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The Metaverse in Supply Chain Management: Applications and Benefits

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Abstract
Businesses are keen to implement new technologies like virtual reality, artificial intelligence (AI), augmented reality, big data, etc. as they see profitable business applications. The supply chain and the larger business community have been paying attention to Metaverse as one of the technology disruptions. The metaverse is being enhanced by several variables, including mobile-based always-on access and virtual currency linkage with reality. Additionally, the growth of the Metaverse and Non-Fungible Tokens (NFT) has taken the metaverse to a new level. This paper performs a comprehensive analysis of the metaverse's attributes, uses, and prospects in global supply chains. The current metaverse-focused study discloses the state of the research and outlines future research goals by reviewing and analysing recent articles that reveal metaverse uses across multiple supply chain activities. It has been demonstrated that the metaverse has several features that help businesses improve supply chain efficiency and customer engagement, including increased visibility into operations, facilities, inventory, and capacity. These characteristics fuelling the metaverse's application in supply chain management and logistics operations. The study further found that metaverse-related research has been extremely growing in the areas of healthcare, retail, and infrastructure, while there is still scope for study in the field of supply chain security and traceability. Finally, it is emphasized that metaverse-related research in logistics, supply chain operations, and agriculture supply chains has the potential to be explored.

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1. Introduction

The metaverse is one of the most key inventions in the everyday lives of individuals, including training, transportation systems, manufacturing and construction. It is also one of the most promising technologies which actualize virtual reality and was considered one of the important technologies at the Consumer Electronics Show (CES) held in 2022 (Lee et al., 2022). The establishment of ubiquitous computing infrastructure is taking place in the appropriate industries as the metaverse emerges as a new trend in a variety of industries, including education, retail, and gaming.

Also, in light of the metaverse's launch, several users can utilize the various metaverse applications in mobile and personal computer contexts (Lee et al., 2021). However, few studies have been conducted on mobile metaverse applications. Considering the increasing number of users of the metaverse, it is important to analyze user experience to provide the metaverse application users with improved services (Yavuz et al., 2021).

The phrase "METAVERSE," created by joining the prefix "meta" (which denotes transcending) with the word "universe," designates a made-up artificial setting that is interconnected with the real world. The phrase "metaverse" first debuted in Neal Stephenson's 1992 science fiction novel Snow Crash (Joshua, 2017).

According to Stephenson's description in this novel, the metaverse is a massive virtual setting that exists alongside the real world and allows individuals to converse via virtual avatars. Since its inception as a computer-generated cosmos, the concept of the metaverse has been described by a variety of ideas, including lifelogging, collective virtual space, embodied internet/ spatial internet, a mirror world, and an omniverse: a space for cooperation and simulation (Lee et al., 2021).

The metaverse's improved internal and external communication capabilities could be advantageous to almost all supply chain levels. More connectivity options enable a direct collaborative approach with suppliers, which decreases production costs and accelerates value chain synchronisation. This link would enable seamless and efficient cost talks between suppliers and customers, making the entire chain more responsive and transparent (Trivedi, 2022).

Despite having too many advantages of a metaverse in supply chain and logistics, diminutive research has been done to identify the existing state of literature, application, and research direction for the metaverse applications in the supply chain. The present study gives an overview of existing literature as well as gaps and potential research directions.

Analysis of papers published in journals, articles, and reports to help improve existing information about metaverse application in the supply chain. This work, on the other hand, adds new dimensions to future investigation. After prior conversations, three leading research questions (RQs) have emerged as:

RQ1: What is the present state of knowledge and comprehension of the usage of the metaverse in supply chains?

RQ2: What are the benefits of metaverse applications across various functions of supply chains?

RQ3: What are the future research directions for metaverse applications in supply chain management based on existing work and identified possible research gaps?

The research is divided into five components. The first section includes an introduction to the topic as well as a summary of the guiding research questions that were identified after a careful review of the literature. The second section includes a literature review.

The third section outlines the approaches used to identify and organise the literature using our classification system. The fourth section reports on the study's findings and conclusions. The study's fifth component finishes with recommendations for future research.

