



Reimagining Value Chains: Socio-Economic Implications of Metaverse-Driven Supply Networks

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Abstract. Metaverse has evolved from the early concept of cyber space and it is convergence of both physical and digital realities together. Use of Digital Twins, Virtual Reality (VR), Augmented Reality (AR) Block Chain Technology (BCT) and Artificial Intelligence (AI) has enabled the business leaders to perform their business with greater efficiency and minimum risk. Metaverse has been increasingly used in Supply Chain Operations to create real time simulations of supply networks. Companies across the globe such as NVIDIA, Schneider have enhanced their agility and reduced their operation cost through metaverse. Decentralized collaborations beyond geographical boundaries and creation of global value chain through metaverse have benefited the present-day businesses economically and led to environmental sustainability. According to the reports of Mckinsey and Gartner, the role of metaverse in creating an intelligent, resilient and ethical supply network would grow significantly by 2030. The present chapter is divided into four sections. Section 1 is Introduction, and this section highlights Metaverse and its significance in the context of Supply Chain Management, Section 2 highlights the application of Metaverse in Supply chain. The social impact of metaverse is discussed in section 3 of this chapter and finally the challenges, outlook and Conclusion is discussed in section 4.

Keywords: Block Chain Technology; Metaverse; Supply Chain Management

1 Introduction

Metaverse as a term was introduced by Stephenson in 1992 in his science fiction novel “Snow Crash” [Joshua, 2017] but later the groundwork for understanding metaverse “Virtual World” began. [Animesh et.al.2011]. Virtual World has undoubtedly laid the foundation for research in Metaverse. The Industrial sector at global level is undergoing transformative revolution backed by metaverse market and is expected to reach \$936.6 Billion by 2030 growing at a CAGR of about 47% from 2025-2030 [Grand View Research report].

The understanding of the term “Metaverse” is completely different compared to as it was described in the science fiction and the Second Life pattern is the first attempt of technical conversion of Metaverse [Berge 2008] which failed due to technical limitations. Metaverse has always been discussed for last 25 years and people at different times and regions have tried to redefine it [Nevelsteen et.al, Park et.al Taylor et.al]. Metaverse then finally made its comeback in 2021 through Meta, formerly Facebook

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by combining VR and AR [Meta 2022]. Covid 19 and the lockdowns between 2019 and 2022 were the prime reason for wide ranging changes in Business operations. The business leaders began their day to day organizational activities on digital platforms and this intensified the virtual activities altogether and introduced the new player, Metaverse in the digital world. According to survey conducted by PwC in 2022 70% of the companies surveyed have already planned to integrate metaverse in their organization and 63% of the companies have planned to fully embed it within a year [PwC 2022]. Metaverse promotes interconnected network of stakeholders which lead to informed decision process [M.M. Queiroz, 2023] and achieve a sustainable competitive edge by enhancing accuracy and efficiency [P.R. Messinger, 2009].

Metaverse has fundamentally transformed the way in which businesses operate and have successfully created values across different sectors and subsectors such as fashion, gaming, automotives, energy, real estate etc.[Harpreet 2025]. Virtual and Augmented Reality i.e VR and AR integration has enabled a major shift towards metaverse enabled businesses across the globe. It is said that one fourth of population would spend at least one hour in Metaverse for various activities related to education, tourism, retail sector etc. This evolution would lead to a transformation of business globally [Gartner 2022]. Metaverse is the next evolution of internet and it is an integration of digital and physical world powered by Block chain technology, Artificial Intelligence, Internet of Things, VR and AR [Maersk]. Metaverse technology have developed very fast and leaders such as Facebook, Nvidia have already made heavy investments [Huynh et al 2000] and some of the other leading business such as Catena X data eco system, BMW, Puma, Gucci, Siemens have already started using the idea of metaverse in Manufacturing, marketing, Supply chain and Operation management [Catena 2022, Barera & Shah 2023]. Metaverse has enabled people to work play and interact at any time, anywhere using different technologies. It is a real game changer after internet with boundless potential and commercial advantages [Joshi R et.al 2024].

