MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages: 3982-3991

Optimization of Supply Chain with Digital Public Infrastructure and Multi-Modal Connectivity: Conceptualizing of Smart Infrastructure Acceleration Theory

Tushar Dhiman
Research Scholar, Faculty of Management Studies, Gurukula Kangri (Deemed to be University) Haridwar, Uttarakhand, India - 249404
23519006@gkv.ac.in
ORCID ID- 0009-0008-1505-9028
Pankaj Madan
Professor, Faculty of Management Studies, Gurukula Kangri (Deemed to be University) Haridwar, Uttarakhand, India - 249404
pankaj.madan@gkv.ac.in
ORCID ID- 0000-0002-4648-9863

Abstract:
This article offers a conceptual research model to comprehend the relationship between the rapid development of digital public infrastructure and multi-modal connectivity and UttarakhandMSMEs supply chain management. The focus is on how these advancements can make supply chains more resilient, efficient, and transparent. In order to identify research gaps and develop a conceptual framework, a comprehensive literature review is conducted. It examines integrating digital public infrastructure- e-commerce platforms, digital payments, and ICT- with multi-modal connectivity, including road, rail, air, and waterways. The goal is to streamline logistics, reduce transportation costs, and enhance market accessibility. Key elements include networked open technology standards, e-governance, and shared competition marketplace. Multi-modal connectivity is assessed based on capacity, duration, velocity, and transfer points, while supply chain efficiency is measured by quality, customer service, productivity, and Cost.Combining digital infrastructure and multi-modal connectivity can significantly enhance supply chain performance, boosting Uttarakhand's competitiveness and sustainable growth of MSMEs. The findings highlight how these innovations impact supply chain dynamics and underscore the crucial role of technology and connectivity in enhancing supply chain capacities. This study also derived a Smart Infrastructure Acceleration Theory; this theory rapidly advances infrastructure by integrating IoT, A.I., big data analytics, and digital twins. It enhances efficiency, sustainability, and resilience, emphasizing real-time monitoring, predictive maintenance, and eco-friendly practices to create adaptive, efficient, and sustainable infrastructure systems for growing urban populations and global challenges.This research comprehensively explains how digital public infrastructure and multi-modal connectivity influence supply chain management in industrial clusters. It offers valuable insights for policymakers, industry stakeholders, and researchers, emphasizing the importance of technology and connectivity in promoting regional sustainability and economic growth. The ultimate aim is to support the development of strategic interventions to foster regional sustainability and economic development.

Keywords: Digital Public Infrastructure, Multi-Modal Connectivity, Supply Chain Management, Business Organisation.

Abbreviations

A.I.- Artificial Intelligence
CBDC- Central Based Digital Currency
DPI- Digital Public Infrastructure
ENSIA- European Union Agency for Cybersecurity
GeM- Government e-Marketplace.
GPS- Global Positioning System
ICRIER- Indian Council for Research on International Economic Relations
IoT- Internet of Things
ITU- International Telecommunication Union
ML- Machine Learning
MMC- Multi-Modal Connectivity
MSME- Micro and Small and Medium Enterprises
OCED- Organisation for Economic Cooperation and Development
ONDC- Open Network Digital Commerce
RBI- Reserve Bank of India
SCD- Supply Chain Disruption
SCP- Supply Chain Performance
SCR- Supply Chain Resilience
UIDAI- Unique Identification Authority of India
ULI- Unified Lending Interface
ULIP- Unified Logistics Interface Platform
UNDP- United Nations Development Programme
UNESCAP- United Nations Economic and Social Commission for Asia and the Pacific
UPI- Unified Payment Interface
WEF- World Economic Forum

1. Introduction-

The convergence of digital public infrastructure and mul-timodal connectivity presents a transformative opportunity to enhance the supply chain dynamics of business organisation. Digital public infrastructure, which includes reliable internet connectivity, digital payment systems, e-governance platforms, and data analytics tools, provides the technological backbone for efficient business operations *(Jambhale, S. 2023).* Reliable and high-speed internet connectivity is fundamental for the digital transformation of supply chains, enabling real-time communication, data exchange, and access to global markets. Increasing internet access to distant and rural areas can help close the digital gap and enable business organisation to participate in the digital economy. Improved internet access allows business organisation to use online procurement, sales, and customer engagement platforms, thus enhancing their operational efficiency and market reach. By offering safe, quick, and transparent payment methods, decreasing reliance on cash transactions, and improving financial inclusion for corporate organizations, the adoption of digital payment platforms likeUPI, e-wallets, and online banking has completely changed financial transactions. Digital payments streamline the procurement process, ensuring timely payments to suppliers and faster receipt of customer payments, improving cash flow and financial management. Integrating e-governance initiatives and digital platforms can streamline regulatory processes, reduce bureaucratic red tape, and provide business organisation with easy access to government schemes, subsidies, and support services. Digital platforms also facilitate online marketplaces, enabling business organisation to reach a broader customer base. For example, e-marketplaces can help business organisation connect with buyers and suppliers nationwide and internationally, thus expanding their business opportunities *(Sankaran, P. 2024)*. Data analytics and Artificial Intelligence (A.I.) can optimize supply chain operations by predicting demand patterns, identifying bottlenecks, and enhancing decision-making

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages: 3982-3991

processes. These technologies enable business organisation to improve inventory management, reduce waste, and enhance efficiency. Business Organisation may make educated decisions about production and distribution, forecast market trends, and improve pricing strategies using AI-driven data *(Ambit. 2024).*

The United Nations Development Programme states that: (i) open technology standards that are networked and constructed with the public good in mind; (ii) facilitating governance; and (iii) a community of competitive and creative participants in the market that workto stimulate creativity, particularly throughout the public programs. Although the concept of DPI is still evolving, there is growing agreement that it consists of these three components. Table 1 displays the clarification provided by the organizations and researchers**.**

Table 1: Definitions of Digital Public Infrastructure

S. N.	Researchers, Scholars, and Organization	Elucidation
01	**Maheshwari, Ankit (2023)**	Platforms like identity (I.D.), payment, and data-sharing systems are examples ofDPI, which enables nations to provide their citizens with essential services. India is no exception in the way that DPI has transformed government processes. A recent surge of DPI initiatives has significantly impacted India's social and economic development.
02	**Aaditeshwar Seth (2023)**	It is claimed that DPIs uphold or facilitate concepts like "open-source," "open APIs," "interoperability," "privacy by design," "inclusive design," and "universal access," suggesting that fundamental moral precepts are ingrained in the technology itself.
03	**Astha Kapoor and Erin Watson (2023)**	The DPI approach uses transparent, responsible, and participatory governance with open technology to achieve societal outcomes. It enables nations to establish digital sovereignty and avoid dependency on proprietary technologies.
04	**Heeks, R. (2020)**	DPI involves using digital technology to improve public resource management, enhance service delivery, increase accountability and transparency in the public sector, and promote citizen participation in governance.
05	**OECD (2020)**	DPI encompasses initiatives including electronic payment platforms, digital identity systems, and e-government services. Globally, nations have been making significant investments in DPI, especially due to the epidemic of COVID-19. This has brought attention to the need for effective digital solutions that facilitate e-learning, telemedicine, and remote work.
06	**Henfridsson, O. and B. Bygstad (2013)**	Organizations hoping to use emerging technologies must have solid digital infrastructures. These infrastructures consist of networks, procedures, and organizational and technical elements. They also cover the social context in which people use digital tools and the infrastructure's designers and developers of systems.

