issue of the sustainability of the metaverse in transition to Industry 5.0. Furthermore, Almarzouqi *et al.* (2022) examined students' perception of applying the metaverse in education by applying a dual-in SCM stage SEM–ANN approach.

The scarcity of metaverse applications in SCM-related research motivated the current research study. Apart from the testing of the proposed model through structural equation modeling (SEM), the present study also applied an artificial neural network (ANN), which is both a linear and a nonlinear association, to determine the efficacy of the predictor and predicted factors in the proposed conceptual model (Sim *et al.*, 2014; Khaw *et al.*, 2022). A second stage of analysis is conducted using the ANN approach to overcome the limitations of SEM (Liébana-Cabanillas *et al.*, 2018; Kalinic *et al.*, 2019).

According to Wang *et al.* (2017), the application of ANN may complement SEM findings and can improve the accuracy of a non-linear model due to its deep learning analytic process through two or more hidden layers. Thus, by considering the justification, the present study has enriched the existing literature regarding metaverse and SCM by applying a dual-stage SEM–ANN analysis. This SEM–ANN approach may represent the first application in the prediction of metaverse technology implementation for managing firms' SCs and explaining barriers and may provide significant theoretical and methodological implications to the literature regarding the metaverse and the SC. Thus, the main purpose of this study is to identify and assess the influence of the barriers on metaverse technology implementation in a firm's SC. The organization of the remaining portions of this manuscript is as follows: The subsequent sections present the review of literature, hypotheses and development of a theoretical framework. Then, the research method and data analysis results are explained, followed by a discussion of the managerial and theoretical implications of the research findings. Finally, the paper ends by presenting limitations and future research directions.

2. Literature review

2.1 Planning the review

A systematic literature review was performed in a rigorous and structured way. Previous studies were downloaded from Scopus.com. A deliberate and thorough technique for compiling and assessing the research papers that have already been conducted on a specific issue is known as a "systematic literature review" (SLR). It entails a meticulous and open process of locating, selecting, evaluating and synthesizing pertinent studies to address a certain research topic or purpose. The literature review used Transfield *et al.*'s (2003) SLR technique. The three primary parts of a systematic literature review are planning, performing and reporting on the findings.

Stage I: Planning of the Literature Review

A panel of academic professionals and experts was formed to review the previous studies. We initially searched and downloaded papers from Scopus.com using the keywords listed below.

Search syntax

(TITLE-ABS-KEY (metaverse) OR TITLE-ABS-KEY (augmented AND reality) OR TITLE-ABS-KEY (virtual AND reality) OR TITLE-ABS-KEY (mixed AND reality) OR TITLE-ABS-KEY (extended AND reality) AND TITLE-ABS-KEY (supply AND chain AND management)) AND (LIMIT-TO (SUBJAREA , "BUSI")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re"))

Stage II

Final selection of the publications process was reported using the PRISMA method. PRISMA, or Preferred Reporting Items for Systematic Reviews and Meta-Analyses, is a reporting format. It is an amalgamation of principles that offers a standardized method for performing and reporting systematic reviews and meta-analyses in a clear and comprehensive way. The PRISMA flow diagram is displayed in Figure 1.

Stage III

Step 1: Searching for an initial collection of studies

A thorough literature study was conducted using publications that were obtained from the Scopus database. We found 58 papers in total during the initial search.

Step 2: Screening

Following the screening of the papers based on metaverse, augmented reality, virtual reality, extended reality and supply chain management, 42 were chosen for further examination.

Step 3: Retrieval

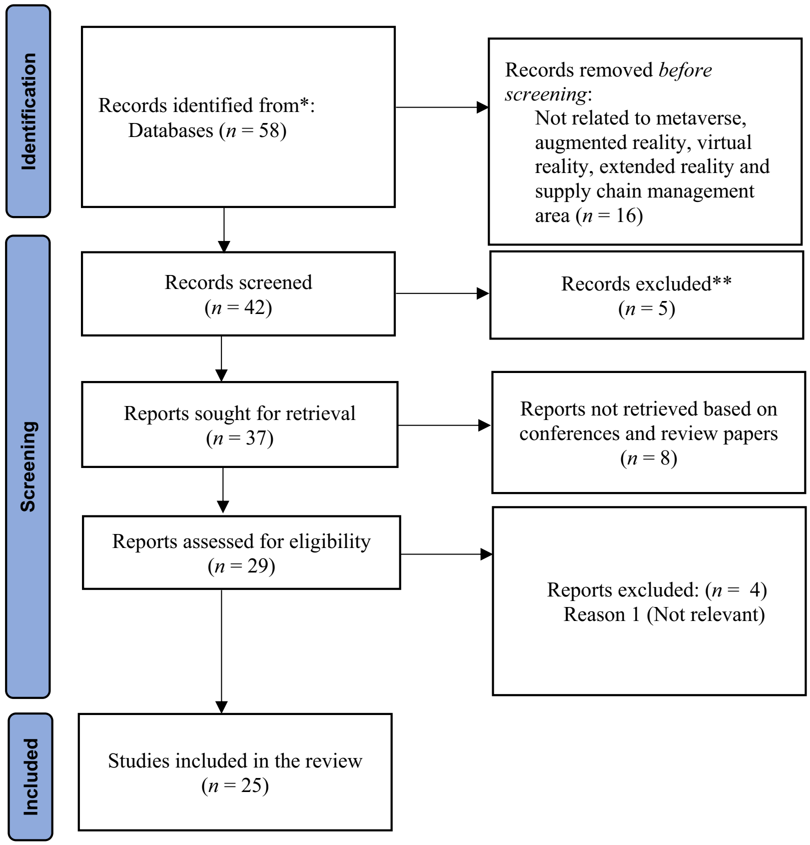
In this step 37 papers were classified further retained.

Step 4: Eligibility

In this step 8 papers were disqualified.

Step 5: Studies included in the review

Finally, after performing a rigorous review, 25 papers were chosen for the study. The analysis of these 25 papers is discussed in the next sections.



Source(s): Authors' compilation

Figure 1.
PRISMA flow diagram review

2.2 Metaverse

In his 1992 book *Snow Crash*, Neal Stephenson initially used the term "metaverse" to describe a virtual reality world in which characters could communicate with one another and with virtual objects (Sparkes, 2021). Since then, the idea has evolved and grown to encompass a wider variety of immersive technologies and experiences. The word "metaverse" has been used to describe a fictitious virtual reality setting in which users can seamlessly interact with both other users and digital items (Peukert *et al.*, 2022). It has been made more widely known by science fiction, which frequently depicts it as a connected, futuristic society in which the distinction between the actual world and the virtual world is ambiguous (Peukert *et al.*, 2022). However, technology businesses and investors have begun to discuss the idea of the metaverse more recently as it has received more attention.

The growth of massively multiplayer online role-playing games (MMORPGs), such as World of Warcraft and Second Life, has been one of the metaverse's breakthroughs (Wiederhold, 2022). Users can design avatars in these games and communicate with other players in a common virtual space. Incorporating aspects of social networking and e-commerce, they also produce a fully immersive experience that combines virtual and actual reality. Metaverse theory is not completely new (Wiederhold, 2022). It has been used for years in publications, motion pictures and video games. The recent new interest in the metaverse, however, is a result of technological developments, particularly in virtual and augmented reality, as well as the expansion of social media and online gaming (Wiederhold, 2022).

The metaverse is thought to be the next step in developing the internet, transforming the existing 2D web into a fully immersive 3D world (Belk *et al.*, 2022). Users could engage with the content there more naturally and intuitively, transcending the constraints of a conventional screen and keyboard. The interconnection of the metaverse is one of its fundamental characteristics (Belk *et al.*, 2022). The metaverse would be a cohesive network of locations, experiences and interactions rather than various virtual worlds. Users could navigate among various virtual environments without any difficulty, interacting with other users and virtual things as they went (Belk *et al.*, 2022).

