Exploring Innovative Frontiers: Digital Public Infrastructure and Multimodal Connectivity as Catalysts for MSME Supply Chain Transformation in India

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ABSTRACT

India's industrial transformation is being rapidly reshaped by the rise of Digital Public Infrastructure (DPI), which integrates platforms such as ONDC, OCEN, UPI, and Gati Shakti to create transparent, inclusive, and technology-driven ecosystems. This paper critically examines how DPI strengthens supply chain dynamics for Micro, Small, and Medium Enterprises (MSMEs), particularly women and specially-abled entrepreneurs, by addressing challenges of digital access, financing, and multimodal connectivity. The research highlights that while India has made significant progress in building interoperable platforms, the adoption and integration of these systems across fragmented MSME clusters remain uneven. By synthesizing insights from existing literature and policy reports, the paper underscores the transformative potential of ONDC in democratizing e-commerce, OCEN in improving credit access, and Gati Shakti in enhancing logistics efficiency. The findings suggest that DPI does not function merely as a set of technological tools but as an institutional framework that redefines market entry, competitiveness, and resilience. However, barriers such as limited digital literacy, infrastructural gaps in rural areas, and concerns over data security continue to constrain full-scale adoption. The study also emphasizes the need for capacity building, robust governance frameworks, and collaborative approaches involving policymakers, private players, and grassroots stakeholders to ensure that MSMEs can leverage DPI effectively. Ultimately, the paper positions DPI as a catalyst for inclusive and sustainable industrial growth in India, capable of bridging structural divides while fostering innovation and competitiveness. The discussion aligns with the broader vision of Viksit Bharat 2047, underscoring how DPI-led supply chain transformation can accelerate India's transition into a global economic hub.

Keywords: Digital Public Infrastructure, MSMEs, Supply Chain Transformation, ONDC, Industrial Growth.

INTRODUCTION

India stands at an inflection point in its economic and technological trajectory: rapid digitalisation is converging with ambitious infrastructure upgrades to create new opportunities for industrial transformation and inclusive growth. Micro, Small and Medium Enterprises (MSMEs) long recognized as the backbone of India's manufacturing, employment and export performance are central to this transition. Yet many MSMEs remain constrained by fragmented logistics, limited market access, and uneven digital readiness. Emerging paradigms such as Digital Public Infrastructure (DPI) and multimodal connectivity promise to address these constraints by weaving an interoperable layer of digital services over increasingly integrated physical transport networks, thereby enabling MSMEs to scale, diversify, and participate more fully in domestic and global value chains (Khimani & Singhal, 2024; Raghavan, Jain, & Varma, 2019). Digital Public Infrastructure embodied by foundational platforms, open protocols, and interoperable public goods for payments, identity, data exchange and commerce has transformed the shape and speed of market participation in India (Raghavan et al., 2019; Mah Sheena K M et al., 2022). Initiatives such as India Stack, Open Network for Digital Commerce (ONDC) and related open-architecture efforts illustrate how public digital utilities can level the playing field for small sellers,

reduce entry barriers, and create a more competitive digital marketplace (Mah Sheena K M et al., 2022; Vijay Kumar & Harshitha, 2023). At the same time, digital tools from cloud-based enterprise resource planning to AI-enabled demand forecasting and blockchain-based traceability are redefining supply chain visibility, responsiveness and trust (Pratyush Kumar Singh, 2023; Acharya, Cisneros Saldana, & Markus, 2024). The literature documents robust gains in MSME productivity and market reach when DPI and enterprise-level digital capabilities are present, but it also highlights uneven adoption and capability gaps that limit the full promise of digital public goods (Arthi Jone & Dhanalakshmi, 2024; Buteau, n.d.). Parallel to digital advances, India's physical logistics ecosystem is undergoing a shift toward multimodal connectivity the coordinated use of road, rail, waterways and ports to optimize cost, time and environmental outcomes. Research on multimodal supply chains underscores how technological and organizational innovations in intermodal transfer, freight aggregation, and real-time data exchange can reduce transaction and transportation costs while improving reliability (Tavasszy, 2018; Cai, Sharkawi, & Taasim, 2024). Such connectivity is particularly consequential for MSMEs, which typically lack the bargaining power and scale enjoyed by large firms; access to optimized multimodal corridors can significantly lower inventory and distribution costs and enable MSMEs to access new markets with predictable lead times (Menon & Shah, 2020; Talluri & Ananthamurthy, 2022). Yet the literature also cautions that physical integration alone is insufficient: multimodality must be paired with interoperable information flows and governance frameworks to realize end-to-end efficiency gains (Hofman, 2015; Tavasszy, 2018).

The complementary relationship between DPI and multimodal connectivity is emerging as a critical research frontier. Digital platforms can orchestrate multimodal logistics by providing standardized data protocols, shipment tracking, marketplace integration and payment settlement effectively knitting together scattered transport assets and commercial actors into coordinated digital supply networks (Acharya et al., 2024; Hofman, 2015). Studies show that such digital-physical integration reduces coordination friction, lowers transaction costs, and supports supply chain diversification and resilience (Cai et al., 2024; Yin & Ran, 2022). For MSMEs, integrated digital-physical systems mean not only lower operational costs but also improved creditworthiness (through digital transaction trails), easier participation in formal procurement, and enhanced resilience to disruptions outcomes that align directly with national objectives of equitable growth and the Vision of a Viksit Bharat by 2047 (Simran Kaur, 2025; Bright, 2025).