1.1 "Unified Lending Interface" & "Central Bank Digital Currency" Initiative:

The Reserve Bank of India's governor has announced two important measures aimed at enhancing the country's DPI: the ULI and the CBDC. These initiatives are set to transform India's financial landscape by leveraging advanced digital technologies to streamline credit access and enhance monetary transactions.The ULI is an innovative step towards democratizing credit access in India. By bringing together various financial entities- such as non-banking financial companies, commercial banks, fintech firms, and digital lending platforms - onto a single, interoperable platform, ULI aims to simplify and accelerate the lending process. This unified approach will reduce the fragmentation in the credit market, making the process more transparent and efficient for both lenders and borrowers. For lenders, ULI provides a seamless, real-time platform to evaluate credit applications using standardized data formats and algorithms, reducing the time and cost associated with lending decisions. For borrowers, especially those in underserved segments, ULI is expected to enhance access to credit by creating a level playing field where their creditworthiness is assessed more fairly and accurately based on diverse data points rather than just traditional credit scores. On the other hand, the CBDC initiative represents the RBI's foray into digital currencies, aiming to create a digital version of the Indian Rupee. Unlike cryptocurrencies, which operate in a decentralized manner, the CBDC is a digital currency issued and regulated by the central bank, ensuring stability, security, and government oversight. The introduction of a CBDC is expected to revolutionize the way digital payments are made in India by offering a secure, efficient, and instantaneous method of transferring value. The CBDC would operate alongside physical currency, but with the advantages of lower transaction costs, reduced dependence on physical cash, and improved transparency in financial transactions. Additionally, CBDCs can play a critical role in enhancing financial inclusion by making digital transactions possible for people without access to traditional banking services.The integration of ULI and CBDC into India's DPI ecosystem is expected to have several far-reaching impacts. First, it can substantially boost financial inclusion by providing underserved populations and small businesses with easier access to credit and digital payment systems. By reducing the costs and frictions associated with lending and payments, these initiatives will support the growth of business organisation, which are critical to the Indian economy. Second, both ULI and CBDC havethe ability to improve financial transactions' effectiveness and transparency, reducing the risks of fraud, money laundering, and other financial crimes. Third, by promoting a cashless economy, the CBDC could help reduce the operational costs associated with printing and managing physical currency, while also enhancing the government'sthe capacity to monitor and control the economy's financial flow. Overall, the introduction of ULI and CBDC underscores the RBI's commitment to advancing India's digital financial ecosystem. By fostering greater inclusivity, efficiency, and security, these initiatives are poised to reshape the country's financial landscape, ensuring that India remains at the forefront of global digital financial innovation.

1.2 Multi-Modal Connectivity:

Multi-Modal Connectivity involves integrating various transportation methods- air, sea, rail, and road into a cohesive network that optimizes the movement of goods and services. This approach can significantly enhance the supply chain dynamics of business organisation by reducing transportation costs, improving delivery times, enhancing accessibility, and fostering resilience. By utilizing the advantages of many modes of transportation, such as combining road and rail transport to save fuel consumption, limit environmental effects, and minimize transportation costs, multi-modal connectivity may maximize the movement of products. Cost-effective logistics are crucial for business organisation, as they often operate on tight margins and must manage expenses carefully to remain competitive.Combining many means of transportation can improve delivery dependability and speed. Efficient coordination between road, rail, air, and water transport ensures timely movement of goods, reducing lead times and improving customer satisfaction. Faster delivery times enable business organisation to meet customer demands promptly, thus enhancing their reputation and market position. Multi-modal connectivity can improve access to remote and underserved areas. By creating a comprehensive transport network, business organisation can expand their market reach and tap into new domestic and international customer segments.Improved accessibility to raw materials and markets allows business organisation to scale their operations and increase their production capabilities. A multi-modal transportation network offers resilience to disturbances and flexibility. Alternative modes of transportation guarantee the uninterrupted functioning of business organisation supply chains in the event of infrastructure malfunctions or natural catastrophes. Resilient supply chains are essential for business organisation to withstand external shocks and maintain steady operations. The convergence of digital public infrastructure and multi-modal connectivity can create a synergistic effect, amplifying the benefits for business organisation. Better coordination between various means of transportation may be facilitated by digital platforms, which can also enable smooth transitions and real-time tracking of items, improve supply chain visibility, and lower the risk of delays and poor management. Combining digital technologies and multi-modal connectivity can lead to the development of intelligent logistics solutions, including automated warehouses, IoT-enabled tracking systems, and blockchain-based supply chain management, enhancing efficiency and transparency.The availability of real-time data from digital systems and multi-modal transport networks allows business organisation to make informed decisions. Data analytics can provide insights into route optimization, demand forecasting, and inventory management, resulting in cost savings and improved performance. Data-driven decision-making enables business organisation should adjust quicklyto adapt to market shifts and optimize their supply chain strategies. The integration of digital infrastructure and multi-modal connectivity promotes sustainable supply chain practices. By optimizing transport routes and reducing fuel consumption, business organisation can minimize

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages: 3982-3991

their carbon footprint and contribute to environmental sustainability. Sustainable supply chains are increasingly important as businesses and consumers prioritize eco-friendly practices. The dynamic interplay between digital public infrastructure and multi-modal connectivity holds immense potential to reshape the supply chain dynamics of business organisation. By leveraging these initiatives, business organisation can overcome traditional supply chain challenges, enhance their operational efficiency, and get a market advantage over competitors. Implementing reliable internet connectivity, digital payment systems, e-governance platforms, and advanced data analytics, combined with a robust multi-modal transport network, can create a resilient and efficient supply chain ecosystem. This transformation is essential for the sustained growth and development of business organisation, fostering economic prosperity and inclusive development in the region. Table 2 shows the elucidation by the Researchers and Organizations.

Table 2: Definitions of Multi-Modal Connectivity

S.N.	Researchers and Scholars	Elucidation
01	**Shashikant Nishant Sharma (2023)**	A complete database of the trunk and utility infrastructure, as well as current and upcoming initiatives from a range of infrastructure organizations, ministries of economics and departments of the central government, states, and unions, is provided by the "*PM Gati Shakti National Master Plan for Multi-modal Connectivity Initiative*". By integrating this data utilizing PM Gati Shakti's GIS-enabled platform, it is possible to plan, develop, and monitor Next Generation infrastructure projects all on one portal.
02	**Sumashni Moodley and Christoffed (2022)**	An essential part of integrated public transportation systems is multi-modal interchanges. Future integrated interchange designs that eventually benefit users will require a more profound knowledge of public transportation users' attitudes, requirements, and priorities as they navigate transport interchanges.
03	**Zhenran Zhu et al. (2019)**	When multiple modes of transportationair, land, sea, train, and pipelineare combined and connected to move people and goods within or between cities, it is referred to as a multi-modal transport network. In recent decades, globalization has quickened, and economic integration has been assisted by rapidly expanding transportation networks. *(Zhang, 2019)*
04	**Moushila De et al. (2017)**	A robust urban transport system helps to promote the urban economy, allows social interaction, boosts resource productivity, gives people mobility, makes opportunities more accessible, and establishes direction and growth patterns. The term "lifeblood of cities" is frequently used to describe transportation as it is the essential connection between different activities and gradually defines the metropolis.
05	**India.gov.in (National Portal of India)**	The National Master Plan for Multi-modal Connectivity, PM Gati Shakti, was launched by the prime minister. It is a digital platform that unites 16 Ministries, including Roadways and Railways, for integrated planning and coordinated execution of infrastructural connectivity projects. The movement of people, commodities, and services between modes of transportation will be made possible by multi-modal connectivity's integrated and seamless connectivity. It will shorten people's travel times and enable last-mile infrastructure connectivity.

The combination of DPI and multi-modal connectivity in the supply chain within business organisation can have profound implications. A robust digital infrastructure may make tracking items in real-time more accessible, managing inventories effectively, and coordinating with many stakeholders. Furthermore, it can make it easier to employ innovative technology like blockchain, A.I., and the IoT, increasing supply chain efficiency even further. The implementation of DPI and multi-modal connectivity has the potential to yield several advantages for business organisation. First, it can shorten the lead time for goods transportation, allowing companies to react swiftly to market and client needs changes. Second, it may reduce losses and damage to items during transportation, guaranteeing the integrity and quality of commodities through the supply chain. Thirdly, it may improve the traceability of commodities, enabling companies to adhere to legal obligations and uphold operational transparency.DPI and multi-modal connectivity can also encourage cooperation and synergy amongst various supply chain participants. Stakeholders, including producers, distributors, logistics companies, and governmental organizations, may pool resources, communicate information, and expedite procedures by establishing a shared digital platform. This collaborative approach may result in a more efficient supply chain, with improved coordination and less duplication.