Metaverse the second generation of internet would offer new business areas [Lee et.al 2021] and thus FB announced the next digital transformation through Metaverse in 2021 [Isaac M, 2021]. Metaverse is shaping the digital future of the world and has enabled us to overcome geographical and economic barriers [Dionisio et.al, 2013]. Metaverse economy is expected to grow to market size of \$13Trillion by 2030 [Ghose et.al, 2022] with concrete design of inclusivity and interaction dimensions [G. D. Ritterbusch and M. R. Teichmann, 2023].

2 Potential Economic and Societal benefits of Metaverse

Transformative technologies such as AI, IoT and Blockchain etc are shaping the production activities and widening the scope of businesses. Industry 5.0 further has reduced the gap between the humans and technology[Rashid, A.B et.al , 2024 & Sharma, R et.al, 2024]. Supply Chain have been a major concern for government and businesses for a long time and also has gained lot of focus in recent times. The use of metaverse has helped the decision makers and business leaders to build an integrated supply chain

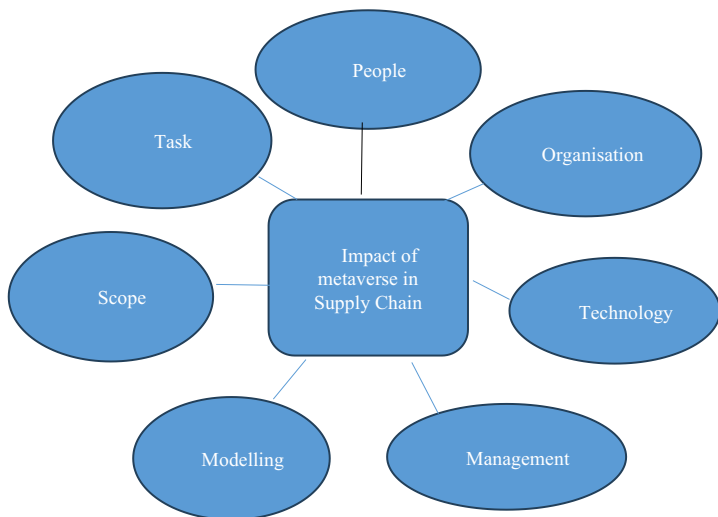
with infrastructure and network which had led to enhance the keyflows of goods, information and overall processes [Power D, 2005]

Metaverse is said to have the potential to enhance the Supply Chain Management through its economic, societal and environmental impact. The impact of metaverse in supply chain is discussed in this section of the chapter. Researchers across the globe believe that Metaverse would help the organization and businesses to create a resilient and profitable supply chain system in future which would not only be cost effective but also help us to fight against the battle of global warming by reducing the carbon emissions. Metaverse, a transformative force has also contributed to SDGs particularly in the context of decision-making processes [Kiarash Sadeghi R, 2025].

Metaverse enhances the decision-making process in businesses especially in Supply chain [P.-K. Chen, 2023] by impacting the flow of information within the supply chain [Y.K. Dwivedi , 2022] and therefore organizations have shifted their interest in harnessing the advantages of metaverse especially in the area of supply chain management.

According to Ivanov, Metaverse Supply chain and Operation Management framework is based on 7 element digital framework which includes people, organization, management technology, modelling, scope and task [Ivanov 2023]. The economic implications of metaverse can be analysed effectively through the lens of 7 element framework. These elements define the ways in which supply chain is to be restructured through metaverse. The use of metaverse in supply chain has two bigger advantages in the form of value creation and cost reduction. The economic and societal Impact can be studied through the 7 dimension framework as given in figure 1

Fig. 1. Impact of Metaverse in Supply Chain Management



2.1 People

Use of metaverse in supply chain has transformed the role of workforce, skill sets and their interactions in modern business era. Technologies such as Digital Twins, VR, AR, Block chain and AI have made supply chain more digitally immersive and has resulted in significant improvement in the productivity of workforce. Businesses across the globe have started investing heavily in training the workforce and improve the digital literacy and has resulted in enhanced productivity and reduced errors [PwC 2022].