A significant degree of customization and personalization would likewise be available in the metaverse. Individual user interests and tastes could be reflected in the avatars and virtual locations that users construct (Cheng *et al.*, 2022). It would be a location where users could engage in creative expression while working with others to produce one-of-a-kind, immersive experiences. The metaverse has countless potential uses (Cheng *et al.*, 2022). It might be employed for socializing, amusement, instruction, business and other purposes. For instance, virtual performances and festivals might take place in the metaverse, providing audiences from all over the world with an immersive and engaging experience (Cheng *et al.*, 2022). In addition, virtual classrooms might be developed, enabling more interesting and involved interactions between students and teachers (Cheng *et al.*, 2022).

Through its virtual, interconnected area that allows users to interact with digital assets and experiences, the metaverse technology can revolutionize SCM, resulting in incredible improvements and efficiencies in these fields (Rathore, 2023). The potential effects include real-time stock visibility, storage optimization, cost savings and virtual warehousing and inventory management. Through simulations and predictive analysis, metaverse capabilities can improve operations and anticipate disturbances (Dubey *et al.*, 2023). The metaverse functions as a platform for collaboration, improving transparency and streamlining SC operations. It enables performance monitoring and virtual testing of enhancements by merging with digital twin technologies (Lee *et al.*, 2021). Furthermore, metaverse-driven augmented reality (AR) applications improve maintenance and employee training activities. Additionally, the metaverse can streamline last-mile delivery routes using creative approaches that make use of current data and sophisticated algorithms. Through the use of blockchain technology and smart contracts, it has the potential to execute automated, secure transactions that improve SC traceability and authenticity. Exploring metaverse technology for SCM is important despite integration hurdles because of the potential benefits (Perano *et al.*, 2023).

However, there could be a number of challenges with putting metaverse technology into practice. Standardization and interoperability are two crucial issues (Golf-Papez *et al.*, 2022). Virtual worlds and associated platforms should be able to connect to one another for communication in order to implement the metaverse, and for this to happen, there would need to be tight coordination and collaboration between several businesses and SC parties. Governance and regulation-related problems are other problems firms may have (Golf-Papez *et al.*, 2022). Concerns regarding how the metaverse should be controlled will surface as soon as it gains popularity and influence. To make the metaverse a secure and friendly location for all users, privacy, security and content moderation concerns must be handled (Golf-Papez *et al.*, 2022).

2.3 Barriers to metaverse technology implementation in managing SCs

The metaverse makes it feasible to cooperate, develop and manage supply chains more efficiently. The metaverse has the potential to modernize SCs, but there are a number of barriers that can stand in the way. Limitations in technology, a lack of governance and standardization, integration issues, poor network diffusion, traditional organizational cultures, a lack of stakeholder commitment, a lack of top-level management support, a lack of innovation, a lack of collaboration and a poor understanding of value by customers are just a few of these barriers. The examination of important barriers will continue after this.

2.3.1 Technological limitations. The metaverse relies heavily on technology, such as high-speed internet connectivity, advanced hardware and software. Some regions or organizations may not have access to the necessary infrastructure or may lack the technical expertise to leverage the metaverse's potential.

2.3.2 Lack of governance and standardization. Without governance and standardization, the implementation of the metaverse across many SC networks might not be consistent. It is possible that different businesses employ different standards for managing inventories or performing transactions in the metaverse, which could make it challenging for them to communicate with one another. As a result, inaccuracies, mistakes and a lack of confidence among various SC participants might emerge.

2.3.3 Integration challenges. Incorporating the metaverse into existing SC systems may prove challenging, particularly for organizations with legacy systems. Integrating these systems could require significant investment and resources.

2.3.4 Poor diffusion through the network. The spread of knowledge, data, or innovation within a network is referred to as "diffusion through the network." Poor dissemination through the network can be a significant hurdle to acceptance when using the metaverse for SCM.

2.3.5 Traditional organization culture. Resistance to change is one characteristic of traditional organizational culture that could prevent the introduction of the metaverse. Many firms may be reluctant to invest in new technologies such as the metaverse because they are comfortable with their current procedures and systems. Lack of creativity and experimentation is another characteristic of traditional organizational culture that can hinder the deployment of the metaverse. Adoption of the metaverse for SCM may be cautious in organizations that are not accustomed to experimenting with new technologies and procedures.

2.3.6 Lack of stakeholder commitment. For any new technology or procedure to be implemented successfully, stakeholder commitment is essential. The metaverse is no different, and a lack of stakeholder support can be a major obstacle to its adoption in SCM. The success of the metaverse implementation and acceptance depends on how each stakeholder supports this new technology and the acceptance and usage of the metaverse rely on them.

2.3.7 Lack of collaboration. For the successful implementation of metaverse technology, cooperation is required from all parties and the lack of trust between various stakeholders in SC processes may lead the failure of technology. An organization may be reluctant to collaborate if it thinks that other stakeholders won't act in their best interests or if they are viewed as rivals.

2.3.8 Low perception of value by customers. The metaverse technology will only be considered useful if customers and other stakeholders accept this technology with full trust. Lack of understanding or expertise of the technology may be a factor in the lack of value seen. Consumers might not be aware of or comprehend the potential advantages of the metaverse for SCM. Lack of observable advantages or return on investment (ROI) may also contribute to a lack of perceived value. Consumers might not immediately notice the advantages of the technology or be able to calculate their return on investment from using it.

2.4 Technology, organization and environment framework

The TOE (Technology, Organization and Environment) framework is employed to examine the factors that impact the adoption and implementation of metaverse technologies in organizations. This framework posits that the successful adoption of new technologies such as metaverse in SCM is determined by the interplay among three crucial factors: technology, organization and environment.

Technology pertains to the attributes and features of the metaverse technology being introduced, such as its complexity, compatibility with existing systems and trialability and observability. Whereas organization refers to the internal structure, culture and processes of the organization, including its size, structure and level of centralization, as well as the attitudes and beliefs of its employees towards metaverse technology. Furthermore, environment encompasses the external factors that influence the organization, including the regulatory environment, competitive landscape and broader social and economic trends.

According to the TOE framework, several factors determine the successful adoption and implementation of metaverse technologies. These factors include the organization's capacity to effectively manage change, its level of technological capability and the degree of support and resources available from external stakeholders.

Organizations may gain a better understanding of the potential and constraints related to the adoption of new technologies by looking at how these elements interact. With this knowledge, businesses can design better plans for handling change and maximizing the advantages of adopting new technologies.

2.5 Hypothesis development

2.5.1 Technological limitations and the failure to implement metaverse technology for SCM. The metaverse is still in its conceptual stage and requires more development. The use of metaverse technology for SCM may be greatly impacted by some technological restrictions (Dwivedi *et al.*, 2022; Tsang *et al.*, 2022). The need for complex and cutting-edge technological infrastructure is one of the largest obstacles to deploying a metaverse for SCM. This need encompasses not only the hardware and software infrastructure necessary to run and construct the metaverse but also the communication and networking technologies that are required for various SC partners (Dwivedi *et al.*, 2022; Queiroz *et al.*, 2023). The need for high-performance computing and device resources presents another difficulty. The intricate virtual world of the metaverse requires high-end graphics processing units and other technology for use in real-time. The cost of this equipment is very high and significant investments are needed (Dwivedi *et al.*, 2022; Queiroz *et al.*, 2023). In addition, concerns exist regarding the security and privacy of important SC data in the metaverse. An issue that must be addressed when embracing the metaverse in SCM is ensuring data security (Dwivedi *et al.*, 2022; Queiroz *et al.*, 2023). The deployment of metaverse technology in SCM has been plagued by difficulties and technological restrictions. Hence, hypothesis 1 (H1) can be stated as follows:

H1. Technological limitations influence the failure to implement metaverse technology for SCM.

2.5.2 Lack of governance and standardization and the failure to implement metaverse technology for SCM. The metaverse is a virtual environment in which individuals can communicate with one another through the use of digital resources and requires a high degree of standardization to assure seamless interaction and interoperability between the virtual platform and applications (Dwivedi *et al.*, 2022; Arora *et al.*, 2023). Users would not be able to easily communicate information between different metaverse platforms without these systems. The difficulties in developing and implementing metaverse technologies in SCM are increased by a lack of standardization (Queiroz *et al.*, 2023; Arora *et al.*, 2023). Standardization refers to the process of creating similar protocols, interfaces and formats to make connectivity and communication across the many virtual systems more straightforward. In the absence of standards, several commercial entities might create proprietary solutions that are incompatible with one another (Bhattacharya and Chatterjee, 2022; Queiroz *et al.*, 2023).

