

**LEVERAGING IMMERSIVE EXPERIENCES FOR DESIGNING RESILIENT AND
SUSTAINABLE SUPPLY CHAIN NETWORKS: INSIGHTS FROM VIRTUAL
REALITY AND METAVERSE INTEGRATION**

Developmental paper

Witold Bahr¹, Muhammad Mustafa Kamal²

¹Keele University, Keele Business School, UK, w.bahr@keele.ac.uk

²University of Exeter, UK, m.m.kamal@exeter.ac.uk

Abstract

This paper explores the use of virtual reality (VR) and metaverse to enhance the resilience and sustainability of supply chain networks, addressing challenges such as visibility, complexity, and coordination. Through a qualitative research approach employing the PRISMA method, the study identifies trends, challenges, benefits, and drawbacks of integrating VR and metaverse. Findings suggest that these technologies can improve supply chain resilience by facilitating digital interoperability and enabling effective communication and collaboration. Key design principles include realistic simulations and immersive experiences. The research contributes to understanding VR and metaverse potential in supply chain management, leading to a transformation for the greater good and value chain synchronization in today's volatile business landscape. It offers practical insights for managers, stressing digital interoperability's role in resilience and efficiency. Paper development plans include expanding the literature review, incorporating emerging case studies, and integrating insights from interviewing expert practitioners.

Primary track

Operations, Logistics and Supply Chain Management

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Introduction

In the era of information technology, the role and impact of digital transformation on building resilient and sustainable supply chain operations have captured the attention of both industry practitioners and scholars. Advocates contend that digital transformation has progressively reshaped governments and enterprises, rendering them more competitive and driven, while also creating numerous opportunities for economic growth and prosperity (Wan *et al.*, 2023; De Giovanni, 2023). In alignment with this evolving perspective, businesses are showing keen interest in adopting innovative technologies such as virtual reality (VR), artificial intelligence (AI), augmented reality (AR), and big data, recognizing their potential for enhancing business applications and profitability (Bhandal *et al.*, 2022). Among these emerging technologies, the metaverse has garnered significant attention from supply chain and business communities due to its promising features (Queiroz *et al.*, 2023). Cui *et al.* (2022) advocate that the metaverse platform provides a comprehensive framework for digitally reorganizing the entire supply chain system, spanning from research and development (R&D) to customer service. More recently, Dolgui and Ivanov (2023) have suggested that VR and the metaverse offer exciting opportunities for supply chain design by simulating the behaviours and processes of physical entities. Despite ongoing enhancements, driven by factors such as mobile-based always-on internet access and the integration of virtual currencies with real-world transactions, the metaverse continues to evolve.

This paper proposes to design resilient supply chain networks by harnessing the capabilities of VR and metaverse, all while considering the digital interoperability of operations. By adopting VR and metaverse applications, there exists significant potential for designing supply chain networks with robust connectivity options, facilitating direct and collaborative interactions with suppliers. This, in turn, can result in reduced production costs and accelerated value chain synchronization. The seamless and efficient communication between suppliers and customers enhances responsiveness and transparency across the entire supply chain. To achieve this, the authors employ a PRISMA-based methodology (Preferred Reporting Items for Systematic Reviews and Meta-Analyses, Moher *et al.*, 2009) to identify key trends and challenges associated with integrating VR technology and metaverse platforms into supply chain networks, while also examining the benefits and drawbacks of this integration.

Literature review

The metaverse embodies an expansive virtual domain that coexists alongside the physical world, enabling interactions through virtual avatars (Zainab *et al.*, 2022). Over time, the concept of the metaverse has been interpreted in numerous ways, including lifelogging, collective virtual space, immersive learning, embodied internet/spatial internet, digital twin, a mirror world, and an omniverse – a space conducive to cooperation and simulation (Park and Kim, 2022). Given its multifaceted nature, the metaverse holds the potential to revolutionize operations, logistics and supply chains, including manufacturing and the services sector, by creating new sales channels and reaching previously untapped audiences, thereby bolstering sales. Within the metaverse, businesses can construct digital replicas of their physical locations such as warehouses or stores, allowing them to monitor inventory locations, stock levels, and identify potential issues (Dincelli and Yayla, 2022). This application can result in cost reductions and improved operational efficiency. Moreover, the metaverse has the capacity to transform supply chain operations by facilitating more efficient collaboration with

suppliers (Queiroz et al., 2023; Polas et al., 2022). Through the establishment of virtual meeting spaces, businesses can seamlessly engage with their suppliers on various tasks, streamlining operations and enhancing overall efficiency.