2. Literature Review

This section covers the background of supply chain and highlights the role of metaverse in supply chain management and its benefits to the business organisation.

2.1 Supply Chain Management

Global value chains are changing because of new industry capabilities, expanding demand, and developing country industry capabilities, as well as a wave of new technologies (Lund et al., 2019). In a supply chain, several different businesses typically work together to manufacture a product and deliver it to the consumer. A supply chain consists of producers of raw materials and components, product assemblers, wholesalers, retailer merchants, and transportation firms (Londe and Masters, 1994). Further, Mentzer et al. (2001), highlighted that a supply chain is the grouping of businesses that coordinates the marketing of goods or services, and that to adopt supply chain management, operations from sourcing to manufacture and distribution must be integrated.

A study conducted by Prajogo and Jan (2012) suggested that operations performance is significantly impacted by logistics integration. Information technology (IT) capabilities and information exchange have a substantial impact on logistics integration Rai et al. (2006) found that information technology-enabled supply chain integration capabilities improve business performance significantly and sustainably, particularly in terms of operational excellence and revenue growth. Management should prioritise the development of an integrated IT infrastructure and its application in the development of process skills for integrating resource flows between a company and its supply chain partners.

Pan (2008) highlighted the fact that supply chain management uses current information technology extensively to reinforce supply network weaknesses, increase operating efficiency, lower operating costs, and build quick reaction strategies. The research conducted by Yuliana et al. (2022) proposed that by utilizing Technology, information sharing, and engagement with supply chain partners, a manufacturing organization might maintain the performance of its supply chain during the Covid-19 pandemic. Precise information can aid decision-makers in making accurate judgments, and information sharing among supply chain nodes can significantly enhance the supply chain's effectiveness (Zhao et al., 2022).

In a study, conducted by Dev et al. (2020) suggested that using a reverse logistics model simulation that includes operations like inventory and production planning policy, additive manufacturing, and proposed to visualise an arrangement of an RFID-enabled and cloud-based ERP system that enables computing product returns with the inbuilt Bass model algorithm module, the effectiveness of the virtual world in an Industry 4.0 environment is investigated.

The study also recommended that the manager should consider the "optimum" promotional investment that enables moving multiple suppliers to the cloud-based cyber-physical-social network system as a common platform, despite the availability of Industry 4.0 capabilities based on cyber-physical and social networks.

Future research may examine environmental and economic performance considering the impact of the disposal of returns, according to the study. For the supply chain to effectively handle both the online and metaverse parts of product sale, as well as the ensuing financial payments and flows, these two factors must be coordinated and connected.

A study by Papagiannidis and Bourlakis (2010) proposed a possible integration of the metaverse with aspects of the traditional supply chain for better distribution and retailing experience. Moreover, the study suggested that research is required that could shed light on the supply chain challenges faced by retailers operating in the metaverse, and operational challenges that are originating due to supply chain complexity in various environments.

2.2 Metaverse in Supply Chain Management

The physical and virtual worlds can now be integrated thanks to the advancement of new information technologies at the start of the twenty-first century. Building digital twins is becoming increasingly popular in industrial engineering, especially in supply chains (Marmolejo-Saucedo, 2022). The "meta supply chain" effort, which has already seen rapid growth, has increased the supply chain industry's digital prospects (Dwivedi et al., 2022).

Applications of the metaverse are frequently used in new operational models developing virtual and augmented reality to improve the experience of customers and suppliers (Li, 2020a). The consumer journey evolves because of a merged experience of social platforms, e-commerce features, games, and smart retail (Tueanrat et al., 2021), but also the company's operating procedures, impacting the supply chain's overall effectiveness. Operations in the metaverse merge physical and digital components of manufacturing, supply chain, and logistics processes in a way that has never been done before (Ivanov and Dolguib, 2021).