The advantages of metaverse technology are constrained by the lack of standardization. Through effective governance, standardization can be implemented. The ownership, distribution and use of digital devices and intellectual property in the metaverse can be unknown and confusing due to a lack of governance. The application of technology can become inconsistent as a result, leading to SC process errors and delays. The hesitation of commercial organizations to invest significant sums of money in situations in which the ownership and control of virtual platforms are ambiguous can impede the adoption of metaverse technology by these organizations (Bhattacharya and Chatterjee, 2022; Queiroz *et al.*, 2023). Governance and standardization are crucial for the use of metaverse technology in SCM to be successful. Without them, it would be difficult for corporate entities to guarantee the security, interoperability and legal compliance required for the broad adoption of metaverse technology. Hence, H2 can be stated as follows:

> *H2.* Lack of governance and standardization influence the failure to implement metaverse technology for SCM.

2.5.3 Integration challenges and the failure to implement metaverse technology for SCM. The use of new, cutting-edge technologies, such as metaverse technology for SCM, can be seen as being hampered or hindered by integration issues; and compatibility issues (Dwivedi *et al.*, 2022; Mozumder *et al.*, 2022; Queiroz *et al.*, 2023). The adoption of new, innovative technology may be severely resisted if the new technology is incompatible with the current system, as incompatibility could result in implementation issues. Any novel technology, such as metaverse, needs to be able to work with other virtual programs. Given the blending of physical and virtual environments, as well as several stakeholders, the integration challenges of metaverse technology in SCM are intricate and multifaceted (Mozumder *et al.*, 2022; Queiroz *et al.*, 2023). The incorporation of metaverse technology into SCM presents some very difficult obstacles, and integration is one of the most significant. The integration of metaverse technology necessitates a high level of technical competence. This integration presents considerable barriers to entry for firms lacking technical expertise. The requirement for compatibility between virtual platforms and systems is another challenge in integrating metaverse technology into SCM (Dwivedi *et al.*, 2022; Mozumder *et al.*, 2022). Integration of metaverse technology with ERP and other software is required for SCM. However, achieving seamless integration between the virtual systems can be difficult and can slow the adoption of metaverse technology in SCM. Thus, H3 can be stated as follows:

> *H3.* Integration challenges influence the failure to implement metaverse technology for SCM.

2.5.4 Poor diffusion through the network and the failure to implement metaverse technology for SCM. It is essential that all participants in the SC network accept and use metaverse technology for SCM. Customers, retailers, distributors, suppliers and manufacturers are all involved in this process. If no one adopts or desires to use metaverse technology, the network's ability to spread would be constrained (Roe *et al.*, 2022). Infrastructure, instruction and data management are all necessary for the use of metaverse technology in SCM (Roe *et al.*, 2022; Queiroz *et al.*, 2023). If the stakeholders believe it to be excessively complex, they may resist adopting it, leading to poor diffusion through the network. Another factor contributing to poor diffusion is a lack of knowledge or understanding of the advantages of metaverse technology for SCM (Roe *et al.*, 2022; Queiroz *et al.*, 2023). There is a chance that none of the stakeholders will adopt or use technology if they are not motivated by its potential benefits, such as increased transparency, sustainability and efficiency. Poor diffusion in this case would indicate a dearth of information and communication regarding the technology and its potential advantages (Roe *et al.*, 2022). Implementing metaverse technology for SCM has failed due to poor network diffusion, which is a major factor. Hence, H4 can be stated as follows:

H4. Poor diffusion through the network influences the failure to implement metaverse technology for SCM.

2.5.5 Traditional organization culture and the failure to implement metaverse technology for SCM. The term "organizational culture" refers to the common beliefs, values, practices and behaviors that shape how employees interact both internally and with stakeholders outside the organization (Arena *et al.*, 2023). Traditional organizational cultures are characterized by centralized decision-making power, a hierarchical structure and a preference for consistency and predictability. A flatter organizational structure, decentralized decision-making and a willingness to experiment and take chances, on the other hand, are traits of a more innovative and dynamic organizational culture (Assoratgoon and Kantabutra, 2023). Adopting metaverse technology for SCM necessitates a willingness to innovate and acceptance of a dynamic organizational culture (Arena *et al.*, 2023; Assoratgoon and Kantabutra, 2023). The organizational culture must be considered as part of a comprehensive strategy for the effective adoption of metaverse technology for SCM (Dwivedi *et al.*, 2022). Lack of knowledge, lack of understanding of the technology, lack of resources, or poor planning and execution can have a large impact on an organization's culture (Dwivedi *et al.*, 2022). Failure to integrate these factors can result in failure of the use of metaverse technology for SCM. The implementation of metaverse technologies is hampered by traditional organizational culture. Thus, H5 can be stated as follows:

H5. Traditional organization culture influences the failure to implement metaverse technology for SCM.

2.5.6 Lack of stakeholder commitment and the failure to implement metaverse technology for SCM. The degree to which the groups impacted by the use of SCM metaverse technology are prepared to support and participate in the implementation process is characterized as stakeholder commitment (Siebold *et al.*, 2023). Assessment of the opinions, attitudes and behaviors of numerous stakeholders at various functional levels of corporate organizations makes the measurement of stakeholder commitment a difficult task (Queiroz *et al.*, 2023). Stakeholder support is essential for the successful integration of metaverse technology into SCs. Lack of stakeholder commitment results in the project's not being finished on schedule (Queiroz *et al.*, 2023). In addition, it causes resistance to organizational change. The stakeholders' work is also of lower quality as a result. Lack of stakeholder commitment may occur as a result of a lack of focus or underinvestment in the resources needed to guarantee high-quality implementation (Dwivedi *et al.*, 2022; Queiroz *et al.*, 2023). This may also occur because people lack the drive to learn new things and lack awareness of the benefits of new technologies. Stakeholders cannot support improving the effectiveness of the SC network if they are not committed to using metaverse technology for SCM. This condition would result in cost overruns, delays and, ultimately, a lack of commitment. Therefore, we propose H6 as follows:

H6. Lack of stakeholder commitment influences the failure to implement metaverse technology for SCM.

2.5.7 Lack of collaboration and the failure to implement metaverse technology for SCM. A situation in which an organization's stakeholders do not cooperate to accomplish a common goal is referred to as a lack of collaboration (Munaro and Tavares, 2023). Collaboration is essential in the context of SCM because it involves numerous parties, including retailers, suppliers and manufacturers and ensures the effective and timely flow of goods. Therefore, any lack of cooperation causes SCM to be ineffective and delayed and to fail (Suzuki *et al.*, 2020; Dwivedi *et al.*, 2022). The inability and unwillingness of an organization to integrate metaverse technology into SCM is exacerbated by a lack of collaboration. Manufacturing, product design, transportation, warehousing and customer services are only a few of the areas in which metaverse technology, a hybrid of virtual and augmented reality, has the potential to make a significant impact (Suzuki *et al.*, 2020; Dwivedi *et al.*, 2022). The potential advantages of metaverse technology for SCM may not be completely realized due to lack of collaboration. The design process for the metaverse technology is prone to mistakes and delays if suppliers and manufacturers do not collaborate to create the virtual model. Similarly, failure of distributors and retailers work together to maximize the use of augmented reality for shipping and installation leads to subpar consumer experiences (Suzuki *et al.*, 2020; Munaro and Tavares, 2023). Therefore, lack of collaboration has an impact on the acceptance and utilization of metaverse technology in SCM. H7 can be stated as follows:

H7. Lack of collaboration influences the failure to implement metaverse technology for SCM.

