RESEARCH PAPER

A Comprehensive Study of Logistics 5.0 Adaptation & Challenges in the Indian Supply Chain Industry

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Abstract

Logistics 5.0 indicates the combination of Industry 5.0's important principles such as human-centricity, resiliency, and sustainability with the advanced digital capabilities of Logistics 4.0. While a growing number of developed countries are starting to adopt AI, digital twins, collaborative robots, and human-machine decision-making systems, there is still only limited evidence available regarding Logistics 5.0 implementation in India. The purpose of this study is to find out the main technological, financial, human, infrastructural, regulatory, organizational, cultural, and sustainability hurdles on the way to Logistics 5.0 implementation in Indian logistics. We used a qualitative analysis of secondary data to conduct the research, using logistics cost assessments data, e-commerce and last mile markets data, previously conducted published studies in the field of Industry 4.0/5.0, and some examples from Delhivery Ltd. The results indicate that following improvements in the logistical cost efficiency of India and rapid growth in the e-commerce logistics, the utilization of technology is still inconsistent within the industry. Factors affecting its implementation include high costs of implementation, shortage of skilled workers, cybersecurity threats, poor last-mile infrastructure, lack of digital capabilities, and resistance within organizations to cooperate with machines. EXPERTS NOTE that most of the large firms in private and public sectors have made significant strides in implementing Logistics 5.0 while small and medium sized enterprises face numerous obstacles. The above article discusses readiness issues of the sector and proposes readiness roadmaps as well as specific steps in accordance with the National Logistics Policy of India and PM GatiShakti framework.

Keywords*:* Logistics 5.0, Industry 5.0, supply chain management, India, digital transformation, adoption barriers, sustainability, human-centric automation, e-commerce logistics, multimodal transport
How to cite this article: Dr Pritha Chaturvedi, Mr Soumyajyoti Bhattacharjee. A Comprehensive Study of Logistics 5.0 Adaptation & Challenges in the Indian Supply Chain Industry. Int J Drug Deliv Technol. 2026;16(88s):837-854. DOI: 10.25258/ijddt.16.88s.86.

1. Introduction

The worldwide logistics and supply chain function is experiencing a series of paradigm transitions from the mechanised efficiency logic of Logistics 3.0 to the cyber-physical, data-driven automation of Logistics 4.0 and to the coming Logistics 5.0 paradigm. Logistics 5.0 is often perceived as the logistics industry's counterpart to Industry 5.0, which emphasises human agency, well-being, and environmental sustainability in tandem with advanced digital technologies such as artificial intelligence, the Internet of Things, digital twins, collaborative robotics, blockchain, and autonomous vehicles (ResearchGate, 2026a).Industry 5.0 is sometimes defined as a next-generation paradigm to Industry 4.0 emphasising human-machine cooperation, resilience and sustainability above automation for the sake of it (Applied Sciences, 2026; ScienceDirect, 2026).

Instead of using automated labour as a proxy for higher performance as Logistics 4.0 implicitly does, Logistics 5.0 emphasises that human and machine capabilities are complementary, and value is created through their combined deployment across planning, warehousing, transportation, and last-mile delivery (Applied Sciences, 2026).This shift is especially significant for a nation like India, where logistics is both a key employment generator and a frequent contributor to trade competitiveness. India's logistics cost has been a matter of much dispute and has been quoted historically in the range of 13%-14% of gross domestic product (GDP). "The first scientifically rigorous hybrid-methodology assessment jointly done

by the Department for Promotion of Industry and Internal Trade and the National Council of Applied Economic Research, using primary data of more than 3,500 industry stakeholders along with secondary national accounts data, estimated the aggregate logistics cost at 7.97% of gross domestic product for 2023-24, substantially lower than the earlier estimates (DPIIT & NCAER, 2025; Outlook Business, 2026; Overseas Logistic, 2025; Press Information Bureau, 2026b).

Yet another CII-Knight Frank assessment (with a different scope and methodology) estimated FY26 logistics cost at 10%-10.7% of gross domestic product (GDP), compared to 13%-14% a decade ago, citing infrastructure investment of USD 360 billion cumulatively and reforms such as the National Logistics Policy (2022), the PM GatiShakti National Master Plan, the Unified Logistics Interface Platform and the Logistics Data Bank 2.0 (Business Standard, 2026; The Statesman, 2026).