Despite the promise, empirical and policy literatures identify several persistent barriers. First, infrastructural heterogeneity across regions "digital deserts" versus "tech havens" creates uneven competitive landscapes for MSMEs, with rural and smaller urban firms lagging in both connectivity and digital skills (Khimani & Singhal, 2024; Gawali, n.d.). Second, resource constraints (capital, managerial capabilities and digital literacy) impede the adoption of sophisticated supply-chain technologies among micro and small enterprises (Khandelwal & Priya, 2024; Pandey, 2024). Third, institutional fragmentation and lack of interoperable standards constrain the formation of federated data pipelines necessary for seamless multimodal operations (Hofman, 2015; Raghavan et al., 2019). Finally, technology adoption without parallel process redesign and capacity building often leads to sub-optimal outcomes, as many organizations fail to reengineer their business processes to exploit new digital tools (Zika, 2022; Choudhury et al., 2021). These gaps point to a systemic problem: piecemeal interventions yield gains for some firms but do not create a broad-based, sustainable transformation of MSME supply chains. The literature also highlights the strategic role of policy and public-private collaboration in accelerating inclusive digitalisation. Government-led initiatives such as ONDC and the broader India Stack demonstrate the catalytic potential of open public goods in stimulating private innovation and bringing small sellers into digital marketplaces (Mah Sheena K M et al., 2022; Government initiatives and digital innovation studies). Scholars argue for an integrated policy mix that combines infrastructure investment, incentives for digital adoption, skilling programs, and regulatory frameworks that encourage interoperability and competition (Buteau; Mah Sheena et al., 2023). Moreover, several studies emphasize that resilience and sustainability including green supply chain practices should be embedded in the digitalisation agenda to ensure long-term competitiveness and ecological stewardship (Zainurrafiqi & Gazali, 2024; Menon & Shah, 2020).

A clear gap in the existing body of work lies at the intersection of DPI, multimodal connectivity and MSME supply chain performance at the regional level especially with respect to integrated frameworks that translate national digital public goods into locally relevant logistics solutions. While many studies document the benefits of digitalisation or of improved physical connectivity in isolation (Pratyush Kumar Singh, 2023; Tavasszy, 2018),

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fewer examine how DPI can be intentionally designed to enable multimodal corridor orchestration that directly serves MSME clusters, including small manufacturers, Agri-processors and micro-retailers. Likewise, evidence is limited on how federated data architectures, open commerce networks and interoperable payment/credit rails can be coordinated with modal investments (e.g., rail freight modernization, inland waterways and last-mile road upgrades) to produce measurable improvements in cost, lead time and market access for MSMEs (Hofman, 2015; Cai et al., 2024). This study addresses that gap by interrogating how Digital Public Infrastructure and multimodal connectivity together can catalyse supply-chain transformation for MSMEs within the framework of India's Vision for Viksit Bharat 2047. The research asks: (1) What are the mechanisms through which DPI lowers transaction and coordination costs across multimodal logistics chains for MSMEs? (2) How can public digital goods and open protocols be aligned with regional multimodal investments to maximize MSME participation in formal markets? (3) What institutional and capability interventions are necessary to ensure equitable outcomes across diverse MSME clusters? Drawing on the literature on digital public goods, supply chain digitization, multimodal logistics and MSME policy, this paper proposes an integrated conceptual framework and empirically grounded recommendations for policymakers, platform designers and industry stakeholders (Khimani & Singhal, 2024; Acharya et al., 2024; Tavasszy, 2018).

The dual thrust of this introduction is to situate MSME supply-chain challenges within the twin possibilities of DPI and multimodal connectivity, and to argue that their deliberate integration rather than isolated deployment is essential for driving inclusive industrial transformation. The sections that follow review the empirical and conceptual literature in greater depth, develop an integrative analytical framework, and present policy and practice recommendations for catalyzing MSME competitiveness in the digital-physical economy that India aspires to build by 2047 (Simran Kaur, 2025; Bright, 2025).

LITERATURE REVIEW

The discourse on Digital Public Infrastructure (DPI), multimodal connectivity, and Micro, Small, and Medium Enterprises (MSMEs) is rapidly expanding, reflecting India's aspiration toward Vision Viksit Bharat 2047. Scholars agree that MSMEs form the backbone of the Indian economy, contributing significantly to employment, exports, and innovation. However, persistent barriers such as fragmented supply chains, high logistics costs, and limited access to formal credit hinder their growth. The literature converges on the argument that DPI and multimodal connectivity offer transformative pathways for resolving these challenges by improving efficiency, inclusivity, and competitiveness. A growing body of research explores the role of DPI in reshaping MSME operations. Khimani and Singhal (2024) highlight how robust digital platforms enhance inclusivity by bridging gaps in access to finance, digital tools, and marketplaces. Their findings suggest that foundational digital infrastructure such as India Stack and the Unified Payments Interface (UPI) lower transaction costs and expand participation for smaller firms. Similarly, Mah Sheena K. M. et al. (2022) examine the Open Network for Digital Commerce (ONDC) and show that open protocols reduce entry barriers, enabling MSMEs to connect with broader consumer markets. These studies collectively argue that DPI functions as a "public good," leveling the playing field for enterprises of varied scales. At the enterprise level, advanced digital technologies like blockchain, artificial intelligence (AI), and Internet of Things (IoT) are increasingly integrated into supply chains. Singh (2023) emphasizes how blockchain enhances transparency and trust in supply chain transactions, while AI and IoT improve demand forecasting and real-time tracking. Acharya, Cisneros Saldana, and Markus (2024) develop "SuppliFlow," a digital platform designed to orchestrate multimodal logistics, underscoring how digital interventions enable coordinated, efficient, and sustainable supply chains. These findings resonate with Arthi Jone and Dhanalakshmi (2024), who argue that digital adoption boosts MSME productivity and market competitiveness, though adoption gaps persist.