2.5.8 Low perceived value by customers and the failure to implement metaverse technology for SCM. In SCM, customers are the most important stakeholders. They are the recipients of goods and services, and SC success depends on their satisfaction and value perception (Dwivedi *et al.*, 2022). The success of metaverse technology depends critically on customer uptake. Customers are less likely to adopt metaverse technology if they cannot immediately understand its advantages. This deficit causes a decrease in demand and a lack of passion for the technology, preventing it from attracting attention (Gursoy *et al.*, 2022; Adams, 2022). Customer perception issues have a detrimental impact on the allocation of resources and investments made in the installation and advancement of metaverse technology. The development and application of metaverse technology are hampered by the willingness of business organizations to invest in technology without significant customer support (Gursoy *et al.*, 2022; Adams, 2022). Customer dissatisfaction or perception of lack of utility from the metaverse technology may result in negative feedback, which would deter potential new users from adopting it. Therefore, to ensure their success in SCM, organizations must consider customer needs and perceptions while implementing metaverse technology for SCM. Hence, H8 can be stated as follows:

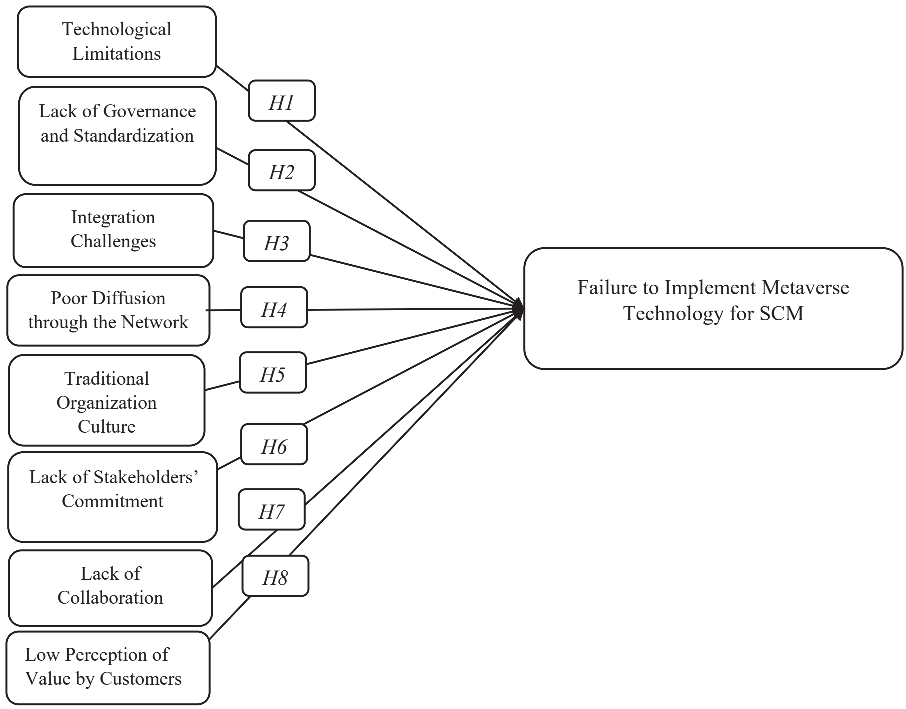
H8. Low perceived value by customers influences the failure to implement metaverse technology for SCM.

Based on the preceding discussion, a model (see Figure 2) was developed.

3. Research method

3.1 Operationalization of constructs

The objective of this study was to examine the structural effects of the barriers to metaverse technology implementation for managing a firm's SCM. Following previous literature, the present study identified eight key constructs as important for the barriers to metaverse technology implementation for managing a firm's SCM (Dwivedi *et al.*, 2022; Mozumder *et al.*, 2022; Queiroz *et al.*, 2023). These eight constructs were technological limitations (TL), lack of governance and standardization (LGS), integration challenges (IC), poor diffusion through the network (PN), traditional organization culture (TOC), lack of stakeholder commitment (LSC), lack of collaboration (LC), low perceived value by customers (CP) and failure to metaverse technology implementation for SCM (MSCN). All items were adapted from existing literature in order to maintain content and construct validity (technological limitations [TL], 4 items;



Source(s): Authors' own

Figure 2. Conceptual framework for barriers to metaverse technology implementation in SCM

lack of governance and standardization [LGS], 4 items; integration challenges [IC], 4 items; poor diffusion through the network [PN], 5 items; traditional organization [TOC], 3 items; lack of stakeholder commitment [LSC], 3 items; lack of collaboration [LC], 4 items; low perception of value by customers [CP], 3 items; failure to metaverse technology implementation for SCM [MSCN], 5 items; see Appendix).

The overall survey questionnaire consisted of three sections, which included the measurement items of the variables, the demographic profile of the respondents, and the background of the firm. The study adopted a five-point Likert scale, with 1 = "strongly disagree" and 5 = "strongly agree," to extract the perception of the respondents in respect to the measurement items of the variables. The questionnaire was pre-tested by five professionals and five academic investigators in the field of SC and information technology systems for ensuring face validity and content validity. The instrument was slightly amended in terms of layout and wording of the items of the constructs after checking the face and content validity of the instrument. A pilot test was conducted with 50 respondents from 25 IT consulting firms (two from each firm). The results generated a satisfactory level of Cronbach's alpha (>0.70) for each construct. The final survey was administered after two weeks of the pilot test of the instrument.

3.2 Sampling and data collection process

The present study's population included employees of selected software and engineering consultancy firms who were assisting companies in the gradual introduction and implementation of metaverse technology in their SC networks. For example, the employees of software and engineering consulting firms had been developing augmented reality and virtual reality for manufacturing, logistics and retail clients to enhance their business planning processes by developing digital SCs for their manufacturing operations.

According to Walbank (2023), the global metaverse market will reach USD 1.35 billion by 2025. The same exploration also identifies the dominant top 10 IT relevant companies that are impacting the significant volume of investments in the metaverse in the next few years, such as Microsoft, Meta, Google, Facebook, Decentraland, Nvidia, Shopify, Unity Technologies, Roblox and Epic Games. In the essence of that, the present study only considered IT consulting firms located in India, where Metaverse and Web3 reflected almost USD$200 billion in business opportunity, driven by the retail and financial services sector (Jose, 2023).

In this study, data collection focused on software and engineering consultancy firms in India, which is one of the largest and most cost-effective information and communication technology production bases in the world, contributing significantly to the country's GDP and public welfare (OECD, 2010-06-30; The World Bank Group, 2002; Keluskar and Mandge, 2022). Responding to global competitive pressure, IT firms in India are providing metaverse development services to firms' SC networks to enhance their competitive advantage. These consulting engineering firms provide end-to-end SC solutions to the entire 3D space efficiently and in a budget-friendly process via digital avatars of the key players in the SC network (The Publishing Pvt Ltd, 2022; Periyasami and Periyasamy, 2022).

We randomly selected 157 firms for our study; the firms were selected from Delhi, Pune, Bangalore, Ahmedabad and Mumbai. The majority of IT firms are located in these locations and are providing metaverse development services to their local and international clients. We selected two experts from each firm who have developed AR/VR based products for operations and SCM. Thus, in total, 314 respondents from 157 firms were invited to participate in the online survey. Out of 314 respondents, 284 completed the survey questionnaire. The survey was conducted over a 6-month period. The results of the descriptive analysis are listed in Table 1.

3.3 Assessing method bias and non response bias

In recent times, empirical research in management studies has given much greater consideration to the issue of common method bias (CMB) (Woszczynski and Whitman, 2004; Laguir *et al.*, 2022; Changalima *et al.*, 2023). CMB as in a collected data set is present when the systematic error variance enters into the measures of the constructs (Doty and Glick, 1998; Podsakoff *et al.*, 2003). Hence, the present study applied both procedural and statistical methods to determine whether CMB was an issue with the collected data set (MacKenzie and Podsakoff, 2012). During data collection, the researchers informed the respondents that their privacy would be maintained and that they could answer the statements of the corresponding variable measures based on their perception, as there were no appropriate or inappropriate answers. Apart from the researchers also applied other multiple strategies to limit the potential cause of common method bias, such as researchers adding cover stories that briefly explain the aim of the research followed by structuring the items randomly (Hulland *et al.*, 2018). Questionnaire strategies include using cover stories that conceal the true purpose of the study, employing different response scales for different items and arranging items randomly. Taking these steps prior to the administration of a survey can help to limit the potential for common method bias. In addition, the data were analyzed through Harman's (1976) common-factor examination to determine whether there was CMB in the data set. Results from this analysis revealed that a single factor explained only 29.28% of the variance. As the results were less than 50%, CMB did not have any impact on the collected data set.