The tremendous expansion of India's e-commerce and quick-commerce ecosystem makes this transformation even more urgent. The last-mile delivery market in India alone was worth about USD 7.4-7.96 billion in 2025-26 and is projected to grow at a compound annual growth rate of about 12.7%-13.5% over the early 2030s. The broader e-commerce logistics market is estimated to go from about USD 19.5 billion in 2025 to as much as USD 104 billion by 2034, depending on the forecasting methodology employed (IMARC Group, 2026a, 2026b; Mordor Intelligence, 2026a, 2026b). Quick commerce platforms have normalised sub-15-minute delivery windows in metro catchments, forcing network planners to build dense micro-fulfilment footprints and pushing logistics providers towards exactly the kind of AI-augmented, human-machine collaborative operating models described in Logistics 5.0 (Mordor Intelligence, 2026a).

Despite this policy-driven infrastructural progress and demand-side growth, the adoption of Logistics 5.0-enabling technologies by Indian supply chain actors, especially the numerically dominant small and medium enterprise segment, is still obstructed by a different set of organisational, financial and human-capital barriers (ResearchGate, 2025; Sahu & Gupta, 2022). The paper therefore aims to identify the major obstacles that hinder the adoption of Logistics 5.0 in the Indian supply chain sector, how these barriers impact differently different segments of the industry such as large integrated private players, modernising public-sector operators and smaller fragmented operators and what policy and managerial interventions could accelerate an inclusive transition.

The rest of the paper is arranged as follows. The literature review portion surveys the conceptual literature on Logistics 5.0, and empirical studies on Industry 4.0/5.0 adoption hurdles in India. The Conceptual Framework part connects the pillars of Logistics 5.0 to the Indian operational situation. The Research Objectives and Questions section describes the objectives of the investigation. The mixed-methods study design is described in the Method section. The Results section provides the data analysis with a consolidated barrier taxonomy and market-sizing evidence. Two case-study parts, one for Delhivery Ltd. and the other for CONCOR, are followed by a cross-case comparison. In the Discussion part, the results are thematically interpreted and followed by a section with a staged preparedness plan. The next sections include policy and management implications, limits, and a conclusion.

2. Literature of Review

2.1. From Logistics 4.0 to Logistics 5.0

Logistics 4.0 evolved as the logistics-specific application of the ideas of Industry 4.0, such as cyber-physical systems, Industrial Internet of Things and cognitive analytics, to increase visibility, automate warehousing and allow predictive decision-making throughout supply chains. A recent bibliometric and systematic review places the transition to smart logistics within the broader continuum of Industry 4.0 to 5.0 (ScienceDirect, 2026). It highlights that digital twins and smart logistics concepts are now being enhanced by a clear sustainability and human-centricity agenda under Industry 5.0.The Industry 5.0 scholarship is based on three pillars: human-centricity, resilience and sustainability, where intelligent machines are seen as collaborators, not replacements for human workers, and where ethical responsibility and social well-being are embedded into the industrial design (Applied Sciences, 2026).

This means, applied to logistics, intelligent supply chain systems that can anticipate disruptions, dynamically reconfigure flows, and support proactive risk management capabilities that have become salient following the COVID-19 pandemic, geopolitical instability and climate-related shocks that revealed the fragility of traditional, purely efficiency-optimised supply chains (Applied Sciences, 2026; ScienceDirect, 2026).A synthesis of enabling technologies for Supply Chain Logistics 5.0 identifies artificial intelligence, the Internet of Things, digital twins, blockchain, cobots and autonomous vehicles as the principal technological substrate, while cautioning that real world application still lags conceptual development, with meaningful research gaps in how these technologies are operationalised at scale (ResearchGate, 2026a).

2.2. Enabling Technologies: A Closer Look

Five technological clusters are recurrent in the literature of Logistics 5.0. Predictive demand forecasting, dynamic routing, and computer-vision-based automated sorting and picking are underpinned by artificial intelligence and machine learning; Indian courier and logistics firms have already used machine learning for intelligent route mapping and natural-language-processing-based customer service, and robotic process automation for repetitive documentation tasks (ResearchGate, 2026b). Secondly, the internet of things allows the real-time monitoring of the state of assets, fleet and cold-chain, providing the data layer on which predictive analytics rely (ResearchGate, 2026a). Thirdly, digital twins can model and optimise warehouse layouts and network settings before physical deployment, thereby minimising the need for expensive trial and error adjustments (Applied Sciences, 2026). Fourth, blockchain has the potential to improve provenance verification and multi-party trust in cross-border and multi-tier supply chains, although Indian adoption is still in its infancy outside of experimental projects (ResearchGate, 2026a). Fifth, collaborative robots and autonomous ground vehicles are emerging in Indian automated sort facilities and are the clearest manifestation of the human-machine complementarity that separates Logistics 5.0 from Logistics 4.0 (ResearchGate, 2026a).