The literature also acknowledges challenges related to uneven digital readiness. Buteau (n.d.) notes that while digital technologies empower MSMEs, disparities in digital literacy and resource availability create uneven benefits. Sumitra (2023) similarly emphasizes that without complementary policy support and capacity building, MSMEs risk exclusion from digital ecosystems. Gawali (n.d.) stresses the importance of bridging the rural-urban divide, warning that digital deserts could deepen inequities if left unaddressed. Together, these studies indicate that while digital platforms are transformative, equitable adoption requires systemic support. Parallel to digitalisation, research on multimodal connectivity highlights its crucial role in reducing India's high logistics

costs. Tavasszy (2018) and Menon and Shah (2020) demonstrate that multimodal transport corridors integrating road, rail, waterways, and air transport reduce time, cost, and carbon footprint. Cai, Sharkawi, and Taasim (2024) further explore how digital tools enhance multimodal efficiency through real-time tracking and route optimization. These findings are particularly significant for MSMEs, which typically lack scale economies and rely on predictable, affordable logistics to remain competitive. Talluri and Ananthamurthy (2022) confirm that improved multimodal corridors empower MSMEs by ensuring reliable access to markets. Hofman (2015) provides a conceptual foundation for integrated logistics systems, arguing that physical connectivity must be paired with digital data interoperability for maximum gains. This insight echoes Yin and Ran (2022), who emphasize that integrated digital-physical systems reduce coordination friction, enhance resilience, and support diversified supply networks. The synergy between DPI and multimodal logistics thus emerges as a critical theme: while digital platforms orchestrate flows of information, multimodal networks optimize flows of goods. A number of studies bridge the gap between digitalisation and logistics. Acharya et al. (2024) propose that DPI-enabled platforms can serve as orchestrators of multimodal logistics by ensuring standardized data exchange, digital payments, and shipment visibility. Similarly, Hofman (2015) highlights the need for federated data pipelines to coordinate multiple stakeholders across transport modes. These insights are corroborated by Cai et al. (2024), who find that integrated systems not only improve efficiency but also enhance MSME creditworthiness by providing digital transaction records useful for financial institutions. Simran Kaur (2025) further argues that such integration aligns with the national vision of a resilient, inclusive, and competitive India by 2047. The literature also identifies barriers to seamless integration. Khandelwal and Priya (2024) point to capital constraints that prevent small firms from adopting advanced supply chain technologies. Pandey (2024) highlights managerial and operational bottlenecks, noting that many MSMEs struggle to adapt business processes to new digital environments. Zika (2022) and Choudhury et al. (2021) argue that technology adoption without organizational restructuring produces suboptimal outcomes, as digitisation must be accompanied by process redesign and workforce upskilling. Together, these findings suggest that infrastructural investments must be complemented by capacity-building measures.

Policy interventions emerge as a recurring theme in the literature. Mah Sheena et al. (2022) stress the importance of government-led initiatives such as ONDC, which catalyze private innovation while ensuring inclusivity. Buteau (n.d.) and Mah Sheena et al. (2023) recommend integrated policy frameworks that combine infrastructure investment with digital literacy programs and regulatory support for interoperability. Bright (2025) and Simran Kaur (2025) reinforce this view by underscoring the role of DPI in advancing the goals of Vision Viksit Bharat 2047, particularly in fostering inclusive growth and global competitiveness. Another important dimension concerns sustainability. Menon and Shah (2020) and Zainurrafiqi and Gazali (2024) emphasize that supply chain reforms must also account for environmental impacts. Studies on green supply chains suggest that combining digital optimization with multimodal transport reduces emissions and improves long-term sustainability. This perspective expands the significance of DPI and multimodal integration beyond efficiency and competitiveness, situating them within broader ecological and developmental goals. Despite the robust literature, gaps remain. Few studies examine how DPI-enabled multimodal logistics specifically benefit MSME clusters in different regions of India. Most existing research either focuses on national-level frameworks (e.g., ONDC, India Stack) or examines logistics improvements in isolation. Hofman (2015) and Tavasszy (2018) provide conceptual models, but empirical evidence on how federated digital systems interact with multimodal corridors to reduce MSME logistics costs is limited. Similarly, the literature rarely addresses how digital transaction trails created through DPI can directly influence MSME access to formal credit markets. These gaps suggest the need for integrated, context-specific frameworks that align national digital platforms with regional connectivity initiatives. Overall, the reviewed literature underscores three central insights. First, DPI is essential for democratizing access to digital tools, markets, and finance, especially for MSMEs. Second, multimodal connectivity offers structural solutions to India's high logistics costs, improving competitiveness across industries. Third, the integration of digital and physical infrastructures is key to unlocking transformative supply chain efficiencies. However, persistent gaps in adoption, capacity, and policy coordination highlight the need for holistic strategies that combine technological, institutional, and infrastructural interventions. This body of scholarship provides the foundation for exploring how DPI and multimodal connectivity can jointly catalyse MSME supply chain transformation. By integrating digital public goods with physical logistics infrastructure, India has the potential to drive inclusive growth, enhance resilience, and realize its vision of becoming a developed nation by 2047.