The widespread adoption of the metaverse, both in academic circles and industry, especially with the integration of VR, has ushered in a novel and transformative approach. VR involves creating immersive, three-dimensional representations of the real world or its constituent objects (Riva et al., 2021). Within a well-designed VR environment, users can actively engage with virtual settings, leveraging their rich components for valuable interactions. A notable advantage of VR lies in its capacity to facilitate repetitive training scenarios (Dincelli and Yayla, 2022). Unlike traditional real-world training, employees can participate in VR simulations multiple times, effectively mastering concepts, tasks, or procedures. This advantage holds significant promise for advancing modern business-related fields, positively influencing business quality, application, and processes (Chen and Yang, 2022; Allam et al., 2022). Notably, the supply chain domain – encompassing all individual operations from production planning and procurement to internal and external logistics and inventory management – stands to benefit significantly from these technological advancements, as businesses collaborate to manufacture and deliver products to consumers (De Giovanni, 2023). Navigating the complexities of a supply chain network presents challenges in achieving flexibility. However, leveraging current innovative technologies can fortify the supply network, enhance operational efficiency, reduce costs, and enable swift response strategies. For instance, the metaverse holds the potential to disrupt supply chains and related networks for two primary reasons. Firstly, within its platform, the metaverse can manage transactions governed by blockchain technology, effectively bypassing intermediaries within the supply chain (De Giovanni, 2022). Secondly, this platform facilitates new connections with diverse suppliers, including businesses that own the platforms and avatar designers (Vishkaei, 2022). Building upon this notion, Queiroz et al. (2023) advocate for redesigning and engineering the current supply chain network into meta supply chains, fostering visibility, transparency, and trust among all entities to continually optimize supply chain streams.

Methodology

To comprehensively explore the existing literature on the role of VR and metaverse platforms in designing resilient and sustainable supply chain networks, a search was conducted in the SCOPUS database using a specially constructed query. This query was crafted by adapting and expanding upon a set of keywords recommended by Setiawan and Anthony (2022). The chosen keywords include ‘virtual reality,’ ‘metaverse,’ ‘supply chain network,’ ‘supply chain,’ ‘sustainability,’ ‘sustainable supply chains,’ and ‘resilien*’ (with an asterisk as a wildcard to account for variations like ‘resilient’ and ‘resilience’). Search results were limited to the peer-reviewed journal articles in the English language.

The literature selection process adhered to the PRISMA four-tiered approach, encompassing identification, screening, eligibility, and inclusion. A search conducted in the SCOPUS database yielded 18 articles that aligned with the specified queries. These articles underwent an initial screening based on their titles and abstracts, followed by a comprehensive evaluation of their full texts. To mitigate potential study selection bias during the screening and eligibility phases, a procedure akin to that outlined by Lim et al. (2013) was adopted. In this process, the two authors independently assessed the articles and resolved any

discrepancies through deliberation and discussion until a consensus was reached. The entire literature selection process is visually represented in Figure 1.