1.3 Supply Chain Efficiency:

Supply chain efficiency involves the optimization of processes, resources, and technologies to guarantee the uninterrupted movement of goods and services from suppliers to end customers. It covers a wide range of tasks, such as distribution, manufacturing, shipping, warehousing, and procurement. At its core,Supply chain efficiency is the efficiency with which a company delivers its items to the right place at the right time for the least amount of money. It involves using sources such as materials and labor in the most efficient manner to manufacture and distribute commodities to customers. Achieving efficiency of supply chain leads to reduced order processing times, improved inventory control, quicker delivery, and frequently increased earnings. The wholeprocess of producing and providing an item or service, from acquiring components and raw materials to the final delivery to the customer, is called a supply chain. It includes every stage and action needed to produce and deliver goods and services. A supply chain aims to transfer goods from the producer to the customer economically and efficiently. The conclusions of the organizations and researchers are explained in Table 3.

Table 3: Supply Chain Efficiency

S.N.	Researchers and Scholars	Elucidation
01	**Aditya Dhiman & Pankaj Madan (2023)**	The Self-Assessment Industry 4.0 Maturity Model for Indian Manufacturing MSMEs is a comprehensive tool to assess the present level of Industry 4.0 adoption by Indian MSMEs. It may be used by businesses to rank areas that need development.
02	**Rajendra Kumar et al. (2021)**	Raw materials are produced via a linked network of facilities called a supply chain, which also converts them into intermediate and final commodities before using a distribution network to deliver the items to consumers. As stated by Lee and Billington (1995), the main supply chain's objective administration is to "optimize the chain's performance to add as much value as possible for the least cost possible." This includes production, distribution, and procurement.
03	**Joby George (2018)**	A supply chain is a group of people connected by exchanging goods, capital, and information to lower overall system costs.
04	**Graham C. Stevens (2015)**	Manufacturing sectors are responsible for generating money through product sales and value addition. All manufacturing businesses must manage material flow from vendors to clients via adding value (production)procedures and routes of distribution. The supply chain operates in this manner.
05	**N. Chandrasekaran (2013)**	Managing the movement of goods, funds, and information from suppliers to component manufacturers to final assemblers to distribution and, eventually, to the customer is known as supply chain management, or SCM.
06	**Saunders (2012)**	The supply chain is the complete line of trade from the original raw material source to ultimate customers via various companies involved in raw material extraction and processing, production, assembly, distribution, and retailing.

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages: 3982-3991

2. Research Objectives-

Three research topics and objectives are the focus of this study:

- To examine the role of Digital Public Infrastructure and Multi-Modal Connectivity in enhancing supply chain efficiency of business organisations, particularly MSMEs.
- To develop a conceptual framework linking Digital Public Infrastructure and Multi-Modal Connectivity with key dimensions of supply chain performance, including cost, productivity, quality and customer service.
- To conceptualize and propose the *"Smart Infrastructure Acceleration Theory*" as an integrated approach for improving supply chain resilience, efficiency and sustainability through advanced digital technologies.

Researchers have addressed the research mentioned above questions by thoroughly examining the literature and suggested a thorough conceptual model for testing in this work.

3. Literature Review-

3.1 Digital Public Infrastructure: While the definition of DPI is still being worked out, there is growing consensus that it comprises three elements: (i) networked, open technology standards designed for the public good; (ii) facilitating governance; and (iii) a community of creative and competitive market participants that collaborate to promote innovation, especially in the context of public programs. (UNDP).

*Vivek Raghavan, Sanjay Jain & Pramod Varma (2019)***.** India has made significant progress in digital inclusion through initiatives like the India Stack, which includes the Aadhaar program for digital identity and the Unified Payments Interface for low-cost digital payments. The open architecture of India Stack has led to the rapid growth of digital payment apps in the country. While the Aadhaar project has faced criticism for privacy and security concerns, the UIDAI has implemented design changes to address these issues. The public discourse around Aadhaar has also emphasized the need for a Data Privacy Law in India, offering valuable lessons for other countries considering similar digital infrastructure platforms. *Ethan Zuckerman (2020)*explains that the infrastructures that enable us to participate in public and civic life in digital places are known as digital public infrastructures. Our digital infrastructures are mostly unintentionally public; for example, Facebook was created primarily to show advertisements to users rather than to promote citizenship. Our goal should be a collection of tools that are purposefully digital public infrastructuresspaces with affordances and norms centered around a set of civic values. The synopsis emphasizes how crucial it is to restructure the digital public infrastructure to put civic ideals ahead of surveillance capitalism. It highlights the necessity of instruments that keep an eye on neighborhood values, promote civic involvement, and sustain journalism using innovative business models. These infrastructures are necessary social benefits that should be funded by governments in order to mitigate negative externalities. *Alfred SIAME (2020)*Digital Public Infrastructure (DPI) in enhancing public service delivery and financial management through digital technologies. It highlights the benefits of DPI in improving transparency, accountability, and efficiency in public finances and supporting financial inclusion. Challenges such as the need for substantial investment and skilled personnel are identified. The research opportunities include exploring blockchain for fiscal transparency and leveraging digital solutions for tax collection and administration to advance sustainable development goals.*Romina Bandura et al. (2023)*DPI acts as the enablement system and the foundation for digitization, enabling digital services to the public and private sectors. The Internet and GPS were two of the first applications of DPI. Although these systems have mostly stayed isolated, DPI is not new. Creative DPI strategies might encourage innovation across industries. Digital identification systems, electronic payment systems, and data exchange systems comprise the three core components of the digital public infrastructure. *Aarushi Gupta and Aman Nair (2023).* The results point to the necessity for further empirical data and investigation into the effects of digital public identification. While the implementation of DPIs like Aadhaar in India was intended to eliminate leakages in the delivery pipeline, studies show that instead of having a substantial impact on leakages or the value of products received by households, these systems have raised transaction costs and excluded mistakes. The G20 is urged to provide recommendations for implementing DPI, support longitudinal research, and hold discussions about data security and privacy. *Ankit Maheshwari (2023)*India's economy and society have been greatly influenced by digital public infrastructure, which has boosted e-governance, financial inclusion, corporate efficiency, research, and education. Digital public infrastructure has its difficulties and controversies, though; they include issues with privacy, security, and execution. In general, the creation and execution of digital public infrastructure projects in India are essential to advancing the country's economic development and raising the standard of living for its people. Effective public administration is crucial for these programs to be implemented successfully, transparently, efficiently, equitably, and sustainably. This research examined several infrastructures, including Digi Yatra, Digi Locker, National Knowledge Network, Aadhar, and Unified Payment Interface. *Aaditeshwar Seth et al. (2023)* The paper discusses challenges faced by digital public infrastructures (DPIs) in India, emphasizing the importance of implementing ethical values like privacy and inclusivity. Issues such as predatory lending, privacy concerns, lack of grievance resolution mechanisms, and gaps in de-duplication processes are highlighted. Recommendations to the G20 include advocating for citizen-empowering governance frameworks for DPIs. To address these challenges effectively, proposed solutions focus on accountability, observability, autonomy, decentralization, and subsidiarity in technology governance. *Ajay Dutta and Novedeep Jeerh (2023)* provide an overview of key initiatives in digital infrastructure and citizen empowerment in India. It mentions the Open Forge Project for collaborative e-governance app development, challenges in A.I. projects, and the Government e-Marketplace (GeM) for electronic procurement. Digital India initiatives focus on empowering citizens through Aadhaar, mobile banking, and e-learning platforms. The summary also touches on the growing popularity of digital currency like Bitcoin globally, indicating potential for widespread adoption in the future. *Aadya Gupta & Suyash Rai (2024)"* The difficulties associated with this procedure, as well as the possibility for DPIs to enhance the economic environment. Effective stakeholder engagement, trust-building, competition promotion and preservation, and maintaining a balance between public and private interests are critical to the success of DPIs. A continuous conversation about legislation and practicality is also necessary to navigate the complexities of DPI deployment. To fully realize the promise of DPIs and ensure fair and sustainable economic growth, governments, the business sector, and international organizations must work together. *Kratika Neema & Arpit Neema (2018)*The Unified Payment Interface is a digital payment system facilitating seamless fund transfers and merchant payments through Virtual Payment Addresses. Key players like Uber and SBI Pay are adopting UPI for transactions. Its advantages include instant transfers, single-click authentication, and secure transactions. Challenges include limited awareness and slow rural adoption post-demonetization. UPI presents a promising mobile payment solution with significant growth potential in India. *Kirti Sharma & Pankaj Madan (2020)* The study's conclusion emphasizes the increasing significance of smartphones and mobile networks in the digital world, stressing the contribution of 4G technology to faster internet speeds and more online commerce. To boost the uptake of m-commerce and consumer pleasure, the research offersconsequences for mobile network executives and engineers, e-marketers, and researchers. These implications center on enhanced security protocols, user awareness, and network services. The study recommends future research on how to investigate whether mobile networks are compatible with current devices, assess how network innovations affect the growth of m-commerce, and improvesthe adoption of m-commerce conceptual model based on the quality of mobile network services. *Mahesh A, &Ganesh Bhat (2021)*The study report's primary focus is the Unified Payments Interface (UPI) in the Indian digital payment ecosystem.A sizeable portion of digital transactions are made using UPI, which provides faster payments and better security features. The study examines UPI's advantages, disadvantages, prospects, and challenges, emphasizing the