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Table 1: Literature Review Table

Sr. No.	Author(s)	Year	Focus	Key Findings	Relevance
1	Khimani & Singhal	2024	Digital infrastructure & MSME competitiveness	Transition from "digital deserts" to "tech havens" enhances innovation & growth	Shows role of infrastructure in MSME competitiveness
2	Mah Sheena K M, Aithal & Sharma	2022	ONDC for SMEs/MSMEs	ONDC enables fair digital commerce & inclusive growth	Highlights e-commerce democratization
3	Acharya, Cisneros & Markus	2023	Supply Chain as a Service	SuppliFlow improves efficiency, reduces cost, enhances visibility	Standardized integration for MSMEs
4	Arthi Jone & Dhanalakshmi	2024	Digital transformation & MSME growth	Boosts productivity & market reach	Policy push for digital adoption
5	(Anon.)	2023	Digital supply chain in India	IoT, AI, blockchain improve efficiency; infra gaps remain	Shows digital opportunities & challenges
6	Sharon	2021	Roadmap for digital MSMEs	End-to-end ecosystem with finance, payments, skills	Calls for govt.–user–provider collaboration
7	Sumitra	2021	Digital transformation survival for MSMEs	Essential for competitiveness amidst crises	Practical strategies for survival
8	Gawali	2022	MSME constraints & digital solutions	Transformation improves productivity & competitiveness	Provides way forward
9	Benkhider et al.	2024	Supply chain transformation	Connectivity improves resilience, transparency	Useful for resilient MSMEs
10	Vijay Kumar & Harshitha	2023	ONDC implementation	Empowers MSMEs & challenges monopolies	Important for small retailers
11	Tiwari et al.	2024	Supply chain digitisation	ERP, IoT, blockchain enhance resilience & trust	Builds traceable supply chain
12	Zainurrafiqi & Gazali	2024	Green & digital supply chain	Positive impact on MSME performance	Shows competitiveness–resilience link
13	Harshitha	2023	ONDC evaluation	Opportunities for MSMEs, curbs monopolies	Relevance for e-commerce adoption
14	Cai et al.	2024	Digitalization & diversification	Lowers transaction costs & improves resilience	Key to supply security

15	Choudhury et al.	2021	Critical success factors in digital SC	12 CSFs identified, TISM model	Framework for SC efficiency
16	Yu et al.	2024	Digital transformation & innovation	Improves collaborative innovation & market performance	Explains innovation pathways
17	Yin & Ran	2022	Supply chain resilience	Diversification + digitalization improve resilience	fsQCA method insights
18	Hofman	2015	Global data pipelines	Need interoperability for logistics	Anticipates global DPI
19	Bright	2025	Digital MSMEs	Ecosystem essential for growth	Reinforces digital policy goals
20	Datta	2024	Digital tech for resilience	Govt + users support ecosystem	Shows resilience-building role
21	Khandelwal & Priya	2024	MSME digital challenges	Growth prospects, but tech knowhow gaps	Policy + skilling need
22	Hemdev	2024	SCM in India	Innovations drive competitiveness	India's path to global hub
23	Vandita & Srivastava	2023	Digitalization in MSMEs	Covid-19 accelerated adoption	Explains survival digitalization
24	Kaur	2025	Commerce role in Viksit Bharat	MSMEs + digital infra vital	Strategic roadmap
25	Menon & Shah	2020	Digital SC for SMEs	Adoption crucial for survival	Warns against lack of awareness
26	Kasim	2023	Digital-based transformation	Improves efficiency & literacy matters	Role of digital literacy
27	Timur	2023	Digital SC challenges	SMEs lag despite benefits	Covid highlighted need
28	Tavasszy	2018	Innovation in multimodal SC	Tech improves efficiency & sustainability	Important for multimodality
29	Mudda et al.	2017	Agriculture SC digitization	IT empowers small farmers	Agriculture supply chain
30	Mah Sheena K M et al.	2023	Govt schemes & MSMEs	ONDC, OCEN, NDEA boost productivity	Govt role in MSME uplift
31	Khatri et al.	2023	Covid impact on MSMEs	Accelerated digitalization	Pandemic-driven adoption
32	(Anon.)	2022	Blockchain in MSMEs SC	Streamlines SC, improves efficiency	Tech adoption gap
33	Pandey et al.	2024	Need for SME digitalization	Improves efficiency & quality	Highlights adoption barriers

34	Jha	2021	Industry 4.0 in SMEs	Evidence of adoption challenges	Industrial readiness
35	Bhattacharya et al.	2022	Enablers of disruption mitigation	Seven enablers, top management crucial	MSME resilience factors
36	Talluri & Ananthamurthy	2022	SC digitalization in mfg	Positive influence on performance	Empirical MSME mfg study
37	Majumdar et al.	2020	E-commerce & ASEAN	Digital connectivity links SMEs	Regional integration
38	Melekhova	2019	Digital SC models	Flexibility & reliability via ML & blockchain	Classification model
39	Wang	2024	SC digitization & business	Impacts digital transformation success	Case analysis
40	Raghavan et al.	2019	India Stack	Smartphone penetration + DPI	Foundation of DPI
41	Shaikh	2024	Digital SC & economy	Enhances efficiency & reduces costs	Business development
42	Pandey	2024	MSMEs & GVCs	Challenges & policy recs	Global supply chain integration
43	Khan & Uddin	2023	Managerial digitalization	Skills crucial for MSME performance	Human capital in digital adoption
44	Khmelnitskaya & Sizov	2020	Digital SC network	SC efficiency via tested systems	Transformation examples
45	Thatai	2016	Digital India initiative	9 pillars for transformation	Foundational national mission
46	Zika	2022	SC procurement	Improves visibility & transparency	Lessons on digital failure
47	Singh	2023	AI & ML in SC	Enhance forecasting & decision-making	Next-gen SCM
48	Tripathi & Gupta	2021	India readiness for Industry 4.0	Readiness score 0.44, govt role	Readiness assessment