Metaverse has enabled interactions across the global supply networks for planning, logistics and procurement has led to adaptive workforce structure and this transformation has contributed to economic resilience across the supply chain ecosystem [Ivanov 2023].

2.2 Organization

A fundamental shift in the organizational structure prompted by metaverse has enabled decentralization across geographical boundaries. The physical infrastructure is now replaced by digital framework for managing procurement and logistics through Blockchain. This revolution led by metaverse has accelerated the decision-making processes and has simultaneously reduced the cost of operations related to physical space, travel and mutual interaction. Decentralized Autonomous Organization (DAO), a critical innovation in supply chain has fostered transparency, automation and integration across geography [World Economic Forum 2023]. Real-time collaboration among the supply chain partners has enabled the organizations to operate with more flexibility and cost effectiveness. Using virtual simulations without disturbing the actual process of supply chain through metaverse also helps the businesses to avoid unnecessary expenditures and enhance the productivity and save time.

2.3 Technology

Technologies such as VR, Artificial Intelligence, AR and Block chain have successfully helped the business organisations to cut down their operational cost significantly post covid 19.

1. VR and AR technologies have facilitated remote collaborations, developing efficient warehouse designs and train the work force effectively. This has enabled the business leaders to reduce the cost of operations significantly and downtime together.
2. Artificial Intelligence has enhanced the predictions and forecasting of demand and this has helped the business decision makers to mitigate the risk and manage the inventories accordingly. Amazon has utilized AI technology for predictive shipping, and has successfully reduced the storage and delivery times finally resulting in decreasing the holding costs [Chong, A. Y. L., et al. 2017].
3. Block Chain technology: BCT, a transformative force in supply chain has enabled decentralized, tamper proof and real time data transfer across different network in recent times. This technology has led to the automatic execution of businesses which

has ensured transparency, reduced risk and delays. For example, according to press release of IBM Nov 11, 2020 Walmart collaborated with IBM Food Trust to improve the traceability of food items. This initiative has reduced food traceability limits from 7 days to 2.2 seconds resulting in significant reduction in spoilage and compliance cost with the help of automated record keeping.

2.4 Management

Metaverse, a strategic management platform helps the business leaders in scenario planning, real time decision making and collaboration effectively. The management process enables the coordination of complex supply chain and digitally streamlines the operations across global network through metaverse. Different teams across procurement, logistics etc. can coordinate and meet in virtual environment and align demand and supply to reduce the risk, delays and cost effectively. Schneider Electric has integrated reality dashboards in its digital operations centers to allow the managers to simulate scenarios such as factory shutdown, lockdown or port congestion and implement contingency plans [Schneider Electric, 2020]

2.5 Modelling

Modelling in Ivanov's digital framework refers to creation, simulation and refinement of virtual representation of supply chain. Metaverse enables real time interaction of supply chain models through digital environment and support predictive decision making. For example; NVIDIA's Omniverse platform provide virtual automotive production facility that allows the managers to test the configuration and detect inefficiencies to optimize the workflow and reduce the down time accordingly [NVIDIA, 2021]. Modelling in the present time has been elevated to interactive ecosystem to design resilient logistic strategies to improve the agility and adaptability of businesses during uncertain times.

2.6 Scope

Use of Metaverse has widened the scope of businesses across the globe by simulating the global supply chain models in digital environment by connecting the various stakeholders such as suppliers, warehouse managers, consumers etc virtually. The businesses can manage dispersed operations beyond geographical boundaries and integrate supply chain holistically. Digital Twins, AR, VR also allows the firms to adapt to the network decisions and optimize the process efficiently. Metaverse acts as a predictive and adaptable operation management technology in the modern business time. For example, NVIDIA Omniverse helps companies like BMW and Siemens to manage production virtually by involving simulations based data driven decisions [NVIDIA 2021].