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages: 3982-3991

company's development potential and user-friendliness. It highlights how crucial it is to comprehend UPI's role in digital payments and suggests areas for more study to expand on its potential and market share. *Vijay Kumar & Harshitha (2023)* The Open Network for Digital Commerce in India seeks to create mutually acceptable guidelines and standards to democratize e-commerce. In order to boost e-commerce penetration, the implementation approach centers on enrolling millions of businesses and customers. By strengthening local vendors, settling conflicts, and facilitating hyper-localization, ONDC helps MSMEs. Due to ONDC's ambitious strategy, which involves collaborations in negotiations with 200 corporations to accelerate e-commerce adoption and benefit current players like Amazon and Flipkart, India's worldwide presence in digital commerce is expected to expand. *Ram Girdhar (2023)* The research highlights the Open Network's role in fostering competition, innovation, and consumer welfare in digital commerce by discussing the possible advantages of the network for digital commerce in India. Research from institutions such as the Indian Council for Research on International Economic Relations (ICRIER) and the Central Bank (RBI) open networks can boost financial inclusion, lower costs, enhance competition, and assist small and medium-sized businesses in accessing digital payment services. With development potential for all parties involved, the ONDC is viewed as a platform that might close the gap between big businesses and small merchants.

3.2 Multi-Modal Connectivity: *Zhenran Zhu et al. (2019)*. When many transportation modes- such as pipelines, water, air, and landare combined and connected to move people and goods within or between cities, it is called a multi-modal transport network. The following criteria are used in this study to quantify multi-modal connection: connectivity, distance, velocity, transfer point, capacity, and duration. Chinese aviation and rail schedule data from 2016 were used to demonstrate the approach. *In 2023,Gopakumar, G.* The PM-Gati-Shakti Initiative, which focuses on six pillars- thoroughness, importance, synchronization, optimization, analytical, and dynamic- integrates important ministries to improve connection and competitiveness. *Mahmoud et al. (2021)* discuss the integration of innovative mobility modes, such as autonomous vehicles and shared mobility, into urban transport networks. The study emphasizes the need for strategic, tactical, and operational planning to incorporate these new modes effectively. The concept of Mobility as a Service (MaaS) is highlighted as a promising approach to integratemany transportation services into one, accessiblemobility assistance. *Noor and Iamtrakul (2024*) exploresmulti-modal transportation systems' resilience.The study contrasts techniques for evaluating how resilient transportation networks focusing on both single-mode and multi-modal network topologies. This study underscores the importance of planning and management to enhance the resilience of transport systems against disruptions.

3.3 Supply Chain Efficiency: *Peter Horscroft and Alan Braithwaite (1990)*emphasize the importance of strategically managing lead times to enhance supply chain efficiency. Key findings include the identification of lead time reductionas a crucial element in obtaining a competitive edge in the marketplace. The authors argue that effective lead time management can streamline operations, reduce costs, and improve customer satisfaction. This work has been influential in subsequent research, highlighting its relevance in supply chain management practices. *Annilie Pettersson (2008 Licentiate Thesis)* As supply chain management gains more attention, performance evaluation is becoming increasingly important. The primary metrics arecost, quality, and time; many measures are based on these three dimensions. Another area of concern is performance, both internally and outside. A few examples of categories in internal performance metrics include Cost, customer service, productivity shipped/employee, asset management, ITO, and quality claims, according to Bowersox and Closs (1996). *N. Chandrasekaran (2013)*SCM is a crucial strategic component for boosting organizational performance and accomplishing objectives, which include enhanced profitability, better customer service, and competitiveness. The supply chain performance metrics, including those for quality, customer service, productivity, and Cost, are covered in this book chapter. *Xuan Wang, Vikas Kumar, et al. (2022)*The summary underscores the positive impact of A.I. and IoT technologies on enhancing supply chain efficiency. It highlights the benefits of improved two-way information flow for collaboration and operational excellence. Challenges in digital supply chains, such as the need for more guidelines and strategic orientation, hinder further digitization. The technologies aid in addressing these challenges, improving sustainability, and optimizing logistics operations. *Lianju Ning and Dan Yao (2023)*provide an example of how supply chain competitive performance is affected by digital transformation. It looks at the moderating impact of environmental uncertainties and the mediating function of supply chain capabilities. The study highlights the significance of digitization in improving supply networks' competitive performance and uses statistical analysis to confirm ideas. The study emphasizes how crucial digital infrastructure is for companies to use digital technologies for cooperation, effectiveness, and responsiveness in the digital economy. The study adds to our understanding of supply chain settings for digital transformation and emphasizes the value of sustainable competitive advantage in a constantly changing market. *Nanyang Zhao et al. (2023)***.** The manufacturing survey included a representative sample of several firm types and industries. The significance of reaction capability is emphasized by Supply Chain Resilience (SCR), which is essential in mediating between Supply Chain Disruption (SCD) and Supply Chain Performance (SCP). Supply chain digitalization is accelerated by digitization, which improves operational quality and efficiency. The influence of digitization on supply chain resilience and performance is highlighted in research on supply chain resilience (SCR) capabilities. *According to Atkinson et al. (1997)*, Cost is the main emphasis of performance measurements, which frequently conflicts with strategic goals and objectives. According to Shapiro (2001), a business should also focus on non-financial goals, including timeliness, quality, and customer service. According to Ghalayini and Noble (1996), it is frequently challenging to quantify metrics such as lead time, delivery accuracy, and customer satisfaction in monetary terms. *Matias G. Enz et. al (2024)* The paper examines the impact of COVID-19 on supply chain management across the USA, France, and Poland, focusing on resilience strategies. Key findings highlight significant challenges in supply, production, and distribution, with collaboration strategies being the most implemented yet perceived as less effective. The study emphasizes the importance of strong buyer-supplier relationships and effective risk management. Data collected through surveys reveal regional differences in strategy implementation and effectiveness, with the USA generally reporting higher effectiveness. Overall, the research underscores the need for adaptability and collaboration in supply chains to navigate future disruptions. *Rinto Alexandro et. al. (2024)* Supply chain efficiency is significantly influenced by macroeconomic infrastructure, which serves as the backbone for smooth operations. Efficient supply chains reduce logistical costs, expedite delivery times, and enhance customer satisfaction, all of which are essential for maintaining competitiveness in the global marketplace. A well-functioning supply chain minimizes disruptions and delays, ensuring that products are available when needed, which in turn reduces operational inefficiencies and costs for businesses. This efficiency not only boosts profitability but also fosters innovation and job creation, contributing to overall economic growth. Therefore, strategic investments in infrastructure are crucial for enhancing supply chain efficiency and, consequently, economic development. *Imad AitLhassan (2024)* Supply chain efficiency is crucial for delivering products effectively while minimizing costs. The study highlights that integrating the Balanced Scorecard (BSC) perspectives- financial, customer, internal business processes, and learning/innovation- positively impacts supply chain performance in Morocco's automotive industry. Efficient supply chain management enhances logistics performance, which is essential for meeting customer demands and maintaining competitive advantage. Key factors include optimizing internal processes and leveraging customer insights to improve service delivery and reduce cycle times, ultimately leading to better inventory management and increased profitability. This integration fosters collaboration across functions, enhancing overall supply chain efficiency and effectiveness.