RESEARCH METHODOLOGY

The present study adopts a qualitative and exploratory research design, relying primarily on a comprehensive review of secondary sources. The methodology is structured to systematically analyse existing scholarship, identify knowledge gaps, and derive research objectives that align with the overarching aim of understanding the role of Digital Public Infrastructure (DPI) and multimodal connectivity in transforming MSME supply chains for Vision Viksit Bharat 2047. The first step involved the identification and collection of relevant academic literature. Nearly fifty research papers were reviewed, representing diverse sources from peer-reviewed journals, conference proceedings, institutional reports, and policy documents. These papers were accessed through established databases such as Scopus, Web of Science, Google Scholar, and ResearchGate, ensuring both breadth and credibility in the selection of literature. The time frame of the sources spanned from foundational works on multimodal logistics and supply chain management to more recent studies on digital public goods, digitalisation,

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and MSME competitiveness, providing both historical and contemporary perspectives. The second step entailed content analysis of the reviewed literature. Each paper was examined for its study objectives, theoretical underpinnings, research design, and key findings. Special attention was paid to works addressing MSMEs, DPI, digitalisation of supply chains, and multimodal logistics in the Indian and global contexts. A structured literature review table was created, capturing citation details, study focus, and key contributions. This systematic organisation facilitated comparative analysis and highlighted recurring themes, contradictions, and underexplored areas. The third step involved synthesising insights from the reviewed literature to identify gaps. The analysis revealed that while extensive studies exist on DPI and multimodal connectivity separately, few explore their combined potential in addressing MSME supply chain challenges. Furthermore, empirical work linking DPI-enabled logistics with MSME credit access, regional cluster competitiveness, and sustainability remains limited. These insights formed the basis of the research gap outlined in this study.

Finally, the research objectives were developed by translating the identified gaps into focused questions and directions for inquiry. The objectives serve as guiding pillars for further empirical or conceptual research and are designed to contribute both to academic discourse and policy formulation. This study employs a literature-based methodology that integrates systematic review, content analysis, and thematic synthesis. By critically engaging with approximately fifty research papers across multiple databases, the methodology ensures rigor, comprehensiveness, and relevance in framing the research gap and objectives. This approach provides a robust foundation for subsequent exploration of how DPI and multimodal connectivity can jointly catalyse MSME supply chain transformation in India.

Research Gap

The reviewed literature provides valuable insights into the transformative potential of Digital Public Infrastructure (DPI) and multimodal connectivity for supply chain management, especially in the context of Micro, Small, and Medium Enterprises (MSMEs). While extensive studies explore the individual impacts of digitalisation and logistics integration, a significant research gap emerges at their intersection, particularly in relation to MSME supply chains in India. First, the literature is fragmented in its treatment of DPI and multimodal connectivity. Studies on DPI largely focus on digital public goods such as India Stack, Unified Payments Interface (UPI), and the Open Network for Digital Commerce (ONDC), highlighting their roles in democratizing market access, reducing transaction costs, and fostering inclusivity. Parallel research on multimodal connectivity emphasizes the importance of integrating road, rail, waterways, and ports to improve logistics efficiency and reduce costs. However, very few studies examine how these two domains converge to generate integrated supply chain benefits. This disconnect represents a critical gap, as MSMEs are most likely to gain from systems where digital and physical infrastructures are designed to complement one another. Second, much of the existing scholarship remains conceptual or descriptive, with limited empirical evidence on how DPI-enabled multimodal connectivity impacts MSME operations at the cluster or regional level. For instance, while Acharya et al. (2024) propose digital platforms such as SuppliFlow for logistics orchestration, empirical validation of such frameworks in real-world MSME contexts remains sparse. Similarly, studies by Hofman (2015) and Tavasszy (2018) present conceptual models for integrated logistics systems but do not address how these can be operationalized within the Indian MSME ecosystem. This lack of grounded empirical work restricts our understanding of context-specific challenges and opportunities. Third, the literature underexplores the role of DPI in addressing financial constraints faced by MSMEs. Several studies point to the importance of digital transaction records in improving creditworthiness, but empirical analyses linking DPI-enabled supply chain visibility to formal credit access are largely absent. This omission is significant because access to affordable finance remains one of the most pressing challenges for MSMEs, and DPI could serve as a bridge by creating transparent digital trails that lenders can rely on. Fourth, there is limited exploration of capacity-building and institutional readiness for adopting integrated digital-physical systems. Scholars such as Zika (2022) and Choudhury et al. (2021) stress that technology adoption without process redesign leads to suboptimal outcomes. Yet the literature offers little guidance on how MSMEs particularly micro and rural enterprises can overcome digital literacy gaps, managerial constraints, and infrastructural limitations when engaging with DPI and multimodal networks. This gap points to the need for research that not only considers technological design but also addresses institutional mechanisms, skilling programs, and governance frameworks necessary for successful adoption.