Immersive engagement with the supply chain at all points, from any place, has the ability to revolutionise the manufacturing and logistics sectors and give the supplier and all other operations management stakeholders the knowledge they need to make informed decisions (Li, 2020b). Companies may now take advantage of the real-time data offered from numerous places, the variety of labor-market situations, as well as cultural and structural differences, without incurring additional costs or wasting time. Operations and supply chain management are affected significantly by the metaverse; these effects can be seen in physical, digital, and meta-supply chain formats (Dwivedi et al., 2022).

2.3 Benefits of Metaverse in Supply Chain Management

The Analysis Group estimates that within ten years, the metaverse will boost the world economy by $3 trillion. Global logistics sector behemoths like DP World are investigating how to leverage the metaverse for a variety of services, such as simulating warehouse and port operations, container and vessel maintenance inspections, safety training, and other practical applications (Sharma, 2022). As per the study conducted by Alpala et al. (2022), metaverse applications can save logistical costs like transportation and procurement of materials and supplies, and users can rehearse as many times as necessary before engaging in real-world practice.

Jürgens (2021) explained how the metaverse may facilitate the measurement, analysis, interaction, and resolution of supply chain management issues. Complex datasets that reflect supply chain end-to-end processes will be gathered and modelled in the metaverse. Buyers can comprehend and engage with virtual models of new or updated products thanks to virtual sourcing. Testing and exercising quality control across huge volumes of products could become considerably easier in a 3D environment because quality is crucial for supply chain compliance and customer delight.

With 3D representations of how items are created, delivered, and sold, the Metaverse will improve supply chain transparency. This would also mean that interested parties would have access to lead times, transit periods, shipping delays, and potentially real-time shipping charges. This transparency and visibility will boost trust and effectiveness among supply chain partners across industries (Kathiala, 2022).

The Metaverse will introduce a new style of client engagement that is closely related to the logistics business. The method will not only create a more detailed process simulation, but it may also inspire the development of immersive virtual worlds to improve training in warehouses and industrial facilities. There are programmes that build digital twins and develop work routines, uncover inefficiencies, and multiply productivity.

Warehouse simulation and digital twins can also help improve logistics and supply chain operations efficiency (Singh, 2022).

3. Materials and Methods

The overall method is to do an exploratory study that includes accessible synthesis on applications, practices, and other literature on metaverse and supply chain applications. To incorporate information gathered on the metaverse and supply chain, the study conducted a literature review. This paper summarised information gathered from literature review.The extant literature on the metaverse, virtual reality, and its applications in logistics and supply chain management, including peer-reviewed journal publications, unpublished / accepted studies, reports, and policies, has been analysed and studied. A systematic search was used to collect papers using phrases like "metaverse in the supply chain", "metaverse in logistics", "extended reality in the supply chain", "metaverse in warehousing", "metaverse in retail", "metaverse in transportation", and "metaverse in distribution".

Various research databases such as Scopus, Google Ccholar, and Research Gate were searched for related papers. Also, the studies related to the field were searched in Emerald, Science Direct, Inderscience, T&F, IGI Global, etc. The authors have referred to various international journals, mainly Scopus-indexed journals. Some of them are the International Journal of Operations & Production Management, International Journal of Information Systems and Supply Chain Management, International Journal of Information Management, Technovation, Computers, Materials & Continua, Applied Sciences, Mobile Networks and Applications, International Journal of Physical Distribution and Logistics Management, Supply Chain Management - an International Journal, Journal of Business Logistics, Production Planning & Control, Journal of Cleaner Production, Resources, Conservation and Recycling, Journal of retailing and consumer services, Technology in Society, etc.

Existing practices and the measures that are taken to integrate metaverse in the supply chain would benefit the participating entities in improving the supply chain performance and overall profitability. Also, it will ultimately improve customer service, experience, and overall satisfaction.This work also seeks to collect and analyse data acquired from a set of individual metaverse investigations using a literature review, assisting in finding trends that require confirmation and pointing out and offering new routes for future research. Rather than being restricted to the findings of a small number of articles, the desk research technique used for this paper yielded a greater range of relevant data, providing a clear description of a metaverse in supply chain studies.

The findings of previous studies were analysed and combined to produce the best possible outcome on the topic, while knowledge gathered from current metaverse research aids in identifying knowledge gaps.