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages: 3982-3991

Table 3: Operationalization of Variables with Supporting Literature

Variable	Constructs / Factors	Authors Citation
Digital Public Infrastructure	Digital Payments (UPI)	Kakade &Veshne (2017); Neema & Neema (2016); Mahesh & Bhat (2021); Raghavan et al. (2019)
	Digital Identity (Aadhaar)	Gupta & Nair (2023); Raghavan et al. (2019); Seth et al. (2023); Maheshwari (2023)
	E-Governance Platforms	Seth et al. (2023); Kapoor & Watson (2023); OECD (2020); Maheshwari (2023)
	Digital Document Systems (DigiLocker)	Maheshwari (2023); OECD (2020); Seth et al. (2023); Kapoor & Watson (2023)
	Open Digital Platforms (ONDC)	Vijay Kumar & Harshitha (2023); Girdhar (2023); Ram (2023); Bandura et al. (2023)
	Digital Infrastructure Awareness & Adoption	Heeks (2020); OECD (2020); Maheshwari (2023); Bandura et al. (2023)
Multi-Modal Connectivity	Integrated Transport Network (Road, Rail, Air, Waterways)	Zhu et al. (2019); India.gov.in (2023); Sharma (2023)
	Multi-Modal Interchange Efficiency	Moodley & Venter (2022); Zhu et al. (2019)
	Logistics Integration Platform (ULIP)	Reddy & G (2023); India.gov.in (2023); Sharma (2023)
	Real-time Tracking & Visibility	India.gov.in (2023); Moodley & Venter (2022); Zhu et al. (2019)
	Transport Efficiency & Delay Reduction	Zhu et al. (2019); Moodley & Venter (2022); Gopakumar (2023)
	Infrastructure Integration (PM Gati Shakti)	Sharma (2023); India.gov.in (2023); Gopakumar (2023)
Supply Chain Efficiency	Cost Efficiency	Rajendra Kumar et al. (2021); Saunders (2012)
	Productivity Improvement	Aditya Dhiman & Madan (2023); Stevens (2015)
	Customer Service	Joby George (2018); Chandrasekaran (2013)
	Quality & Value Addition	Stevens (2015); Rajendra Kumar et al. (2021)
	Supply Chain Integration	Chandrasekaran (2013); Saunders (2012)
	Digital Supply Chain Performance	Ning & Yao (2023); Zhao et al. (2023)

4. **Research Gap-** According to the literature analysis, most studies have been conducted in industrialized nations. Regarding initiatives for multi-modal connectivity and digital public infrastructure, not much effort has been made in developing countries like India. The research gap identifies several topics that need more study. First, given the particular context of business organisation, there needs to be a more scholarly focus on the effects and effectiveness of digital public infrastructure and multi-modal connectivity efforts. It is possible that the material currently in publication needs to adequately discuss how these activities are incorporated into these clusters' supply chains. To evaluate the full impact of DPI on logistics, inventory control, and overall operational efficiency inside these clusters, it is imperative to comprehend this connection. Second, studies still need to be done on how connection and DPI initiatives improve the competitiveness of business organisation. While some studies highlight the broad advantages of these kinds of activities, further research is required to determine how precisely they affect market access, cost reduction, and coordination among cluster participants.Furthermore, more thorough coverage of the implementation and policy issues related to DPI and connectivity projects in this area must be more thorough. Examining these issues is essential for developing and implementing policies that work. Furthermore, there needs to be more literature concerning comprehending the regional context and stakeholders' viewpoints on DPI and connection projects. To ensure the success and sustainability of these programs, it is imperative to have insights into the perceptions and interactions of enterprises, government agencies, and other stakeholders. Finally, only some comparison studies and assessments of best practices from different nations or areas that have carried out comparable connectivity and DPI projects exist. Lessons from successful situations elsewhere can offer practitioners and policymakers invaluable direction. In addition to enhancing academic knowledge, filling in these research gaps would help DPI and multi-modal connectivity efforts succeed in the real world and shape supply chain dynamics inside business organisation.

5. **Proposed framework of Digital Public Infrastructure and Multi-Modal Connectivity dependent on Supply Chain Efficiency-** A conceptual model was created even though the research model (Figure 1) shown below was the result of a thorough comprehension of the concepts and material from the collection of earlier research investigations (see the literature review). In the proposed framework,DPI and MMC are identified as independent variables influencing the dependent variable, supply chain efficiency. DPI encompasses digital tools and platforms that enable real-time data exchange, transparency, and automation within the supply chain. MMC integrates various transportation modes to ensure seamless and efficient movement of goods. The framework posits that improvements in DPI and MMC will improve the effectiveness of the supply chain by reducing operational costs, minimizing delays, and improving coordination. This, in turn, boosts the productivity and competitiveness of business organisation.

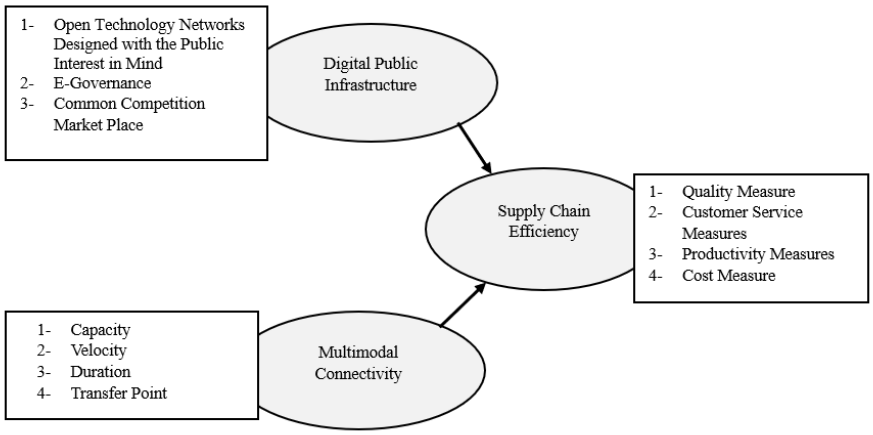

Figure 1: Proposed Framework

5.1 Description of Framework:

DPI is crucial in modernizing and optimizing supply chain operations by integrating three key components: networked open technology standards, e-governance, and common competition marketplaces. First, DPI promotes adopting networked open technology standards, such as interoperable APIs and data exchange protocols, ensuring seamless communication and collaboration among supply chain stakeholders. Secondly, DPI supports e-governance initiatives by providing digital platforms for streamlined regulatory processes, permits, and compliance,

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages: 3982-3991

reducing administrative burdens and enhancing transparency. Thirdly, DPI facilitates the creation of common competition marketplaces where business organisation can engage in transparent and fair market transactions, promoting competitiveness and economic growth. Together, these elements of DPI create a robust digital ecosystem that improves supply chain efficiency, supports business growth, and fosters economic development.

5.1.1 Digital Public Infrastructure:

According to the UNDP (undp.org) report, the Digital Public Infrastructure consists of three elements: Open Technology Networks Designed with the Public Interest in Mind, E-Governance Common Competition Marketplace.

According to ENSIA, open standards ensure interoperability and security in digital infrastructures. They allow for creating adaptable and resilient systems, thereby supporting the development of robust public services *(ENISA, 2015).* Additionally, the International Telecommunication Union (ITU) emphasizes that open standards are essential for the global harmonization of technology, which is necessary for achieving sustainable development goals *(ITU, 2017). The World Bank (2016)* highlights that digital public infrastructure should prioritize inclusivity and accessibility to ensure all citizens benefit from technological advancements. This strategy encourages socioeconomic justice and aids in closing the digital gap. Similarly, the *United Nations Development Programme (UNDP)* stresses that public interest should be at the core of digital infrastructure projects to ensure sustainable and inclusive growth *(UNDP, 2018).*

Utilizing digital platforms and technology to increase efficacy, openness, and accessibility of public services is known as e-governance. It seeks to increase civic engagement, expedite administrative procedures, and enhance communication between the government and its constituents. According to the Organization for Economic Cooperation and Development, E-governance is crucial for modernizing public administration and enhancing service delivery (OECD, 2018). Through digital technology, e-governance efforts may significantly increase government efficiency, save costs, and improve public happiness by streamlining and automating administrative procedures. Additionally, the World Bank (2016) notes that e-governance can improve accountability in public services and decrease corruption.