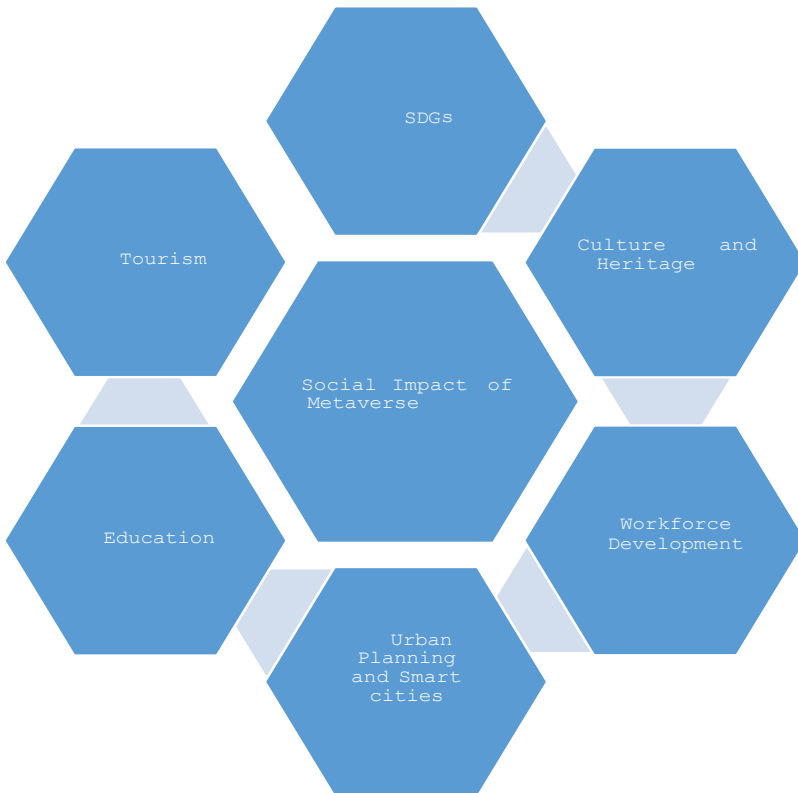
2.7 Task

The task dimension of business operation is being transformed significantly by the use of metaverse especially in supply chain management. The virtual scenario planning and collaborative logistics simulations have fostered the decision-making process. For example, the use of Virtual Reality (VR) environment is being used by DHL to train the workers in warehouses particularly dealing in picking and packing procedures. This has not only reduced the errors but also has improved the work flow drastically. The shift from physical trial and error to virtual experimentation has helped DHL to achieve process optimization.

3 Societal Implications of Metaverse in Supply Chain Management and Operations

The societal implications of metaverse are multidimensional and benefit all the sectors of economy. The significant social impact of metaverse is discussed in the present section of the chapter.

Fig. 2. Social Implications of Metaverse



3.1 Metaverse and Sustainable Development Goals

Sustainable Development Goals (SDGs) launched by the United Nations in 2015 addressed the complex challenge of today's world i.e. Climate change and Global warming. Environmental concerns of people across the globe have also forced businesses towards development and adoption of cutting-edge technologies to mitigate the risk of climate change in production, consumption and distribution. SDGS comprising of 17 goals and 169 targets has provided a common language of resource optimization and fostered collaborations among various stake holders [Linnerud et.al 2021] as they promote sustainable practices by improving resilience and adaptation [Sharifi, A., & Allam, Z. 2022]. Heavy investment is being made by business leaders in renewable energy sources, circular economic models, waste reduction technologies etc. Digital technologies like AI, IoT, BCT, Metaverse etc have helped the economic agents (Producers, Consumers and Distributers) to take environmentally responsible choices. Tools like metaverse have enabled the business to smart management of resources through optimization of supply chain. Integration of digital technologies has enabled the business leaders not only in meeting regulatory compliances but also actively contributing to climate mitigation efforts through smarter and cleaner operations [UNEP 2020].