4. Findings and Discussion

This section presents the applications of the metaverse in different components of the supply chain such as procurement, manufacturing, logistics, and retailing.

4.1 Applications of Metaverse in Multi-echelons of Supply Chains

A study by Scaff (2022) explained how some of the major supply chain challenges can be removed with metaverse, and how metaverse is providing more visibility and sustainability across the supply chain. The study also showed that the metaverse is assisting businesses in removing supply restrictions by giving them improved visibility into processes, facilities, inventory, and capacity. It gives a better grasp of what consumers desire, making demand completely "knowable."

Understanding both perspectives could help balance supply and demand. Think about a shop and its suppliers having a "collaboration space" in the metaverse. Teams can virtually meet in this space to go over anticipated sales predictions, estimated production schedules, and any supplier restrictions that might have an impact on manufacturing volume.

Also, they may virtually tour important ports to identify potential shipment delays caused by congestion and simulate potential alternatives to keep goods moving in the right direction using an immersive supply chain network map. Some of the applications of metaverse across various functions of supply chains are as follows:

4.1.1 Sourcing and Procurement

The collaboration between all parties involved in a supply chain will be enhanced by the metaverse, both inside and internationally. It entails enabling limitless and contemporaneous cooperation throughout the value chain, not just with direct vendors' vendors for cost engineering and innovation. Through increased collaboration, the entire supply chain will be more efficient and transparent, including cost talks between buyers and sellers.

The margin of error for production would improve product quality and service, lower customer churn and return rates, and promote more extensive production-optimized design collaboration. Reduced quality control expenses and travel expenses to vendor locations can lead to even more efficiencies (Kathiala, 2022). Virtual sourcing has become a more feasible option for companies and has made it possible for buyers to understand and interact with virtual models of new or updated products.

To cite an example, the "3D Virtual Showroom Feature" launched by Alibaba last year enabled procurement teams and potential vendors to browse and examine products using virtual reality technology.

4.1.2 Manufacturing

Physical manufacturing can also be simulated, and the processes can be optimized by simulating them in a metaverse environment. Before actual production, many scenarios for the distribution of assets and labour resources can be tested. The simulated manufacturing experience will result in waste control and environmental sustainability, as well as lower manufacturing process costs (Brydges, 2021). A tailored experience will also increase the customer's pleasure and engagement, which is important, and the supply chain relationships will continue to be stronger than ever (Dwivedi et al., 2022).

Additionally, the Metaverse will enable the digital simulation of goods, manufacturing procedures, and facilities to optimise resource allocation throughout the supply chain, run production scenarios, and even conduct operator training in a more realistic setting. By doing this, it is possible to prevent physical manufacturing facilities from starting and stopping as well as lengthy downtimes and learning curves in factories when there is a change in the type of product being created.

This will have significant effects on satisfying consumer demands for personalised products, which have been difficult to create affordably in conventional facilities designed for mass production (Kathiala, 2022). Workers can use Metaverse to change the factory's capacity, tools, and workforce to maximise productivity. For instance, it is anticipated that BMW's adoption of Nvidia's "Omniverse" metaverse platform to coordinate the production of automobiles at 31 facilities will increase production planning efficiency by about 30% (Chang et al., 2022).

4.1.3 Logistics Operation

The traditional logistics function can be transformed using the metaverse. Future packing and loading of items into unmanned vehicles or drones for final delivery to the destination will undergo dramatic changes (Dwivedi et al., 2022). Before constructing physical sites for storage and inventory management, XR (extended Reality), augmented reality, and virtual reality can be used to design warehouses (Kovács, 2020).

Operator training can be carried out without interfering with regular business operations and where changes to warehouse flow and layout can be tested. If the number of SKUs increases or the properties of the products change, improved space efficiency will result from dynamic space modelling, slotting, and racking optimization.

Although optimization and slotting have always been crucial, the move towards smaller and even micro-fulfilment centres, where storage space is at a premium, has made them even more crucial (Kathiala, 2022).