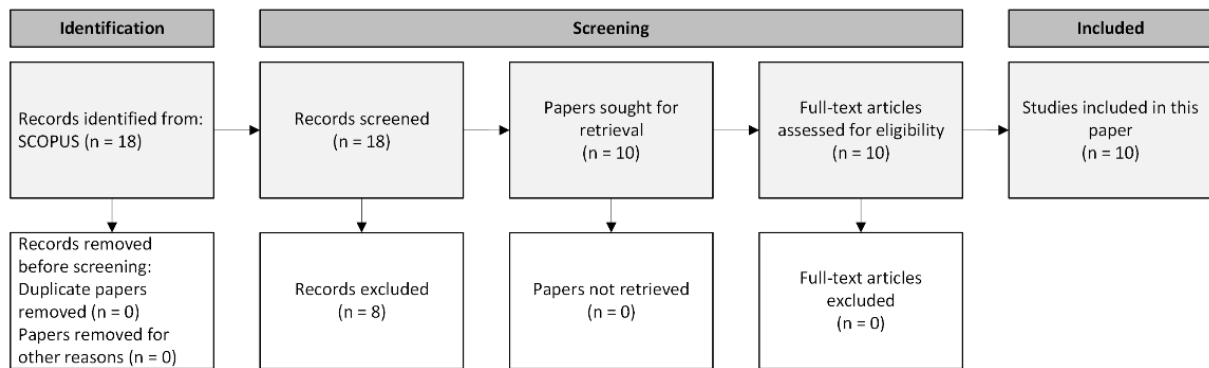


Figure 1: Literature selection process

Discussion of results

The findings from the extant literature reveal that the metaverse plays a crucial role in enabling virtual collaboration and communication among supply chain partners, which is essential for improving decision-making and coordination. Additionally, the metaverse offers opportunities for virtual simulations and scenario planning, allowing companies to test and optimize their supply chain strategies.

The metaverse refers to a VR environment that encompasses virtual reality elements across various dimensions, including place, time, and interactions between humans and their surroundings. Similarly, VR constitutes a computer-generated environment that elicits various sensory responses, such as visual and auditory sensations. VR enables users to experience a sense of presence and immersion (Akram et al., 2022). Beyond the advantages mentioned, the metaverse is poised for increased popularity due to the growing acceptance of VR games, the affordability of VR devices for immersive experiences, and the utilization of traceable blockchain technology to ensure secure transactions.

In contrast, the integration of VR within supply chains is contingent upon the specific context of the business and industry. Notably, the fashion industry stands out as a major sector poised to reap benefits from metaverse and VR applications. Advocates contend that VR contributes to the development of personalized products and enhances the online shopping experience for customers by creating immersive retail environments through virtual features. This can be achieved through real-time visualization of smart fabrics and garments within the virtual network. These observations align with the significance of digitalization in tailoring user needs and desires, as highlighted by Lăzăroiu (2022). However, it is essential to recognize that the heightened user interaction inherent in metaverse and VR experiences, compared to traditional online interactions, introduces challenges related to security. Managing risks associated with VR devices and safeguarding against compromised avatars and accounts within the metaverse becomes more complex. Consequently, businesses must leverage digitalization techniques to fortify relevant domains and establish robust platforms while maintaining cost-effectiveness.

Paper development plans

The development plans for the paper involve several key enhancements:

1. **Expanded Literature Review:** The initial literature review focused solely on the SCOPUS database. To enrich the review and ensure a comprehensive understanding of the topic, it is proposed to expand the search to include additional databases such as Web of Science, EbscoHost, and ProQuest. This broader approach will capture a larger pool of existing literature, allowing for a more thorough analysis of the subject matter.
2. **Emerging Case Studies:** To provide a more up-to-date and relevant perspective, the paper will incorporate emerging case studies in the field of VR and metaverse applications within supply chain design. These case studies will offer real-world examples of how these technologies are being implemented and their impact on supply chain resilience and sustainability.
3. **Interviews with Experts:** In addition to academic literature and case studies, the paper will draw on insights from semi-structured interviews with expert practitioners in the field of supply chain management and technology implementation. These perspectives will provide valuable practical insights and enrich the discussion by offering real-world perspectives on the opportunities and challenges associated with integrating VR and metaverse platforms into supply chain networks.
4. **Framework development:** The study will further develop existing findings by constructing a conceptual framework that elucidates the interplay between virtual reality, the metaverse, and supply chain resilience. This framework will synthesize key insights providing a comprehensive understanding of how these technologies can be strategically integrated into supply chain management practices.

By implementing these development plans, the paper will offer a more comprehensive and nuanced analysis of the potential utility of VR and metaverse platforms in designing resilient and sustainable supply chain networks, thereby contributing significantly to the existing body of knowledge in this field.

Conclusion

This study investigates the potential of VR and metaverse platforms in designing resilient supply chain networks, examining integration challenges, benefits, and drawbacks. Employing a PRISMA approach, an in-depth literature review reveals metaverse-enabled virtual collaboration's value for decision-making and coordination. Additionally, metaverse offers virtual simulations for risk-free supply chain strategy testing. However, concerns regarding the costs associated with implementing immersive technology take precedence. Future research will expand the literature review to include additional databases, incorporate emerging case studies, and integrate expert practitioner insights to further explore these themes.

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