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Finally, sustainability considerations are underrepresented in the integrated discussion of DPI and multimodal connectivity. While individual studies highlight green supply chains and multimodal transport's role in reducing emissions, very few examine how digital platforms can be harnessed to monitor, manage, and optimize sustainable practices across supply chains. This represents an opportunity to link MSME competitiveness with broader environmental and developmental goals, aligning supply chain transformation with India's sustainability commitments. The literature establishes the foundational importance of DPI and multimodal connectivity for MSME growth but leaves critical questions unanswered: How can DPI be deliberately designed to orchestrate multimodal supply chains for MSMEs? What mechanisms ensure that these integrations translate into measurable improvements in cost efficiency, credit access, and market expansion? How can policy frameworks and institutional support systems be structured to enable equitable adoption across diverse clusters? And how can sustainability be embedded into this integration? Addressing these gaps is essential for developing an evidence-based framework that aligns with India's vision of a digitally empowered and logistically efficient Viksit Bharat by 2047.

Research Objectives

RO1: To examine how Digital Public Infrastructure (DPI) lowers transaction and coordination costs across multimodal supply chains for MSMEs in India.

RO2: To investigate how the integration of DPI with multimodal connectivity can enhance MSME access to markets, finance, and formal supply chain networks.

RO3: To analyze the institutional, infrastructural, and capacity-building challenges that hinder MSMEs from fully adopting integrated digital-physical supply chain systems.

RO4: To propose a conceptual framework that aligns DPI and multimodal connectivity with the policy vision of Viksit Bharat 2047, focusing on efficiency, inclusivity, and sustainability.

India's Digital Public Infrastructure (DPI): A Revolution in Inclusion:

India's Digital Public Infrastructure (DPI) represents one of the most ambitious and transformative public digital initiatives in the world. At its core, DPI is designed as a set of secure, interoperable, and open-standard digital systems that enable equitable access to essential services at scale. Unlike proprietary digital ecosystems that often exclude vulnerable groups, India's DPI is framed as a societal-level public good, ensuring that every citizen regardless of geography, income, or social status can participate in the digital economy.

The Foundation of DPI

The foundation of India's DPI lies in its open, secure, and interoperable architecture. By adhering to open standards, it ensures that multiple stakeholders from government agencies to private enterprises can build upon the same base without creating fragmented or siloed systems. This design principle is critical for inclusion, as it prevents monopolization and ensures that citizens can access services through diverse channels. DPI is not just a technological framework but also a governance innovation that balances scale, accessibility, and security.

Core Components of DPI

The success of India's DPI can be traced to its three core components, which function synergistically to empower citizens:

- **Aadhaar:** With over 1.4 billion unique digital identities, Aadhaar serves as the foundation for identity verification and service delivery. It has enabled millions to access welfare benefits, open bank accounts, and authenticate themselves in the digital economy. Aadhaar reduces duplication, curbs fraud, and ensures that benefits reach the intended recipients efficiently.

- **Unified Payments Interface (UPI):** UPI has revolutionized India's financial ecosystem by allowing seamless, real-time, and low-cost digital payments. It is interoperable across banks, fintech platforms,

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and merchants, ensuring that even small businesses and individuals can engage in digital transactions. For MSMEs and rural populations, UPI has been a lifeline, enabling financial inclusion and expanding access to markets.

- **Data Empowerment and Protection Architecture (DEPA):** DEPA provides individuals with control over their personal data while enabling them to use it productively. By empowering citizens to share verified data with consent, DEPA supports access to credit, insurance, and other critical services. This framework balances innovation with privacy and security, addressing global concerns about data misuse.

Transformative Impact of DPI

The impact of DPI has been profound. Financial inclusion in India has surged from around 17 percent to over 80 percent in less than a decade, driven largely by the synergy of Aadhaar-enabled authentication, Jan Dhan Yojana bank accounts, and UPI-based transactions. Subsidy leakages, once a chronic issue in welfare distribution, have been significantly reduced saving the government an estimated $25 billion annually. These savings not only improve fiscal efficiency but also ensure that resources are redirected toward development priorities. Beyond numbers, DPI has democratized access to essential services such as healthcare, education, and e-commerce. By lowering transaction costs, enhancing transparency, and creating digital trails, it has also expanded credit access for small businesses and individuals who were previously excluded from the formal financial system. The ability of DPI to scale equitably makes it a model for other developing countries seeking to combine digital innovation with inclusion.

India's Digital Public Infrastructure is more than a technological framework; it is a societal innovation that bridges the digital divide and fosters inclusion at scale. By integrating identity, payments, and data empowerment, DPI has transformed the way citizens access services and participate in the economy. Its success demonstrates that digital systems, when designed as public goods, can drive both economic efficiency and social equity. As India advances toward Vision Viksit Bharat 2047, DPI will remain a cornerstone of inclusive growth and a benchmark for global digital governance.

Credit Enablement Network (OCEN): Democratizing MSME Credit Access:

Micro, Small, and Medium Enterprises (MSMEs) play a pivotal role in India's economy by contributing significantly to employment, manufacturing, and exports. However, one of the greatest barriers faced by MSMEs has been access to affordable and timely credit. Traditional financial institutions often view these enterprises as high-risk due to the lack of collateral, limited formal records, and irregular cash flows. As a result, MSMEs have long been trapped in a cycle of credit exclusion, relying on informal lending channels that impose high interest rates and constrain growth. To address this systemic challenge, the Credit Enablement Network (OCEN) has emerged as a groundbreaking digital framework aimed at democratizing credit access for MSMEs.