4.1.4 Retailing

It's big business to sell items that users can utilise in the metaverse. By 2026, a quarter of the world's population would spend at least one hour each day in the Metaverse, according one of the most recent Gartner reports. This will occur for a variety of reasons, including job, study, fun, gaming, and shopping. During this transition, retailers will generate real revenue from the sale of digital things from the metaverse.

The lack of expenses associated with running a physical business or supply chain is one of its specific benefits. Retailers are learning, however, how the metaverse might function as a platform for online sales of tangible goods. For instance, at the ComplexLand 3.0 metaverse event in May 2022, early adopter of the metaverse retail space Pacsun recently ran a multidimensional digital commerce endeavour.

While Walmart says its existing omnichannel retail footprint drives 230 million customers into its 10,500 stores and dozens of global eCommerce properties each week, even a 1% pickup of Roblox's equally large user base would bring a material boost in visitors (Pymnts, 2022). Flipkart, the Indian e-commerce behemoth, just debuted its "Flipverse" metaverse.

After creating an 'avatar' and a pseudonym for themselves, users may begin buying on the Flipkart app. Flipkart already has collaborations with over 20 different businesses for its Flipverse. Among the brands on the list are Colgate, Lavie, Noise, Puma, Noise, Nivea, Tokyo Talkies, Campus, VIP, Ajmal Perfumes, Himalaya, and Butterfly India. When a consumer comes at a counter and chooses a product in a virtual world, the Flipverse summarises the features and product information.

If the user chooses to claim or purchase the deal at that time, the app directs them to the product page (Kar, 2022). The applications of metaverse in supply chain functions and the benefits it offers to the organizations are presented in Fig. 1. To summarize the findings, in the context of a supply chain, a metaverse can play several roles, which are as follows:

- Collaboration: Collaboration between various supply chain participants, such as suppliers, manufacturers, distributors, and clients, can be facilitated via a metaverse. Users can communicate with one another virtually, share knowledge, suggestions, and criticism, and collaborate to enhance the efficacy and efficiency of the supply chain.

- Simulation: A metaverse can be used to simulate different scenarios in a supply chain, allowing users to test the impact of changes to the supply chain before implementing them in the real world. This can help to minimize risk and improve decision-making.
- Visualization: With the use of a metaverse, users can see how resources, information, and products move through a supply chain in a virtual setting. This can assist users in identifying bottlenecks, inefficiencies, and other supply chain issues and developing plans to address them..
- Training: A metaverse can be used to train users in different aspects of a supply chain, including logistics, inventory management, and quality control. Users can interact with virtual objects and environments to learn new skills and techniques, and to practice applying them in different scenarios.

Overall, a metaverse can provide a flexible and immersive platform for users to collaborate, visualize, simulate, and train in the context of a supply chain. By leveraging the power of virtual reality and other advanced technologies, a metaverse can help to improve the efficiency, effectiveness, and resilience of a supply chain, and to create new opportunities for innovation and growth.

4.2 Future Research Directions

Using metaverse technology in supply chain operations opens a new research field. To enable people to acquire a high-quality virtual experience without indulging in it to the point that it interferes with daily life, additional research can be done to strike a balance between the virtual and the real worlds (Chang et al., 2022). Moreover, the research direction can focus on analysing how a metaverse might affect a particular industry's supply chain, such as the FMCG, agricultural, or automotive supply chains. Research can also be done to understand how adding other Industry 4.0 technologies like IoT, Robotics, and AI improves supply chain performance. Another direction for more research and development efforts is to create metaverse settings based on virtual reality for the smart factory, smart warehousing, and modular design and development, as previously suggested by Alpala et al. (2022).

5. Conclusion

Despite the complexity and interconnectedness of global supply chains, many businesses continue to use laborious paper processes and old, isolated databases. They were unable to quickly recognise and respond to unanticipated geopolitical and climate-related obstacles during the pandemic as a result, leaving them vulnerable to supply chain shocks, working capital liquidity issues, and increased regulatory and reputational risk.