Metaverse, a virtual world co existing with real world is increasingly becoming a transformative force in various industries [Matthew Ball, 2022] and technologies like VR, AI and AR helps the businesspeople to integrate their business process virtually and more efficiently [IEEE 2021]. The societal impact of metaverse is discussed in the following section with examples.

3.2 Metaverse for building Smart cities

Digital technologies have also been successful these days in urban planning and building smart and sustainable cities. The development of smart city technologies has contributed towards tackling the global challenges efficiently through better resource management and data driven decisions [Lin & Mao, 2023; Sharifi et al., 2024]. The world is facing severe developmental challenges like poverty, climate change, hunger and environmental degradation [Ali et al., 2024; Kaklauskaitė & Streimikiene, 2024] and many of those are due to heavy concentration of population in cities and therefore effective urban planning and establishment of smart cities can help us to achieve the sustainable goals effectively.

Seoul Metaverse project provides public services and cultural experiences in virtual environment to enhance service efficiency and accessibility [de Almede 2023]. Dubai has also successfully created a more connected and efficient city with the adoption of metaverse technologies in urban planning. Cities like Boston, Vegas, Singapore are exploring metaverse to build smart cities and enhance their resource management through better urban planning management using metaverse [Allam, Z et al., 2022].

3.3 Metaverse for Transformation in Education

The education sector is being revolutionized with the integration of metaverse with digital technologies. An immersive and interactive learning environment can be created using metaverse enabling the learners to interact in simulated environments. The greatest advantage of this technology in education sector is to help the students learn beyond the boundaries of time, location and physical infrastructure. For example, class VR enables the students to experience field trips virtually and enhances the understanding through learning by doing. Metaverse fosters collaboration among the students and teachers by enabling their meetings in shared virtual spaces. Virtual lectures and discussions are very popular in universities and institutions and they are enabled through metaverse.

The challenges faced by current education sector are disengagement and lack of personalized instructions. It is recently proved by the researchers that metaverse enabled classrooms can help the decision makers to overcome those challenges. According to recent research, the use of Multi-layered Immersive Learning Environment (meta-MILE) has engagement and skill acquisition and competency based experiential learning approaches. The findings of the study highlight the fact that metaverse class rooms has the transformative potential of meeting the diverse needs of learners worldwide [Yeganeh, L. N et al 2025]. It is also noteworthy to mention that the metaverse classrooms lead to efficient use of resources and help us to adopt sustainable and environmental conscious practices [Lo, S. C., & Tsai, H. H. 2022]. This technology has the potential to evolve into global collaboration hubs by connecting the students, teachers and professionals around the world.

3.4 Metaverse for Transformation in Health care services

In the era of Industry 4.0, advanced digital technologies are being developed and adopted across the sectors and health care is also one among them [Lee, S. M., & Lim, S. 2018] and these technologies has contributed significantly towards the improvement of health care system across the countries [Lee, D. 2019].

The health care sector, considered as one of the prominent sectors, is being revolutionized and transformed through metaverse. Immersive, interactive and patient centered experiences enabled through this technology have helped people to eliminate location-based barriers. Metaverse offers significant opportunities in value creation through virtual experiences and has helped to improve disease diagnosis and treatment [Jeong, E., Lee, D., 2025]. Digital technologies play a significant role in augmenting the decisions of the doctors as they employ a large volume of medical research and patient records [Bennett, C. C., & Hauser, K. 2013] and it is found in one the study that AI enabled technology can diagnose skin cancer more accurately than a dermatologist [Esteva, A.,2017].