Digital Footprint Analysis

At the heart of OCEN lies the use of digital transaction data to create accurate and reliable credit profiles for MSMEs. Instead of relying solely on collateral or traditional financial statements, OCEN leverages the digital footprints generated by businesses through payments, invoices, and other transactions. By aggregating and analyzing this data, lenders can build a clearer picture of an MSME's financial health and operational viability. This approach helps overcome the asymmetry of information that has historically disadvantaged small enterprises in formal lending.

Streamlined Application Process

Another key feature of OCEN is its ability to simplify the loan application process. MSMEs traditionally face significant paperwork, complex procedures, and repeated compliance requirements when approaching banks for credit. OCEN eliminates much of this friction by standardizing the application process and reducing dependency on collateral. By connecting borrowers, lenders, and digital platforms through a common protocol, it ensures

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that loan applications can be processed quickly and transparently. This not only reduces transaction costs but also improves trust between lenders and MSMEs.

Expanded Credit Availability

OCEN enables financial institutions to design tailored financing solutions that reflect the actual performance of MSMEs. Since creditworthiness is assessed through real-time business data rather than static financial records, lenders can extend credit even to those firms previously excluded from formal banking systems. This expands the availability of credit and makes it more inclusive, particularly for micro and rural enterprises that form the majority of India's MSME sector. By diversifying risk assessment methods, OCEN also encourages more lenders to participate in the MSME financing ecosystem.

Growth and Job Creation

The ultimate impact of OCEN is visible in its potential to foster growth and job creation. Access to affordable credit allows MSMEs to invest in technology, scale up operations, and expand into new markets. This in turn creates sustainable employment opportunities and drives regional economic development. By linking digital public infrastructure with credit access, OCEN also strengthens financial inclusion and aligns with India's long-term development goals under Vision Viksit Bharat 2047.

The Credit Enablement Network represents a paradigm shift in how credit is assessed, delivered, and consumed in the MSME sector. By leveraging digital footprints, streamlining processes, expanding credit availability, and fueling growth, OCEN has the potential to democratize finance for millions of enterprises. It transforms credit from being an obstacle into a growth enabler, thereby ensuring that MSMEs the backbone of India's economy are equipped to thrive in the digital era.

DISCUSSION

The emergence of Digital Public Infrastructure (DPI) marks a defining moment in India's journey toward industrial transformation. Unlike isolated technology interventions, DPI operates as a system of interoperable platforms that reconfigure how businesses, markets, and governments interact. This section discusses the findings in relation to the four research objectives, highlighting both opportunities and constraints in strengthening supply chain dynamics for India's MSME clusters.

To analyze the role of DPI in strengthening MSME supply chains in India

Digital Public Infrastructure has become the backbone of inclusive industrial growth by providing MSMEs with platforms that reduce entry barriers, lower transaction costs, and increase visibility in national and global markets. For example, ONDC (Open Network for Digital Commerce) democratizes e-commerce by creating an open and interoperable network where small retailers can list their products alongside large corporations. This directly challenges the dominance of monopolistic platforms while giving MSMEs fairer access to customers. Similarly, OCEN (Open Credit Enablement Network) redefines credit access by enabling cash-flow–based lending rather than asset-based financing, a structural shift that benefits undercapitalized entrepreneurs. The adoption of these platforms has already shown positive results in MSME clusters engaged in textiles, handicrafts, and food processing, where supply chains are typically fragmented. ONDC allows these producers to bypass intermediaries, leading to better margins and greater transparency. Additionally, DPI-driven logistics initiatives, such as PM Gati Shakti, improve multimodal connectivity, enabling MSMEs to integrate more seamlessly with domestic and export markets. Thus, DPI not only strengthens operational efficiency but also enhances resilience by making supply chains more adaptive to disruptions such as the COVID-19 pandemic.

To evaluate the potential of DPI in promoting inclusivity for women and specially-abled entrepreneurs

A distinctive strength of DPI lies in its inclusive design philosophy. By embedding accessibility and interoperability, DPI platforms provide opportunities for marginalized groups traditionally excluded from industrial growth. Women entrepreneurs, who face systemic barriers such as limited mobility, lack of collateral,

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and time constraints, benefit from ONDC-enabled digital storefronts that reduce dependency on physical marketplaces. Similarly, OCEN-backed microcredit mechanisms give women-led businesses and specially-abled entrepreneurs access to working capital without lengthy bureaucratic procedures. Evidence suggests that women-led MSMEs adopting digital tools demonstrate higher revenue growth and greater resilience to market shocks. For specially-abled entrepreneurs, DPI platforms that integrate assistive technologies (voice commands, simplified interfaces, and vernacular support) remove critical barriers to participation. These advances directly contribute to social equity, ensuring that industrial transformation does not remain limited to resource-rich actors but instead empowers groups historically left behind. However, inclusivity is not automatic. Persistent gender gaps in digital literacy, unequal access to devices, and cultural biases restrict participation. Similarly, while DPI frameworks are technically inclusive, their successful implementation requires capacity-building programs that train entrepreneurs to navigate digital systems confidently. Without such interventions, there is a risk of reinforcing rather than dismantling inequalities.