Furthermore, the collected data set was also tested by the one-sample Kolmogorov–Smirnov test to assess the multivariate assumption. The p-values were less than 0.05,

Table 1.
Demographic profile of firms and respondents

Details		Percentage
Age Group	20–30	4.93%
	31–40	8.80%
	41–50	48.24%
	51–60	32.39%
	Above 60	5.63%
Educational Qualifications	Postgraduate	83.10%
	Graduate	16.90%
Designation	CEO/President/Owner/Managing Director	4.23%
	President/Vice President	9.86%
	Senior Manager	55.99%
	Manager	19.01%
	Data Scientist	4.93%
	Data Engineer	5.99%
No. of Employees in your Organization	Less than 100	1.76%
	101–300	29.58%
	301–500	52.46%
	501–1000	16.20%
Age of the Organization (Years)	Above 20	69.72%
	10 to 20	27.82%
	Less than 10	2.46%

Source(s): Authors' own

indicating non-normality in the distribution of the data set. In addition, the scatter plot also showed that the data were close to the straight diagonal line, justifying homoscedasticity (Hew and Syed Abdul Kadir, 2016). In fact, all VIF values were less than 5, implying no multi-collinearity problems in the collected data set (Teo *et al.*, 2015).

Non response bias is one of the primary concerns in any empirical study that applies the survey method (Pearl and Fairley, 1985). Hence, the early response and late response data were compared through a *t*-test (Armstrong and Overton, 1977). The results of the *t*-test showed no significant differences between early and late response data. Thus, non-response bias was not a concern in this study.

4. Data analysis

The present study validated the study constructs through exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). Exploratory factor analysis was conducted through principal component and varimax rotation to examine whether the proposed factors were consistent with the survey data (Fabrigar *et al.*, 1999). In addition, the analysis also derived a linear combination of measurement items embedded with maximum variance extracts from each construct (Reio and Shuck, 2015). The study conducted a CFA to confirm the construct of the factor structure explored in the EFA analysis. CFA was also applied to investigate the validity of the measurement model (Thompson, 2007).

After performing reliability and validity analyses through EFA and CFA, we applied covariance-based SEM via Amos software to test the proposed hypotheses. Hence, we conducted a multi-stage data analysis approach (SEM-ANN) to predict the antecedents of the barriers to metaverse technology implementation for SCM. We operationalized these two statistical approaches based on multiple rationales. First, the result of CB-SEM only identified linear relationships by focusing only on the mathematical model, which may have distorted managerial decision-making processes (Hew *et al.*, 2019; Leong *et al.*, 2020). Second, unlike SEM, the ANN process can detect both linear and nonlinear relationships for prediction, which may assist the complexity of managerial decision-making processes (Priyadarshinee *et al.*, 2017). Finally, to address the shortcomings of SEM and ANN and complement the results of SEM, this study applied a dual-stage approach to data analysis that integrated both SEM and ANN. The proposed hypotheses were tested with CB-SEM, and the significant predictors were then explored via the ANN model.

4.1 Assessment of reliability and validity

To assess the reliability and validity of the measurement model, we conducted exploratory factor analysis (EFA). In this process, we applied principal component and varimax rotational approaches. The EFA analysis was conducted primarily to determine whether the proposed factors were consistent with the survey data. The results from the analysis showed the presence of nine factors that matched those identified in the research model. All constructs generated an acceptable range of Cronbach's alpha that ensured the reliability of the corresponding constructs. In addition, all constructs' respective eigenvalues were greater than 1.00, confirming the convergent validity of the study constructs (Hair *et al.*, 1998). The results of the EFA analysis are shown in Table 2.

In this phase of data analysis, we examined the measurement model through confirmatory factor analysis (CFA) to determine the validity of the variables. The measurement model consisted of 35 items considering nine factors to test composite reliability, convergent validity and discriminatory validity of the measurement model (Leong *et al.*, 2012). The results from CFA analysis showed that all constructs' corresponding standardized loadings were above 0.50 and accordingly significant (see Table 2). Thus, this result shows that all the items under each construct fulfilled convergent validity (Kline, 1998). The composite reliability (CR) of each construct was also above 0.700, implying that the measurement items were valid (Molina *et al.*, 2007). Furthermore, all constructs' corresponding AVE values were greater than 1, indicating acceptable convergent validity (See Table 2). The measurement model test also confirmed discriminant validity for all latent constructs, as the square roots of all constructs' AVEs were greater than the correlation coefficients (see Table 3). Above all, the results of the CFA analysis indicated that all goodness-of-fit statistics met acceptable criteria. The results presented in Table 4 demonstrate that the measurement model exhibited a satisfactory level of model fit.

4.2 Structural model

The overall structural model was tested using AMOS 20.0. The proposed conceptual model depicted eight constructs (see Figure 2) of barriers to metaverse technology implementation for SCM, specified as independent constructs. The results from the analysis of the structural model showed that all the values of fit indices such as GFI, CFI, AGFI and NFI were above 0.90, while the values of RMSEA were less than 0.08 (Anderson and Gerbing, 1988). In addition, the normed chi-squared index (X^2/df = 1.987) was also acceptable. Thus, the structural model fit well. The results of the goodness-of-fit indices are provided in Table 5.

4.3 Hypotheses testing

The proposed hypotheses were examined by applying the CB-SEM process. The analysis results confirmed a positive and significant relationship between technological limitations, lack of governance and standardization, integration challenges, poor diffusion through the network, traditional organization culture, lack of stakeholder commitment, lack of collaboration and low perception of value by customers and barriers to metaverse technology implementation for SCM (confirming H1 to H8).

Results from EFA analysis			Results from CFA analysis		
Construct name and items	Factor loading	Total variance explained	Factor loadings	CR	AVE
TL (*Eigenvalue = 2.618, Cronbach's alpha = 0.846)*				0.836	0.561
TL1	0.823		0.801		
TL2	0.751		0.749		
TL3	0.739		0.726		
TL4	0.748	0.589	0.719		
LGS (*Eigenvalue = 2.618, Cronbach's alpha = 0.846)*				0.854	0.594
LGS1	0.795		0.769		
LGS2	0.754		0.734		
LGS3	0.829		0.801		
LGS4	0.795	0.647	0.779		
IC (*Eigenvalue = 2.618, Cronbach's alpha = 0.846)*				0.869	0.625
IC1	0.807		0.793		
IC2	0.796		0.761		
IC3	0.847		0.839		
IC4	0.781	0.629	0.769		
PN (*Eigenvalue = 2.618, Cronbach's alpha = 0.846)*				0.881	0.599
PN1	0.796		0.793		
PN2	0.778		0.761		
PN3	0.769		0.839		
PN4	0.743		0.769		
PN5	0.739	0.617	0.703		
TOC (*Eigenvalue = 2.618, Cronbach's alpha = 0.846)*				0.816	0.598
TOC1	0.731		0.719		
TOC2	0.803		0.793		
TOC3	0.839	0.603	0.806		
LSC (*Eigenvalue = 2.618, Cronbach's alpha = 0.846*)				0.800	0.573
LSC1	0.769		0.749		
LSC2	0.819		0.806		
LSC3	0.729	0.601	0.713		
LC (*Eigenvalue = 2.618, Cronbach's alpha = 0.846)*				0.829	0.550
LC1	0.859		0.839		
LC2	0.736		0.706		
LC3	0.718		0.708		
LC4	0.729	0.607	0.705		
CP (*Eigenvalue = 2.618, Cronbach's alpha = 0.846)*				0.821	0.604
CP1	0.801		0.791		
CP2	0.793		0.773		
CP3	0.789	0.681	0.769		

(*continued*)

Table 2.
Psychometric properties of the study variables

Results from EFA analysis Construct name and items	Factor loading	Total variance explained	*Results from CFA analysis* Factor loadings	CR	AVE
MSCN (*Eigenvalue = 2.618, Cronbach's alpha = 0.846)*				0.889	0.617
MSCN1	0.841		0.807		
MSCN2	0.798		0.739		
MSCN3	0.769		0.849		
MSCN4	0.767		0.759		
MSCN5	0.749	0.826	0.771		

Note(s): Technological limitations (TL), 4 items; lack of governance and standardization (LGS), 4 items; integration challenges (IC), 4 items; poor diffusion through the network (PN), 5 items; traditional organization culture (TOC), 3 items; lack of stakeholder commitment (LSC), 3 items; lack of collaboration (LC), 4 items; low perceived value by customers (CP), 3 items; barriers to metaverse technology implementation for SCN (MSCN), 5 items. CR: composite reliability; AVE: average variance extracted
Source(s): SPSS software output

Table 2.