3.5 Metaverse to boost tourism sector

The tourism industry is reshaped after Covid 19 where people have started travelling extensively but another transformation is the increasing interest of people towards sustainable and responsible tourism. The pandemic has acted as a important incident that has encouraged both travelers and tourism industry to prioritize environmental and social impacts. Tourists today are showing interest in choosing eco-friendly accommodations, carbon-offset travel options, and destinations.

Metaverse is revolutionizing the tourism industry by enabling the tourist to experience immersive and interactive virtual experiences that complement. Virtual Reality (VR) and Augmented Reality (AR), has enabled the users to explore digital replicas of popular landmarks, cultural heritage and natural scenes from the comfort of their homes. For example, Google Arts & Culture and VR Travel allow the tourist to experience virtual walk through the Louvre Museum. Tourism sector is leveraging the Metaverse to promote various destinations across the countries. One good example is of South Korea's Seoul, the government launched "Metaverse Seoul", a virtual city where tourist can explore various destinations and also enabled the tourist to participate in festivals. The digital innovations have definitely enhanced touring experiences of people and also provided accessibility to people with physical or financial constraints and has led to higher travel intent [Guttentag, D. 2019]

3.6 Facilitate social interaction and preserving cultural heritage

In the era of globalization, preserving the rich culture and tradition of nations is a crucial endeavor. The precious identities of human civilization are under serious threat due to rapid urbanization and environmental degradation [Laguna-Palma et al., 2024]. Cultural heritage including tangible aspects such as artwork, monuments etc and intangible aspects like customs, tradition and language has to be preserved for maintaining a sense of identity [Lyu 2022]. Cultural heritage provides sense of identity and belongingness to the communities worldwide [Longo 2023] and metaverse has emerged as a groundbreaking platform to explore and preserve the cultural heritage [Hutson and Ratican, 2023].

Metaverse, a recent digital innovation has helped the nations to preserve the rich culture and tradition of different places by amplifying social interactions through avatars in shared and meaningful experiences. This feature of metaverse plays a crucial role in preserving the culture and heritage of nations worldwide. Applications such as VR and AR have transformed the ways of engaging digital content [Oladokun, B. D. et al., 2023] and has found increasingly useful in entertainment, tourism, training and healthcare [Al-Ansi, et al., 2023]. Metaverse has empowered communities of modern age to actively contribute towards the protection of cultural heritage through collaborative engagement [Mitibwa, 2024]. Metaverse has enhanced the accessibility to different cultural content regardless of location and economic status [Zen, I. S., et al., 2023] promoting long term sustainability and archiving cultural assets for future generations [Ariza et al., 2024]

3.7 Human development and well being

Metaverse, a digital environment has reshaped the landscape of human development and wellbeing through social interactions. People have persistently finding more ways to interact with people after Covid 19 and metaverse has enabled them to build the social interactions and has resulted in psychological wellbeing of individuals [Saucier & hafner 2010; Shaw & Gant 2004]. VR based therapies are very effective in treating issues related to anxiety and stress [Freeman et al., 2017]. The digital technology enables the users to experience social, special and self-interactions [Han, E., 2023] and finally leads to enhance the user experience, engagement, and well-being [Oh, H. J.,2023]. According to a study conducted by Hyun Jung Oh in the context of South Korea, Metaverse platforms facilitate supportive interactions among young users and have helped the Millennials and Gen Z to reduce the feeling of loneliness through self-efficacy [Hyun Jung Oh, 2023].

3.8 Metaverse and Energy Transition

Metaverse is emerging as a strategic tool in the energy sector and has accelerated global transition to clean and green energy through simulations, collaboration and immersive training. World is fighting against global warming and UN has emphasized carbon neutrality by 2070 and countries like Germany, China, USA, India etc have accelerated the adoption of renewables such as solar, wind, biogas, biomass etc to achieve net zero by 2050[Pawłowski, A., & Rydzewski, P. (2024)]. Digital technologies such as Blockchain technology, Metaverse have played a significant role in exploring the potentials of renewables [Oum R, 2024]. For example, Siemens Xcelerator with NVIDIA enabled simulation of renewable energy systems particularly in wind farms and solar plants by creating photorealistic digital twins of energy systems [Siemens, 2022].