The Common Competition Marketplace is a digital platform that enables various service providers to compete in offering solutions for public services. This marketplace fosters innovation, ensures high-quality service delivery, and promotes efficiency by encouraging provider competition. *The World Economic Forum (WEF)* argues that digital marketplaces in governance create a competitive environment that drives innovation and improves the quality of public services *(WEF, 2020).* By providing a platform where multiple service providers can compete, governments can leverage market dynamics to achieve better outcomes for citizens. Additionally, the OECD reports that such marketplaces can enhance transparency and accountability in public procurement and service delivery *(OECD, 2018).*

5.1.2 Multi-Modal Connectivity:

Integrating several modes of transportation (such as air, sea, land, and rail) to produce a smooth and effective transportation network is known as multi-modal connectivity. The capacity, velocity, duration, and transfer points are the four main metrics that should be used to gauge this connectivity. *Zhenran Zhu et. al (2019)*

- **Capacity:** The volume of goods or passengers transported through a given mode or combination. High capacity ensures that the transportation network can handle large volumes efficiently.
- **Velocity:** The speed at which goods or passengers are transported. Higher velocity reduces transit times, leading to quicker deliveries and improved service quality.
- **Duration:** The whole travel time, including any waiting or transfer periods. Reducing wait times improves the network's overall dependability and efficiency.
- **Transfer Points:** The locations where goods or passengers switch from one mode of transportation to another. Efficient transfer points reduce delays and facilitate smooth transitions between different modes.

According to Rodrigue et al. (2020), multi-modal transportation systems enhance the efficiency and flexibility of logistics networks by integrating various transportation modes. Efficient multi-modal connectivity reduces transportation costs and improves service reliability. *The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP)* emphasizes that well-designed multi-modal transport networks can significantly boost trade and economic development by improving accessibility and connectivity *(UNESCAP, 2019).*

5.1.3 Supply Chain Efficiency:

Any company's ability to succeed depends heavily on the effectiveness of its supply network. It may be quantified using a range of indicators that assess supply chain activities' efficacy and performance. The four most important metrics are productivity, Cost, customer service, and quality metrics. (*N. Chandrasekaran (2013)).* The quantity of error-free notes invoiced, order entry accuracy, picking/shipping accuracy, number of customer returns, frequency of damage, number of credit claims, and information availability are a few of the often-used quality metrics in supply chain efficiency. Order lead time, order input technique, customer order path, delivery metrics, customer service satisfaction metrics, customer query time, and gauging customer perception of services are a few of the often-utilized customer service metrics in supply chain efficiency. Various cost indicators, such as total inventory costs, total distribution costs, financing costs, logistic costs, and asset assessment, are frequently employed to assess the effectiveness of supply chains.Units delivered per employee, units to labor cost, equipment downtime, capacity utilization, order per salesperson, and order entry efficiency are a few of the often-used productivity metrics in supply chain efficiency.

6. Smart Infrastructure Acceleration Theory-

The novel paradigm, "Smart Infrastructure Acceleration Theory," aims to integrate digital technology, data analytics, and intelligent systems to advance infrastructure construction quickly. According to this hypothesis, utilizing innovative technology significantly improves an infrastructure project's resilience, sustainability, and efficiency. Artificial intelligence (A.I.) and machine learning algorithms enhance operational performance and predictive maintenance. In contrast, the Internet of Things (IoT) provides real-time monitoring and control of infrastructure assets. The theory also highlights how critical big data analytics are to decision-making processes, enabling more precise resource allocation, risk management, and forecasting. A central tenet of Smart Infrastructure Acceleration Theory is the concept of digital twins- digital public infrastructure and the development of virtual replicas of physical infrastructure resulting in quantifiable sustainable development practices that can simulate and analyze performance under various conditions. This enables proactive identification of potential issues and facilitates data-driven planning and design.

In order to reduce the environmental effect of infrastructure development, the theory also promotes incorporating sustainable practices, such as using eco-friendly materials and renewable energy sources. Smart Infrastructure Acceleration Theory seeks to develop more flexible, effective, and sustainable infrastructure systems that can satisfy the needs of expanding urban populations and changing global concerns by utilizing these cutting-edge technologies and methodologies.

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages: 3982-3991

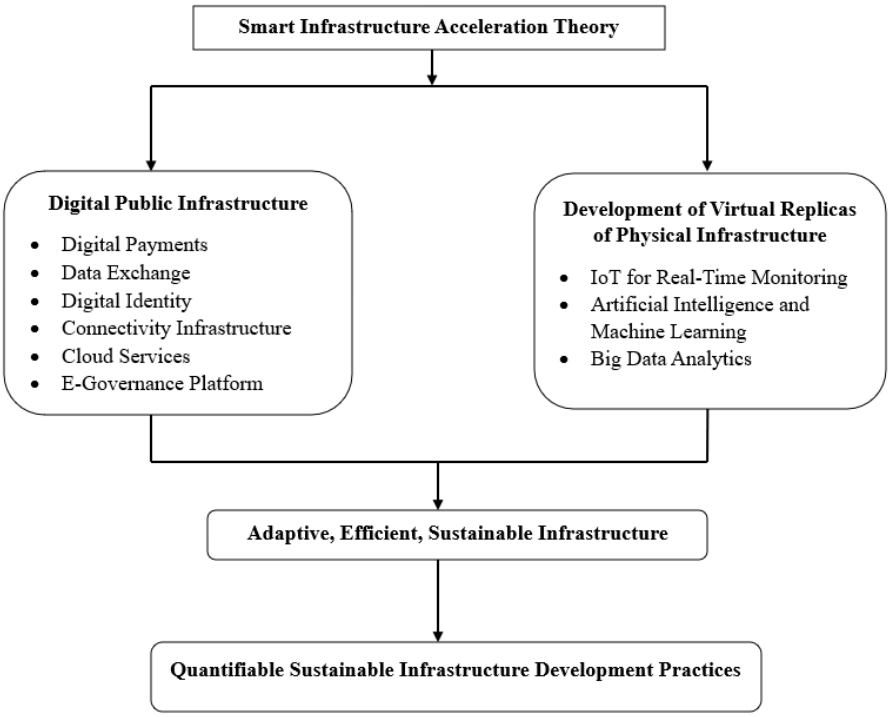

Figure 2: Flow Chart of Smart Infrastructure Acceleration Theory

This involves incorporating various advanced technologies to enhance infrastructure projects. By leveraging these technologies, infrastructure systems can be more intelligent, efficient, and responsive to changing conditions. Real-time data gathering and monitoring are made possible by the IoT, which links physical systems and devices to the Internet. IoT may be utilized in infrastructure to track asset performance and condition, identify problems early, and streamline maintenance procedures.Algorithms using A.I. and M.L. examine vast volumes of data to forecast outcomes, spot trends, and streamline processes. A.I. and M.L. in infrastructure can facilitate predictive maintenance, cut downtime, increase operational efficiency, and improve decision-making. This entails incorporating renewable and environmentally friendly energy sources into infrastructure construction. Sustainable practices use eco-friendly materials, cut carbon footprints, and encourage energy efficiency to limit adverse environmental effects. Specific, quantifiable steps are taken as part of quantifiable sustainable development methods to reduce environmental impact, improve resource efficiency, and foster social responsibility. These methods include using water-saving fixtures to conserve water, lowering energy usage using efficient technology, and lowering greenhouse gas emissions with renewable energy sources. The ultimate goal of the theory is to develop infrastructure systems that are adaptive to changing conditions, highly efficient in operation, and sustainable over the long term. These systems are designed to be resilient, environmentally friendly, and capable of supporting growing urban populations and evolving global needs. Processing and analyzing enormous volumes of data in order to get valuable insights is known as big data analytics. This can support precise resource allocation, risk management, and forecasting in the infrastructure sector, resulting in better informed and efficient decision-making. Virtual counterparts of tangible infrastructure assets are called digital twins. They make it possible to test and analyze without incurring expenses or physical dangers by simulating real-world circumstances and performance. Digital twins enable continuous optimization of infrastructure systems, planning and designing with knowledge, and proactively identifying problems.