To examine challenges in the adoption and implementation of DPI in MSME supply chains

Despite the promise of DPI, its adoption across India's diverse MSME clusters faces substantial challenges. The first and most visible challenge is the digital divide. Rural and semi-urban clusters, where many MSMEs operate, still suffer from patchy internet connectivity, low bandwidth, and limited access to affordable devices. This restricts their ability to fully leverage platforms like ONDC or logistics tools embedded in Gati Shakti. The second challenge lies in digital literacy and trust. Many MSME owners remain hesitant to engage with digital platforms due to limited technical knowledge and concerns over data security, privacy, and fraud. For instance, while ONDC promises transparency, small entrepreneurs may still distrust algorithm-driven visibility or fear being overshadowed by larger, tech-savvy competitors. Third, institutional and regulatory readiness remains uneven. While policy frameworks such as the Data Protection Act and DPI guidelines exist, their enforcement is still evolving. MSMEs worry about compliance costs, cyber threats, and the complexity of aligning their operations with multiple digital frameworks simultaneously. Finally, financing adoption poses hurdles. Although OCEN enables cash-flow–based lending, many MSMEs are reluctant to borrow due to prior experiences with debt traps or hidden costs. Without strong financial literacy programs, credit access risks becoming underutilized. These challenges underscore that DPI's transformative potential can only be realized through multi-stakeholder collaboration involving government, private players, technology providers, and grassroots organizations.

To suggest strategies for leveraging DPI to ensure resilient and competitive MSME ecosystems

To move from promise to practice, India must focus on strategies that bridge gaps in infrastructure, literacy, and governance. First, capacity-building initiatives tailored to MSME clusters are essential. Training programs should focus on digital literacy, cybersecurity awareness, and the practical use of platforms like ONDC and OCEN. Partnerships with local trade associations and NGOs can amplify reach and contextualize training. Second, targeted infrastructure investments are required in rural and semi-urban areas to ensure equitable access to high-speed internet and affordable devices. Public–private partnerships can accelerate the rollout of connectivity solutions, enabling MSMEs in remote areas to participate fully in DPI ecosystems. Third, fostering trust and adoption requires transparent governance mechanisms. Clear regulations on data protection, algorithmic fairness, and grievance redressal will increase confidence among small entrepreneurs. Moreover, platforms must adopt human-centric design, offering vernacular language support, simple navigation, and features tailored for women and differently-abled users. Finally, the integration of sustainability principles within DPI is critical. By embedding environmental, social, and governance (ESG) frameworks into supply chain platforms, India can ensure that digital transformation does not come at the expense of long-term ecological and social well-being. MSMEs adopting green practices can be incentivized through preferential lending on OCEN or visibility boosts on ONDC, aligning competitiveness with sustainability.

DPI is not just a technological framework but a socio-economic transformation tool. Its impact is evident across supply chain efficiency, inclusivity, and resilience. Yet, successful adoption requires addressing structural challenges that impede equitable access. By aligning policy, infrastructure, and stakeholder participation, DPI can become the cornerstone of India's industrial transition, driving both competitiveness and social equity in line with the aspirations of Viksit Bharat 2047.

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CONCLUSION

India's industrial transformation is at a critical juncture where technology, policy, and entrepreneurship converge. This study set out to explore how Digital Public Infrastructure (DPI) through platforms like ONDC, OCEN, and PM Gati Shakti can strengthen supply chain dynamics for MSMEs, with particular attention to women and specially-abled entrepreneurs. The findings confirm that DPI is more than a technological innovation; it is an institutional framework that redefines access, efficiency, and inclusivity within India's supply chains. First, the research highlights DPI's ability to democratize markets and finance. ONDC enables small firms to compete with established players by creating open, interoperable e-commerce networks. Similarly, OCEN's shift to cash-flow–based lending empowers undercapitalized MSMEs to secure credit without the traditional barriers of collateral or credit history. These structural changes not only level the playing field but also increase resilience by reducing dependency on intermediaries and informal lenders. Second, inclusivity emerges as both a strength and a challenge. Women and specially-abled entrepreneurs benefit from the accessibility of digital storefronts, simplified credit systems, and supportive logistics infrastructure. However, without targeted capacity building, the risk of digital exclusion persists. Bridging gendered digital divides, designing assistive interfaces, and offering vernacular support remain critical tasks for policymakers and platform developers alike. Third, adoption challenges underscore the complex reality of implementation. Infrastructure deficits, low digital literacy, and concerns over trust and data privacy limit the speed and scale of DPI penetration, particularly in rural and semi-urban MSME clusters. Unless these barriers are systematically addressed, DPI risks reinforcing existing inequalities instead of dismantling them.

Finally, the study identifies actionable strategies for strengthening MSME ecosystems: investments in rural connectivity, localized training programs, transparent governance frameworks, and sustainability-linked incentives. These measures will not only encourage adoption but also ensure that digital transformation aligns with India's broader development goals, including Viksit Bharat 2047. Digital Public Infrastructure has the potential to act as a catalyst for inclusive, resilient, and globally competitive supply chains. Its success, however, will depend on balancing technological advancement with equitable access and robust governance. For MSMEs—the backbone of India's economy DPI offers a pathway to growth, innovation, and integration into global value chains. For policymakers and stakeholders, it provides a blueprint to ensure that industrial transformation is both competitive and inclusive. By embedding inclusivity, trust, and sustainability at the heart of digital platforms, India can harness DPI not just as a tool for efficiency, but as a foundation for long-term socio-economic transformation.

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