Variable Name	TL	LGS	IC	PN	TOC	LSC	LC	CP	MSCN
	SEM correlations[2]								
TL	0.748								
LGS	0.439**	0.770							
IC	0.469**	0.379**	0.790						
PN	0.398**	0.319**	0.397**	0.773					
TOC	0.407**	0.497**	0.406**	0.428**	0.773				
LSC	0.427**	0.428**	0.417**	0.419**	0.304**	0.756			
LC	0.483**	0.410**	0.447**	0.430**	0.519**	0.378**	0.741		
CP	0.417**	0.438**	0.473**	0.405**	0.409**	0.418**	0.482**	0.777	
MSCN	0.438**	0.417**	0.408**	0.417**	0.413**	0.435**	0.413**	0.437**	0.785

Source(s): SPSS software output

Table 3. Analysis of discriminate validity

Goodness of fit measures	Recommended value	CFA model (result)
X^2 test statistics/df	$\leq 3.00^a$	1.209
GFI (goodness-of-fit index)	$\geq 0.90^a$	0.949
AGFI (adjusted goodness-of-fit index)	$\geq 0.90^a$	0.901
CFI (comparative fit index)	$\geq 0.90^a$	0.973
NFI (normed fit index)	$\geq 0.90^a$	0.953
RMSEA (root mean square error of approximation)	$\leq 0.08^a$	0.038

Source(s): AMOS software output

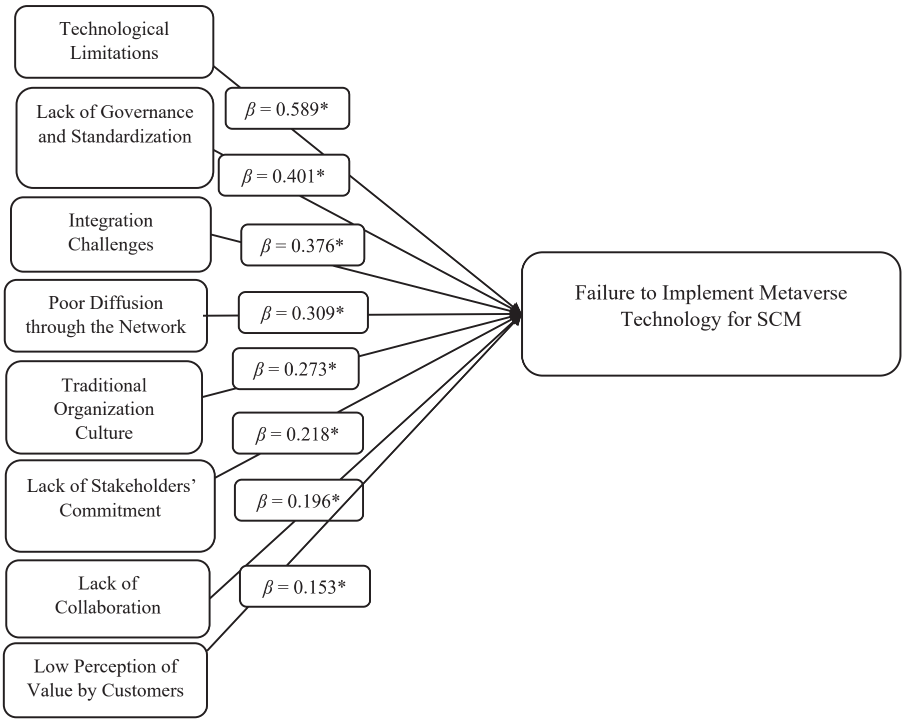
Table 4. Measures of model fit: measurement model

The results demonstrated a strong positive relationship between a firm's technological limitations and failure to implement Metaverse technology for SCM ($\beta = 0.589$, critical ratio = 4.808, $p < 0.01$) followed by lack of governance and standardization ($\beta = 0.401$, critical ratio = 3.701, $p < 0.01$), integration challenges ($\beta = 0.376$, critical ratio = 3.051, $p < 0.01$), poor diffusion through the network (β = 0.309, critical ratio = 3.039, $p < 0.01$), traditional organization culture (β = 0.273, critical ratio = 2.961, $p < 0.01$), lack of stakeholder commitment (β = 0.218, critical ratio = 2.361, $p < 0.01$), lack of collaboration (β = 0.196, critical ratio = 2.084, $p < 0.01$) and low perception of value by customers (β = 0.153, critical ratio = 2.701, $p < 0.01$). The relationships among these variables are also shown in Figure 3, which provides the respective β values for each hypothesis. The results also revealed that the structural model could explain 54.40% of the variance in the barriers to metaverse technology implementation for SCM, indicating 45.6% of the effect size and justifying a large effect (Cohen, 1988).

Table 5.
Measures of model fit: structural model

Goodness of fit measures	Recommended value	CFA model (result)
X^2 test statistics/df	≤3.00[a]	1.987
GFI (goodness-of-fit index)	≥0.90[a]	0.937
AGFI (adjusted goodness-of-fit index)	≥0.90[a]	0.910
CFI (comparative fit index)	≥0.90[a]	0.958
NFI (normed fit index)	≥0.90[a]	0.928
RMSEA (root mean square error of approximation)	≤0.08[a]	0.027

Source(s): AMOS software output



Note(s): * = $p < 0.050$ (significant)
Source(s): AMOSS software output

Figure 3.
Results of hypothesized relationships

4.4 Deep ANN modeling

SEM can only explain linear relationships among variables; therefore, the probability is high that it may oversimplify the complexities of the managerial decision in understanding the barriers to metaverse technology implementation for SCM. Therefore, to address the limitations of SEM findings, the present study applied SEM–ANN methods for data analysis, as findings from ANN can identify both linear and non-linear relationships, which are more robust and can provide higher prediction accuracy (Morris *et al.*, 2004; Leong *et al.*, 2013). Thus, the study conducted deep ANN modeling to explore non-linear relationships among the variables in the predictive model. The dependent variable (i.e. barriers to metaverse technology implementation for SCM) was classified as low (<7), medium (7–10) and high (>10). Using SPSS version 22, the data were run through a neural network multi-layer perceptron algorithm with two hidden layers. Cross-validation was operationalized along with a sigmoid activation process chosen as a function of hidden neurons and output, in which eight independent variables were used to predict the dependent variable (Arpaci and Bahari, 2023). The results from the ANN analysis showed that root-mean-square error (RMSE) values for the testing and training data were all within acceptable limits. The results from the ANN analysis were close to the findings from the CB-SEM analysis. The deep ANN model predicted the barriers to metaverse technology implementation for a firm's SCN with a mean accuracy of 69.50% (training) and 60.06% (testing; see Table 6).

Finally, we analyzed the sensitivity to reveal the relative impact of the input (independent) variables on the output (dependent) variables. The results from the analysis showed the importance of the variables, for instance, technological limitations (importance: 20.25%), lack of governance and standardization (importance: 17.25%), integration challenges (importance: 15.43%), poor diffusion through the network (importance: 12.10%), traditional organization culture (importance: 10.86%), lack of stakeholder commitment (importance: 9.25%), lack of collaboration (importance: 8.06%) and low perceived value by customers (importance: 6.80%).