2.3. Industry 4.0/5.0 Adoption Barriers in the Indian Context

A significant amount of Indian literature on operations management has evaluated the hurdles for Industry 4.0 adoption, mostly with the use of interpretative structural modelling, DEMATEL or multi-criteria decision-making methodologies such as TOPSIS, VIKOR and PROMETHEE to rank the barriers. A multi-criteria decision-making study based on expert elicitation from production managers, academicians, and information-technology specialists, which is widely cited, finds that the dominant Industry 4.0 implementation barriers among Indian small and medium enterprises (Sahu & Gupta, 2022) are fear of unemployment among the workforce, lack of information-technology training, and poor information-technology infrastructure. Sectoral evidence supports such a trend. A systematic literature review of the Indian textile and clothing industry based on Scopus and using DEMATEL analysis has identified the most influential barrier cluster as cybersecurity risk, skill gap, cost of investment, supply chain integration difficulty and environmental and sustainability concerns, with lack of advanced information-technology infrastructure functioning as a root-cause driver barrier that amplifies the others (Discover Applied Sciences, 2025).

Specifically regarding logistics and supply chain technology, an evaluation of technology adoption in India's logistics and supply chain industry notes that about 70 per cent of surveyed small and medium enterprises consider high implementation cost a significant barrier, 55 per cent mention skill shortages, and 40 per cent report organisational resistance, especially among more traditional firms; the same body of work observes that resource-constrained small and medium enterprises frequently postpone the adoption of digital technologies such as the Internet of Things and cloud computing due to concerns about cybersecurity exposure and lack of in-house expertise (ResearchGate, 2025).

Similarly, a larger sample of 300 Indian small and medium enterprises across manufacturing, logistics and retail finds that while Internet of Things adoption helps improve resource-utilization efficiency, blockchain improves ethical sourcing and artificial intelligence-enabled predictive maintenance reduces downtime, the pace and depth of adoption remains constrained by resource limitations, a shortage of qualified personnel and systems-integration challenges, echoing the small-and-medium-enterprise-centric barrier structure identified elsewhere in the literature (MDPI Sustainability, 2025).

2.4. Sustainability and Green Logistics in India

Sustainability as an imperative underpins both Industry 5.0 and Logistics 5.0, and the Indian logistics industry has started to reflect this to a certain degree. Emerging green last-mile initiatives include state-level electric-vehicle subsidies, such as Karnataka's incentive scheme, credited with supporting deployment of around 12,000 electric last-mile delivery vehicles in Bengaluru by March 2026. Large e-commerce logistics players report continuing investment in electric fleets, energy-efficient warehousing, and eco-friendly packaging as competitive differentiators (Mordor Intelligence, 2026a). Yet, industry analyses caution that adoption of sustainability-linked technology is currently concentrated in metro and Tier-1 clusters, with Eastern and rural regions lagging due to road-density deficits and patchy connectivity (Mordor Intelligence, 2026a), given regional disparities in supporting infrastructure.

Human-Centric Work Design and the Gig Economy

A major characteristic of Indian last-mile logistics is the strong dependence on gig and platform-based delivery workers across food, grocery and quick-commerce sectors (IMARC Group, 2026b). The workforce structure raises human-centricity questions at the center of the Logistics 5.0 agenda: whether AI-driven dispatch and performance-management algorithms are designed to support worker well-being

and skill development, or simply to maximise routing efficiency at the expense of labour conditions, is a live design and policy question that the reviewed Indian technology-adoption literature has only begun to address, and which represents an important direction for future Logistics 5.0-specific research.

2.5. India's Policy and Infrastructural Response

The National Logistics Policy (2022) of Government of India, specifically requires the construction of a standardised, evidence-based logistics-cost measurement system, culminating in the above-mentioned 2025-26 evaluation (DPIIT & NCAER, 2025). Complementary initiatives like the synchronisation of multimodal infrastructure planning under PM GatiShakti, the Strengthening Multimodal and Integrated Logistics Ecosystem programme piloted in eight cities with Asian Development Bank support, the Unified Logistics Interface Platform for cross-departmental data integration and the Logistics Data Bank 2.0 for real-time container visibility collectively form the institutional scaffolding within which the adoption of Logistics 5.0 in India needs to be understood (Press Information Bureau, 2026a).