3.9 Metaverse and workforce development

Metaverse has helped the organization to improve the efficiency and productivity of their workforce by training them through simulated environments. This technology has improved the safety and the engagement of the workers to a larger extent. For example, Use of VR training by Walmart for their employees has also helped them to cut the attrition rates and also made their employees to perform better [Harvard Business Review, 2019]. Further it is also believed that development of digital technologies like AI, big data, BCT, Cloud computing and Metaverse affects the digital skills of the workers and enables them to adapt to changing environments accordingly. Individuals are now forced to acquire digital competencies and integrate them in their day-to-day operations, leading to increased productivity and innovations. These emerging technologies have fostered a culture of lifelong learning among the employees and are also capable of harnessing the full potential of digital transformation.

4 Limitations of Metaverse

Supply Chain Management in the present day has become more dynamic due to the disruptions witnessed in the past such as Industry 5.0 (Dolgui, A., & Ivanov, D. (2020)., Covid 19 (Wang, et.al 2020) Russia- Ukraine War (Jagtap, S.,2022) and therefore it is identified as a game changer for supply chain industry (Chen, P. K.,2024). Metaverse adoption in Supply Chain has impacted the logistics sector positively but the managerial challenges have posed serious threats to the adoption of this technology (Goldsby, T. J., & Zinn, W. 2016).

Lack of managerial understanding in metaverse application generates operational inefficiency in any organization and the structure and size of the organization poses serious threats in the adoption of metaverse (Chen, P. K. et.al, 2023). Managerial issues like poor knowledge transfer and lack of contextual awareness among managers have been considered as a serious limitation in the adoption of this technology (Mishra, D.,2023).

5 Conclusion

Metaverse in Supply chain operations have together enhanced the functionality and offered economic benefits to businesses across the globe. Immersive technologies, Virtual trainings, and real time digital twins have significantly reduced the operational efficiency and optimized the business process. The above discussion in the light of the seven-dimension framework of Ivanov illustrates the potential economic and societal implications of metaverse, which is not only a technological advancement but a driver to sustainability. The social benefits of metaverse discussed in section 3 of this chapter highlight the use of this digital technology in various sectors such as tourism, education, energy, human development, work force, urban planning and attaining sustainability. The targets of net zero and SDG goals in next few decades have forced the businesses to align their long-term plans and processes contributing to sustainable and cost-effective supply chain management. Metaverse is not a technological advancement but a powerful enabler of integrated value creation helping the business to achieve the economic and environmental goals together.

The adoption of Metaverse in supply chain operations has many economic and societal benefits but also faces several challenges. Firstly, high cost of technology involved in deploying including AR/VR hardware, advanced sensors etc restrict the usage to bigger organization. Secondly, Issues like data privacy and cybersecurity concerns, are also associated with the use of metaverse and therefore businesses are hesitant towards its adoption. Thirdly Interoperability issues due to lack of standardized protocols pose some threat towards adoption of metaverse insupply chain operations. Finally, work-force readiness is considered to be a critical barrier as employees resist unfamiliar virtual interfaces and it further results in digital divide allowing only bigger firms to employ those technologies. Despite the challenges, the future of the Metaverse in supply chains appears to be promising. The Metaverse will likely play a central role in building

resilient, transparent, and sustainable supply chains, especially through predictive modeling and decentralized collaborations. Robust governance frameworks together with effective policies promoting digital inclusion could redefine supply chain management in the coming decade. Metaverse in supply chain management has far reaching economic and social implications ranging from enhancing efficiency to attaining environmental sustainability. It can be said that metaverse is not just a digital innovation but a societal catalyst.

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