The analysis results show the crucial factors that play a significant role in the successful implementation of metaverse technology in SCM. Understanding these factors is essential for organizations aiming to adopt and leverage this transformative technology effectively. The first factor is "Technological Limitations (Importance: 20.25%)". This factor indicates that certain technological constraints may hinder the seamless integration of metaverse technology into existing SC systems. Overcoming these limitations is vital to unlock the full potential of the metaverse, enabling organizations to explore new possibilities and

Network	Sum of square error (training) (MSCN)	Sum of square error (testing) (MSCN)
ANN1	0.789	0.698
ANN2	0.628	0.708
ANN3	0.708	0.651
ANN4	0.716	0.608
ANN5	0.703	0.598
ANN6	0.697	0.701
ANN7	0.716	0.607
ANN8	0.698	0.769
ANN9	0.678	0.718
ANN10	0.618	0.742
Mean	0.695	0.606
Std Dev	0.047924594	0.060402355

Source(s): SPSS software output

Table 6. Classification accuracy and RMSE values

optimize their operations. The second factor is "Lack of Governance and Standardization (Importance: 17.25%)". The absence of clear governance and standardization frameworks poses challenges in establishing a cohesive and standardized approach to utilizing metaverse technology across the industry.

The third factor is "Integration Challenges (Importance: 15.43%)". Integrating metaverse technology with existing SC processes is a complex task. Addressing integration challenges effectively will determine how well organizations can leverage the metaverse to enhance efficiency, transparency and communication throughout the supply chain. The fourth factor is "Poor Diffusion Through the Network (Importance: 12.10%)". Diffusing metaverse technology effectively through the network requires strategic planning and targeted initiatives. Overcoming resistance to change and ensuring broad adoption among relevant stakeholders is essential for maximizing the benefits of the metaverse. The fifth factor is "Traditional Organizational Culture (Importance: 10.86%)". Organizational culture deeply influences technology adoption and implementation. Cultivating an innovative and adaptive culture that embraces new technologies will foster a favorable environment for successfully integrating metaverse solutions into logistics and supply chain processes.

The sixth factor is "Lack of Stakeholder Commitment (Importance: 9.25%)". Gaining commitment from all relevant stakeholders, including top management, employees and partners, is critical for successfully implementing any transformative technology. Ensuring alignment and buy-in will enhance the likelihood of a smooth and effective metaverse integration. The seventh factor is "Lack of Collaboration (Importance: 8.06%)". Collaboration among various players in the SC ecosystem is vital for achieving synergy and optimizing the benefits of metaverse technology. Encouraging collaboration and knowledge-sharing will strengthen the overall SC performance. The eighth factor is "Low Perceived Value by Customers (Importance: 6.80%)". Customers' perception of the value provided by metaverse technology can influence its adoption in SC processes. Effectively communicating the advantages of the metaverse to customers and demonstrating tangible benefits will enhance their acceptance and engagement.

This analysis underscores the multifaceted nature of challenges and opportunities associated with implementing metaverse technology in SCM. By addressing these factors strategically and proactively, organizations can position themselves for a successful transformation, harnessing the metaverse's potential to drive efficiency, innovation and competitive advantage within the industry. Embracing a holistic approach, which involves technology, culture, collaboration and stakeholder engagement, will be crucial in realizing the full benefits of metaverse technology in this dynamic and evolving landscape.

5. Discussion

5.1 Implications for theory

This study has significantly advanced the understanding of obstacles that exist to the adoption of metaverse technology in SCM. An association among virtual ethics, moral conduct and data-driven green lean practices were discovered by Bag *et al.* in 2023. In the context of data-driven lean and green practices, these authors also discussed the feasibility of sustainable and digital supply chain performance. Our research has addressed the challenges of applying metaverse technology and advances in digitalization. Advanced computer systems and virtual or augmented software are needed for metaverse technology. According to the current study, use of metaverse technology is hindered by a lack of modern technology. We found that the industry's current digital infrastructure is incompatible with metaverse technology. This study has concluded that the inability to adopt metaverse technology for SCM is largely due to technological limitations. Hence, H1 is supported.

The significance of the metaverse, a new degree of relationship between the real and virtual worlds that creates new potential and opportunity for business models, was explained by Dwivedi *et al.* (2022). They identified various difficulties associated with metaverse technology, including those related to government, safety, ethics and morality. Further addressed in our findings is how a lack of governance results in reluctance by stakeholders to adopt metaverse technology for SCM. This study has found that a lack of governance and standardization leads to problems with security, privacy and morality. Hence, H2 is supported.

According to Queiroz *et al.* (2023), using metaverse technology in SCM is possible. Along with the lack of necessary skills, these authors discuss the costs of implementing metaverse technology. From our investigation, we can also state that it is crucial to integrate metaverse technology with other programs and that expertise and human factors are essential. Interoperability, complexity and technological issues are the main hurdles to integration. The failure of metaverse technology in SCM is greatly impacted by integration issues. Hence, H3 is supported.

According to Salvini *et al.* (2022), a virtual chain game is a creative way to accelerate the speed of digitalization in SCs. They add that four barriers—lack of urgency, lack of a customer-centric strategy, lack of understanding of virtualization and lack of cooperation—need to be overcome. However, these authors overlooked a crucial barrier, namely a poor diffusion network. Because the information is asymmetrical, poor communication may have an adverse effect on supply chain management productivity and efficiency. The study reported here has concluded that poor diffusion networks significantly contribute to the failure of SCs to adopt metaverse technology. Hence, H4 is supported.

According to Queiroz *et al.* (2023), the largest obstacles to integrating metaverse technology in SCM are price and technological acceptance. These authors avoided discussing the traditional organizational culture, which serves as a roadblock to adopting metaverse technologies. The present study has concluded that traditional organizational cultures are resistant to change and innovation, inhibiting the adoption of metaverse technologies. A traditional organizational culture has a detrimental impact on the adoption of metaverse technology in SC and limits a company's capacity to make use of the technology's advantages. As a result, the presence of a traditional organizational culture makes it more difficult for SCM to successfully implement metaverse technology. Hence, H5 is supported.

According to Queiroz *et al.* (2023), the implementation of metaverse technology in SCM is dependent on efficiency, creativity and information sharing; stakeholder concerns regarding the advantages of metaverse technology were another finding. The present study has found that a key barrier to the effective application of metaverse technology is a lack of stakeholder commitment. Firms cannot participate in the metaverse implementation process due to a lack of stakeholder commitment. Hence, H6 is supported.

Five themes for extended reality and cyber-physical systems in IOT-enabled logistics and SCM were highlighted by Tsang *et al.* (2022), collaboration between humans and computers was among them. Our research has broadened the field of inquiry into the function of collaboration in metaverse technology. This study has established that the main impediment to deploying metaverse technology in SCM is a lack of stakeholder collaboration. Hence, H7 is supported.

Understanding the consumer experience is made easier with the assistance of artificial intelligence (Arora *et al.*, 2023). Arora *et al.* (2023) reached the conclusion that cutting-edge technology, such as artificial intelligence, improves customer perception. The significance of consumer perception in integrating metaverse technology has been explored further in our study. This study has concluded that consumers will refuse to use metaverse technology if they do not perceive any benefits from doing so. According to our findings, low customer perceived value have a direct impact on the failure of SCM initiatives involving metaverse technology. Hence, H8 is supported.

5.2 Implications for practice

This study has identified various barriers to implementing metaverse technology in the SC and one of the key barriers is technological limitations. Therefore, the main resulting consideration for SC managers is to be aware of their technological readiness. To address technological limitations, SC managers can first conduct a technology assessment to identify gaps in their organization's technological infrastructure. Then, they should identify suitable metaverse technologies that align with the organization's needs. This approach can help reduce the cost of IT infrastructure for firms. Overall, developing a comprehensive implementation plan and evaluating the use of the technology are crucial steps that managers should take to ensure the successful implementation of metaverse technology.

The second identified barrier is a lack of governance and standardization. To address this issue, SC managers can establish governance and standardization protocols and collaborate with industry partners to develop common standards. Collaboration with industry partners is essential for managers to establish uniform standards and best practices for using metaverse technology in the SC. Collaboration can facilitate consistent and standardized use of the technology by all stakeholders in the SC.

Integrating new technology, particularly metaverse, with existing systems is always challenging for organizations. To overcome this challenge, organizations can pilot-test the integration of metaverse technology in a small-scale project, collaborate with SC stakeholders and understand the limitations of their existing IT infrastructure. Technical training of employees can help the technological infrastructure to function smoothly.