7. Conclusion and Discussion-

The study paper's conclusion highlights the critical effects of combining multi-modal connectivity and digital public infrastructure on business organisation supply chain management. Supply chain resilience, efficiency, and transparency are achieved by combining several means of transportation (road, rail, air, and waterways) with digital tools and platforms like e-commerce and digital payments.

Business Organisation benefit from streamlined logistics processes, reduced transportation costs, and improved market access, contributing to their competitiveness and growth. The discussions highlight several vital insights. Firstly, adopting digital infrastructure enhances supply chain resilience and efficiency by enabling better coordination and real-time tracking of goods. This capability allows quicker adaptation to disruptions, making supply chains more robust. Secondly, multi-modal connectivity optimizes logistics by reducing transit times and costs through flexible and reliable transportation options, which is particularly beneficial for geographically diverse regions. Thirdly, digital infrastructure significantly increases market accessibility for business organisation, enabling them to reach broader markets beyond local boundaries, thereby boosting sales and growth opportunities. For example, *according to the Report of the United Nations Development Programme (2023),* ONDC is an open e-commerce platform to connect sellers with buyers across multiple e-commerce platforms.3 It has scaled to 236 cities and hosts 36,000 merchants. Its modular approach is highly customizable - building blocks can be easily reconfigured to build e-commerce platforms. It uses open protocols for customizing and integrating commercial modules, ensuring seamless data exchange and interoperability. ONDC simplifies doing business for small- and medium-sized enterprises, including those run by women in informal sectors, by facilitating logistical support and fair competition. It delivers resilience by supporting modular and adaptable supply chains. Its highly modular approach lowers the barrier of entry to e-commerce as it standardizes operations, including cataloging, inventory management, and order fulfillment. Logistics and financial service providers are integrated with the platform, allowing customizable and innovative offerings. The transaction fees are a quarter of those offered by private e-commerce players.

Additionally, the study acknowledges the influence of external factors such as government policies, regulations, and the socioeconomic environment in successfully adopting and implementing these innovations. Supportive policies and a conducive environment are critical for effectively leveraging digital and multi-modal connectivity solutions. Lastly, the combined effect of digital infrastructure and multi-modal connectivity fosters sustainable economic growth, enhancing the competitiveness of business organisation and contributing to overall development. The key findings reveal that integrating digital public infrastructure and multi-modal connectivity significantly improves supply

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages: 3982-3991

chain performance for business organisation. The research identifies specific mechanisms through which these innovations enhance supply chain dynamics, including better logistics coordination, cost reduction, and increased market reach. The study underscores the crucial role of technology and connectivity in augmenting the supply chain capacities of industrial clusters, leading to greater efficiency and sustainability. These insights offer valuable guidance for policymakers and industry stakeholders, emphasizing the need for strategic interventions to support adopting these technologies and connectivity solutions. Ultimately, the research provides a comprehensive understanding of how digital public infrastructure and multi-modal connectivity can drive regional sustainability and economic growth, presenting a pathway for the sustainable development and improved competitiveness of business organisation.

8. References-

1. A, M., Bhat, G., 2021. Digital Payment Service in India - A Case Study of Unified Payment Interface.
2. Alexandro, R., &Basrowi, B. (2024). The influence of macroeconomic infrastructure on supply chain smoothness and national competitiveness and its implications on a country's economic growth: Evidence from BRICS countries. Uncertain Supply Chain Management, 12(1), 167–180. https://doi.org/10.5267/j.uscm.2023.10.007
3. Alfred SIAME, 2022. Impact of Digital Public Infrastructure. Academia. DOI: https://doi.org/10.1373/Journal.024934
4. Ambit. (2024). Digital Public Infrastructure for MSME Growth 2024. Retrieved from https://finvest.ambit.co/blog/msme-growth-digital-public-infrastructure
5. American Society for Quality (ASQ). (2013). "Total Quality Management." https://asq.org/
6. Aparicio, J. T., Arsenio, E., & Henriques, R. (2022). Assessing robustness in multimodal transportation systems: A case study in Lisbon. *European Transport Research Review*, *14*(1), 28. https://doi.org/10.1186/s12544-022-00552-3
7. Bandura, R., McLean, M., Sultan, S., 2023. Unpacking the Concept of Digital Public Infrastructure and Its Importance for Global Development https://www.csis.org/analysis/unpacking-concept-digital-public-infrastructure-and-its-importance-globaldevelopment#:~:text=A1%3A%20DPI%20is%20the%20foundation,systems%20have%20remained%20largely%20siloed
8. Beamon, B.M., 1999. Measuring supply chain performance. International Journal of Operations & Production Management 19, 275–292. https://doi.org/10.1108/01443579910249714
9. Chandrasekaran, N., 2010. Supply chain management: process, system, and practice. Oxford University Press, New Delhi. ISBN-10- 0-19-806302-4
10. Chandrasekaran, N., 2010. Supply chain management: process, system, and practice. Oxford University Press, New Delhi. *ISBN- 9780198063025*
11. Christopher, M. (2016). "Logistics & Supply Chain Management." Pearson UK.
12. Council of Supply Chain Management Professionals (CSCMP). (2019). "Supply Chain Management: Processes, Partnerships, Performance." https://cscmp.org/
13. De, M., Sikarwar, S. and Kumar, V., 2017. Importance of efficient Multimodal local connectivity at transit hubs for effective implementation of Delhi Transit Oriented Development Policy 2012. DOI: 10.24321/2393.8307
14. Dhiman, A., Madan, P. (2023). Self-Assessment Industry 4.0 Maturity Model for Indian Manufacturing MSMEs (India Patent No. 202321031938). The Indian Patent Office. https://search.ipindia.gov.in/IPOJournal/Journal/Patent (Patent Publication)
15. Dutta, Ajay. (2023). Digital Infrastructure Development in India for Citizen Empowerment 11. 2320-2882. 10.1729/Journal.32631.
16. Ellram, L. M., & Cooper, M. C. (1990). "Supply Chain Management, Partnerships, and the Shipper-Third Party Relationship." International Journal of Logistics Management, 1(2), 1-10.
17. Enz, M. G., Ruel, S., Zsidisin, G. A., Penagos, P., Bernard Bracy, J., & Jarzębowski, S. (2024). Supply chain strategies in response to a black-swan event: A comparison of USA, French and Polish firms. *The International Journal of Logistics Management*, *35*(7), 1–32. https://doi.org/10.1108/IJLM-07-2023-0288
18. European Union Agency for Cybersecurity (ENISA). (2015). "Interoperability in Digital Public Infrastructures." https://www.enisa.europa.eu/
19. George, J., Pillai, V.M., 2019. A study of factors affecting supply chain performance. J. Phys.: Conf. Ser. 1355, 012018. https://doi.org/10.1088/1742-6596/1355/1/012018
20. Girdhar, R., The Critical analysis of open network for digital commerce in India.
21. Gupta, A. and Nair, A., 2023. Unpacking Digital Public Infrastructure: Navigating Conceptual Ambiguities.
22. Gupta, A., Rai, S., 2024. The Economic Case for Digital Public Infrastructure, https://carnegieindia.org/2024/02/29/economic-case-for-digital-public-infrastructure-pub-91839#:~:text=DPIs%20offer%20economic%20opportunities%20both,pay%20merchants%20in%20various%20countries.
23. Heeks, R. 2023 Digital Public Infrastructure: A new approach to delivery public services. Development policy review 38(2), 159-173.
24. Henfridsson, O. and Bygstad, B., 2013. The generative mechanisms of digital infrastructure evolution. MIS quarterly, pp.907-931.
25. Horscroft, P., & Braithwaite, A. (1990). Enhancing Supply Chain Efficiency - The Strategic Lead Time Approach. *The International Journal of Logistics Management*, *1*(2), 47–53.
26. https://doi.org/10.1108/09574099010804590
27. https://goulip.in/
28. https://logixtics.nldsl.in/
29. https://pib.gov.in/PressReleasePage.aspx?PRID=1864095
30. https://pmgatishakti.gov.in/pmgatishakti/about_pmgati
31. https://pmgatishakti.gov.in/pmgatishakti/n
32. https://www.india.gov.in/spotlight/pm-gati-shakti-national-master-plan-multi-modal-connectivity
33. Institute of Supply Management (ISM). (2020). "Supply Chain Productivity." https://www.ismworld.org/
34. International Telecommunication Union (ITU). (2017). "Open Standards for Sustainable Development." https://www.itu.int/en/Pages/default.aspx
35. Jambhale, S. (2023). Digital public infrastructure to unlock the potential of MSMEs. *Times of India*. Retrieved from https://timesofindia.indiatimes.com/blogs/voices/digital-public-infrastructure-to-unlock-the-potential-of-msmes/
36. Kakadel, R.B. and Veshne, N.A., 2017. Unified Payment Interface (UPI)–a way towards a cashless economy. *International Research Journal of Engineering and Technology*, *4*(11), pp.762-766.
37. Kapoor, A. and Watson, E., 2023. Defining the Digital Public Infrastructure Approach.
38. Kumar M N, V., M, H., 2023. An evaluation of open network for digital commerce (ONDC) implementation for Msme's in India IJTRET 07, 43–45. https://doi.org/10.54473/IJTRET.2023.7108