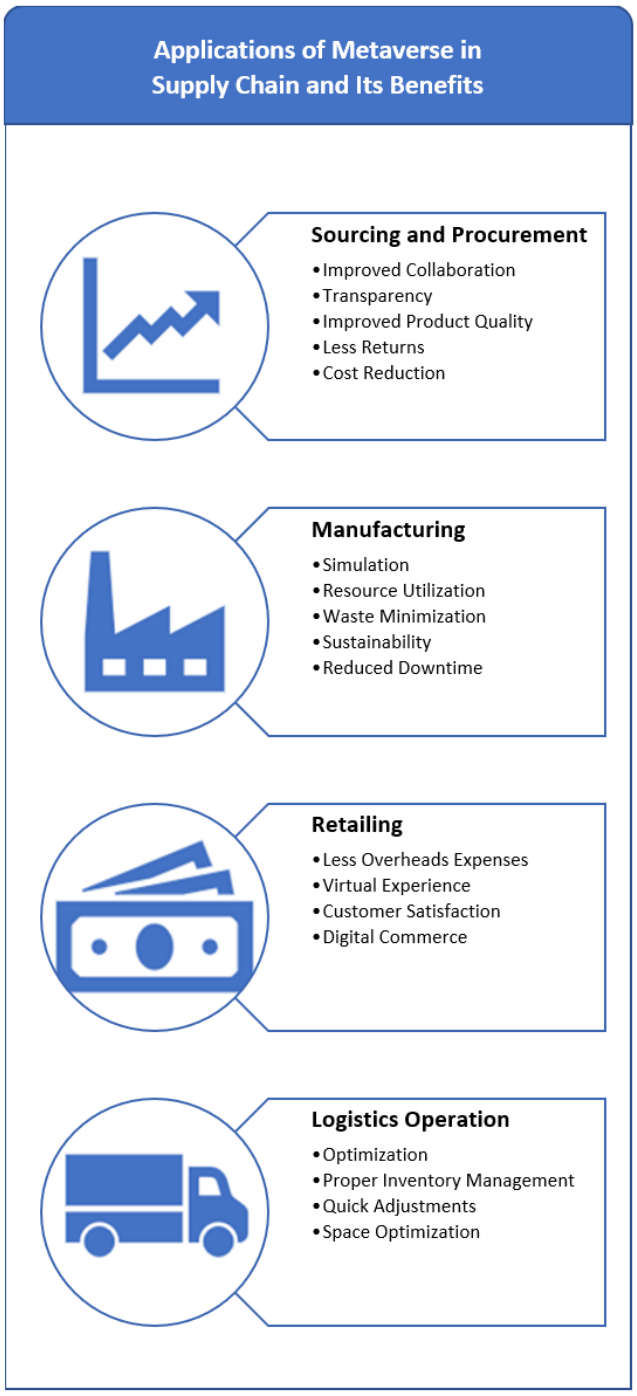

Figure 1. Applications of metaverse in supply chain functions and the benefits

The metaverse's immersive features have the potential to be extremely useful and have many applications to deal with this kind of complex and dynamic circumstances. The goal of the current study is to provide important insight into the use, advantages, and status of increasing acceptance of the metaverse from various supply chain echelons and affected corporate and societal sectors.

The study emphasized the applications of a metaverse in different areas of the supply chain such as procurement and sourcing, manufacturing, logistics operations, and retailing. Moreover, the examples of companies that successfully adopted the metaverse for improving and advancing their supply chain are also highlighted in this study. Future studies should examine the characteristics of developing metaverse retailing as well as if existing retail business models and marketing strategies need to be modified to be more effective in this new business environment. According to a study, companies should build their promotional methods using a comprehensive and all-encompassing plan, especially if they wish to compete in the metaverse stage. Finally, the authors suggest several potential study directions and emphasise the urgent necessity for policy formulation addressing the metaverse issue.

The study is limited to secondary data-based research that can serve as a foundation for supply chain academicians and scholars to understand the emerging trend of the metaverse and its applications in various components of the supply chain, ultimately resulting in supply chain performance and overall organisational growth. A primary / empirical based study can also be carried out in a particular supply chain considering the present study.

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