Poor network spread is a problem for new technologies whenever they are introduced, and this problem exists for the metaverse as well. There are a number of initiatives that businesses may take to improve the SCs' poor dissemination and lack of acceptance of metaverse technologies. They should first conduct market research to determine the elements, such as the requirements and preferences of all parties involved, that affect the acceptability of metaverse technology. Second, managers must explain the advantages of implementing metaverse technology in the SC, including increased effectiveness, openness and traceability. To increase the adoption rate of metaverse in SCM, managers should create a common alliance with technology experts and various stakeholders of SC.

Additionally, this study has demonstrated that traditional organizational culture, which consists of shared ideals, norms, customs and behaviors that influence how workers relate to one another and stakeholders outside the company, may act as a hindrance to the effective application of metaverse technology for SCM. To overcome this barrier, firms can take several steps. First, they can create a culture of innovation and openness. Second, they can provide adequate training and support. Third, they can foster a collaborative approach. Finally, they can ensure that senior leaders are actively involved. By taking these steps, firms can increase understanding and acceptance of the technology and ensure that it is used effectively by all employees.

Another essential element for the effective application of metaverse technology in SCM is stakeholder commitment. It is challenging to quantify since it requires evaluation of the beliefs, attitudes and actions of numerous stakeholders at various organizational levels (Queiroz *et al.*, 2023; Siebold *et al.*, 2023). Businesses must overcome the potential hurdle of a lack of stakeholder commitment to achieve effective implementation. To do this, businesses should involve important stakeholders early in the process and make sure that everyone is in agreement about the aims and advantages of the technology. Additionally, businesses should address any issues or objections that stakeholders may have, show them the potential benefits of the technology and provide incentives and rewards for those stakeholders who actively support its deployment. To ensure the efficient and prompt flow of products, coordination between stakeholders—including retailers, suppliers and manufacturers—is essential for the successful use of metaverse technology in SCM. SCs' that are ineffective and fail might be brought on by a lack of collaboration. Firms should explain the technology's advantages to stakeholders and include them in decision-making to foster a collaborative atmosphere in order to overcome this obstacle. Increase engagement and ensure successful use of the technology by rewarding and motivating stakeholders for their assistance and by giving them the necessary training.

As customer satisfaction and perception of value are critical for the success of its application in SCM, this study has also shown that low consumer perception of value is a significant component (Dwivedi *et al.*, 2022). Businesses may take a number of actions to improve client adoption and guarantee effective deployment. Companies should carry out market research to comprehend client needs and adjust the technology. Additionally, businesses should clearly explain to customers the advantages of using metaverse technology in SCM, provide training and support to customers to ensure that they are comfortable using the new technology, and reward and incentivize those who use it and actively support it. These actions can help businesses increase customer happiness and value perception, encouraging more firms to use metaverse technology for SCM.

6. Conclusion

Management of the SC could be completely transformed by metaverse technology. However, businesses must consider a number of implementation barriers. To respond to RQ1, this study's initial step was identifying the barriers. To address RQ2, this study also examined how these barriers affect the use of metaverse technology in SCM. The various stakeholders in the supply chain management process must work together to overcome these obstacles. The creation of standards and protocols is necessary to enable system interoperability and overcome technical barriers. Investments in powerful computers and high-speed internet access can also help in the adoption of metaverse technology. Strong leadership and resource management are necessary to overcome organizational hurdles. Furthermore, overcoming cultural barriers calls for the development of clear policies and guidelines for data privacy and security, the establishment of trust among stakeholders and the creation of an inclusive environment that promotes collaboration and innovation. SCM could change due to integrating metaverse technology, but overcoming acceptance barriers will require collaboration and other factors discussed in previous sections.

The limitations of this study involve collecting data from a single academic database (Scopus). Moreover, we have surveyed IT consultancy and SC solutions development firms in India. Readers must keep these limitations in mind while interpreting the findings. Future research could examine metaverse implementation in SCM using RBV or DCV perspective. Also, social media data can be a valuable tool for researchers and businesses seeking to understand the factors influencing the successful implementation of the metaverse in business. By leveraging social media analytics, we can gain valuable insights into user perceptions, needs, challenges and successful adoption strategies. This knowledge can inform decision-making processes and enhance the overall effectiveness of metaverse implementation initiatives.

Two well-known models that investigate the factors influencing users acceptance and adoption of technology are the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Davis, 1985; Goli *et al.*, 2023; Rahman *et al.*, 2023; Venkatesh *et al.*, 2003). TAM and UTAUT both offer important perspectives on how users accept and use technology. While TAM primarily concentrates on perceived utility and usability, UTAUT adopts a more thorough approach and takes into account a variety of aspects that can affect technology acceptance. These models can be used by future academics and practitioners to evaluate user attitudes and behavior about the adoption of metaverse technology and to develop strategies for the successful use and integration of metaverse in SCM.

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Appendix

Sl No.	Items	Source
Technological limitations (TL)	TL1: The need for real-time data integration is a challenge for the firm TL2: The need for real-time data processing is a challenge for the firm TL3: We do not have the capability for constant monitoring of data from various sources (e.g. inventory levels, delivery times and production schedules) TL4: We do not have the capability for constant analysis of data from various sources (e.g. inventory levels, delivery times and production schedules)	Dwivedi *et al.* (2022), Mozumder *et al.* (2022), Queiroz *et al.* (2023)
Lack of governance and standardization (LGS)	LGS1: There is no agreed-upon standard for metaverse implementation LGS2: There is no agreed-upon standard for established rules for metaverse platform governance LGS3: Different metaverse platforms and systems (protocols, interfaces and data formats, making) challenging to share information between them LGS4: Different platforms create silos of information that can hinder collaboration and coordination across the supply chain network	
Integration challenges (IC)	IC1: Supply chain systems are often developed separately IC2: Supply chain systems using different technologies and standards can be difficult to manage IC3: Supply chain processes are implemented separately IC4: Integrating the metaverse into these existing systems can be challenging, as it requires bridging the gap between the virtual and physical worlds	
Poor diffusion through the network (PN)	PN1: Metaverse is a new and emerging technology that is still in its early stages of development PN2: There is limited awareness of the technology and many potential users may be hesitant to adopt it PN3: There is a limited understanding of the technology, and many potential users may be hesitant to adopt it PN4: There are fewer users to spread the technology and its benefits PN5: Low awareness levels can lead to poor diffusion through the network	
Traditional organization culture (TOC)	TOC1: Traditional organizational cultures may not be conducive to the experimentation TOC2: Traditional organizational cultures may require risk-taking to implement the metaverse in supply chain management TOC3: A culture of collaboration and open communication, which may not exist in traditional organizations with rigid hierarchies and siloed departments	
Lack of stakeholder commitment (LSC)	LSC1: There is a lack of collaboration from various stakeholders, including supply chain managers, IT professionals and end-users LSC2: The stakeholders are not committed to the project's success LSC3: Metaverse is a new and emerging technology, and many stakeholders are uncertain about the benefits and potential returns on investment	

(*continued*)

Table A1. Operationalization of the constructs

Sl No.	Items	Source
Lack of collaboration (LC)	LC1: Metaverse requires collaboration between different technology domains, including virtual reality, blockchain, and artificial intelligence, which is missing LC2: It can be challenging to effectively implement the metaverse in supply chain management LC3: Stakeholders lack the necessary expertise LC4: Stakeholders lack the necessary knowledge in these domains	
Low perception of value by customers (CP)	LVC1: Customers are hesitant to invest in the necessary technology infrastructure LVC2: Customers are hesitant to effectively implement the metaverse in supply chain management LVC3: Customers perceive the metaverse as a novelty technology that has limited practical value for their business needs, which has limited their interest in adopting the technology	
Failure to metaverse technology implementation for SCM (MSCN)	MSCN1: Failed to define the goals and objectives of the project MSCN2: Failed to assess the technological readiness of the organization's infrastructure to support the metaverse technology MSCN3: Failed the organization can develop a roadmap for the implementation of the metaverse technology MSCN4: Failed to build the necessary infrastructure to support the metaverse technology MSCN5: Failed to test and validate the metaverse technology in a controlled environment	

Table A1. **Source(s):** Authors own

Corresponding author
Surajit Bag can be contacted at: surajit.bag@gmail.com