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages: 3982-3991

39. Kumar, B., &Gajakosh, A. R. (2021). MSMEs Issues and Prospectus of Uttarakhand: A Conceptual Investigation with Special Reference to COVID-19. *SEDME (Small Enterprises Development, Management & Extension Journal): A Worldwide Window on MSME Studies*, *48*(3), 299–310. https://doi.org/10.1177/09708464211073536
40. Kumar, S. (2022). Role of Micro, Small, and Medium Enterprises (MSMEs) in the industrial development of Uttarakhand. *International Journal of Scientific Development and Research (IJSDR)*, 7(9), 123-130. Retrieved from https://www.ijsdr.org/papers/IJSDR2209029.pdf
41. Lambert, D. M., & Pohlen, T. L. (2001). "Supply Chain Metrics." International Journal of Logistics Management, 12(1), 1-19.
42. Lhassan, I. A., Azdod, M., Razzouki, M., Bouayad, M., &Babounia, A. (2024). The contribution of balanced scorecard perspectives for improving supply chain performance: A PLS-SEM approach. Uncertain Supply Chain Management, 12(4), 2741–2752. https://doi.org/10.5267/j.uscm.2024.4.027
43. Maheshwari, A., 2023. Digital Public Infrastructure in India. Global Media Journal, 21(63), pp.1-3.
44. Mahmoud, A., Chouaki, T., & Puchinger, J. (2021). The Integration of Innovative Mobility into the Urban Transport Network: A Literature Review. In S. Mira-Bonnardel, F. Antonialli, & D. Attias (Eds.), *The Robomobility Revolution of Urban Public Transport* (pp. 153–166). Springer International Publishing. https://doi.org/10.1007/978-3-030-72976-9_7
45. Mentzer, J. T., Flint, D. J., & Hult, G. T. M. (2001). "Logistics Service Quality as a Segment-Customized Process." Journal of Marketing, 65(4), 82-104.
46. Moodley, S., Venter, C., 2022. Measuring the Service Quality at Multimodal Public Transport Interchanges: A Needs-Driven Approach. Transportation Research Record: Journal of the Transportation Research Board 2676, 194–206. https://doi.org/10.1177/03611981221088782
47. Neema, K. and Neema, A., 2016. UPI (Unified Payment Interface)–A new technique of Digital Payment: An Exploratory study. *International Journal of Current Research in Multidisciplinary*, *3*(10), pp.1-10.
48. Ning, L., Yao, D., 2023. The Impact of Digital Transformation on Supply Chain Capabilities and Supply Chain Competitive Performance. Sustainability 15, 10107. https://doi.org/10.3390/su151310107
49. Organisation for Economic Co-operation and Development (OECD). (2018). "Public Sector Innovation and E-Governance." https://www.oecd.org/
50. Pettersson, A., 2008. *Measurements of efficiency in a Supply chain* (Doctoral dissertation, Luleåtekniskauniversitet).
51. Raghavan, V., Jain, S., Varma, P., 2019. India stack---digital infrastructure as a public good. Commun. ACM 62, 76–81. https://doi.org/10.1145/3355625
52. Reddy M, S., G, G., 2023. PM-Gati Shakti: A Case Study of Demand Forecasting. https://doi.org/10.20944/preprints202308.0535.v1
53. Rodrigue, J. P., Comtois, C., & Slack, B. (2020). "The Geography of Transport Systems." Routledge.
54. Sankaran, P. (2024). MSME Day 2024: 'Digital public infrastructure laying foundation for MSMEs' digital growth'. *The Financial Express*. Retrieved from https://www.financialexpress.com/business/sme/msme-day-2024-digital-public-infrastructure-laying-foundation-for-msmes-digital-growth/3535865/
55. Saunders, L.W., Kleiner, B.M., McCoy, A.P., Lingard, H., Mills, T., Blismas, N., Wakefield, R., 2015. The effect of early supplier engagement on social sustainability outcomes in project-based supply chains. Journal of Purchasing and Supply Management 21, 285–295. https://doi.org/10.1016/j.pursup.2015.05.004
56. Seth, A., Vitagliano, L.F., Udupa, N., Singh, P.J., Swamy, R., Singh, S. and Venugopal, V., 2023. A Governance Framework for Digital Public Infrastructure: Learning from the Indian Experience.
57. Sharma, S.N., Tag: infrastructure. PM Gati Shakti's National Master Plan to provide multimodal connectivity infrastructure to various economic zones
58. Shukla, R.K., Garg, D. and Agarwal, A., 2011. Understanding of supply chain: A literature review. *International Journal of Engineering Science and Technology*, *3*(3), pp.2059-2072.
59. Singh, P.K., Maity, R. and Sarkar, T., 2013. Towards the best use of National Knowledge Network for knowledge sharing. *International Journal of Computer Applications*, *975*, p.8887.
60. Stevens, G.C., Johnson, M., 2016. Integrating the Supply Chain … 25 years on. International Journal of Physical Distribution & Logistics Management 46, 19–42. https://doi.org/10.1108/IJPDLM-07-2015-0175
61. Supply Chain Management Institute (SCMI). (2018). "Cost Management in Supply Chains." https://scm-institute.org/
62. United Nations Development Programme (UNDP). (2018). "Inclusive Digital Development." https://www.undp.org/
63. United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). (2019). "Review of Developments in Transport in Asia and the Pacific 2019." https://www.unescap.org/
64. Wang, X., Kumar, V., Kumari, A., Kuzmin, E., 2022. Impact of Digital Technology on Supply Chain Efficiency in Manufacturing Industry, in Kumar, V., Leng, J., Akberdina, V., Kuzmin, E. (Eds.), Digital Transformation in Industry, Lecture Notes in Information Systems and Organisation. Springer International Publishing, Cham, pp. 347–371. https://doi.org/10.1007/978-3-030-94617-3_25
65. World Bank. (2016). "Digital Dividends." https://www.worldbank.org/en/home
66. World Economic Forum (WEF). (2020). "The Future of Government Services: E-Governance and Digital Marketplaces." https://www.weforum.org/
67. Zhao, N., Hong, J., Lau, K.H., 2023. Impact of supply chain digitalization on supply chain resilience and performance: A multi-mediation model. International Journal of Production Economics 259, 108817. https://doi.org/10.1016/j.ijpe.2023.108817
68. Zhu, Z., Zhang, A., Zhang, Y., 2019. Measuring multimodal connections and connectivity radiations of transport infrastructure in China. Transportmetrica A: Transport Science 15, 1762–1790.
69. Zuckerman, E., 2020. What is digital public infrastructure? *The Center for Journalism and Liberty*.