India's rise in the World Bank Logistics Performance Index, from 54th position in 2014 to 38th in 2023, is frequently mentioned as external validation of this infrastructural progress. The same industry assessments, however, caution that continued over-reliance on road freight, delayed development of integrated multimodal logistics parks, and persistent first- and last-mile connectivity gaps continue to limit realised efficiency gains, with approximately 216 multimodal logistics parks still requ Taken together, the literature points to a two-track reality. On one hand, macro-level infrastructural and cost indicators are steadily improving under sustained policy push. In contrast, micro-level technology adoption, particularly the human-centric, collaborative dimension distinctive to Logistics 5.0, is still held back by firm-level financial, skill and cultural barriers that have not yet been systematically mapped onto the Logistics 5.0 framework specifically. This study fills that gap.

3. Conceptual Framework

The paper conceptualises the adaptation of Logistics 5.0 in India based on the literature reviewed, on three interdependent pillars i.e. human-centricity, resilience and sustainability, mapped onto specific Indian operational manifestations and associated adoption barriers as summarised in Table 1. The fundamental argument of the concept is that adaptation is not a one-time binary event, but a progressive state of preparedness at the business level, which is concurrently influenced by macro-level enablers (policy, infrastructure, market demand) and micro-level restrictions (cost, talent, culture, cybersecurity).

Table 1

Conceptual Mapping of Logistics 5.0 Pillars Onto Indian Operational Manifestations and Barriers

Logistics 5.0 Pillar	**Indian Operational Manifestation**	**Principal Constraining Barriers**
Human-centricity	Human-machine collaborative dispatch, cobot-assisted sortation, gig-worker algorithmic management, reskilling programmes	Fear of unemployment; skill/data-literacy gap; absence of human-machine work-design standards
Resilience	Predictive disruption forecasting, multimodal redundancy (rail-road-sea), digital twins for network reconfiguration	Over-dependence on road freight; fragmented fleet ownership; incomplete multimodal logistics park network
Sustainability	Electric last-mile fleets, green warehousing, carbon-tracking dashboards, reverse-logistics optimisation	Regional disparity in charging/grid infrastructure; high upfront electric-vehicle capital cost; absence of standard

		carbon-accounting norms

Note. Framework developed by the authors, synthesising ResearchGate (2026a), Applied Sciences (2026), and Mordor Intelligence (2026a).

4. Research Objectives and Questions

Building on the identified gap and conceptual framework, this study pursues five objectives:

1. To conceptually map the Logistics 5.0 paradigm onto the operational realities of the Indian supply chain industry.
2. To synthesise and rank the principal challenges to Logistics 5.0 adaptation using triangulated Indian secondary and empirical evidence.
3. To examine, through fact-based comparative case studies, how a leading private logistics technology firm and a modernising public-sector operator are operationalising Logistics 5.0-adjacent capabilities, and what this implies for the wider ecosystem.
4. To propose a phased readiness roadmap and policy/managerial recommendations for accelerating inclusive Logistics 5.0 adaptation.
5. To develop a validated primary-data collection instrument for future confirmatory research on Logistics 5.0 barriers specific to the Indian context.

Therefore, the study is concerned with four research questions: (a) What are the major technical, financial, human-capital, infrastructural, legal, cultural and sustainability related impediments to Logistics 5.0 adaption in India? (a) What is the intensity difference of these barriers between big, well-capitalised operators and small-and-medium enterprise size logistics providers? (c) What can a comparative examination of a private technology native third-party logistics provider and a public-sector multimodal operator tell us about the paths to, and constraints of, Logistics 5.0 adoption in the Indian institutional context? (d) What are the most effective phased policy and management initiatives that may help reduce the adoption gap outlined in the first two questions?

5. Method

5.1 Research Design

This study adopts mixed-methods, exploratory-descriptive design combining (a) systematic secondary-data synthesis of governmental, industry-body, market-research, and peer-reviewed sources; (b) a two-case, embedded comparative case study of Delhivery Ltd. and CONCOR; and (c) a structured primary-data collection instrument designed for future large-sample validation. This design follows established practice in Indian Industry 4.0/5.0 barrier research, where literature-derived barrier lists are typically validated through expert surveys and multi-criteria ranking techniques (Discover Applied Sciences, 2025; Sahu & Gupta, 2022), and follows Yin's (2018) logic of purposive, information-rich case selection for theory-building case research.

5.2 Data Sources

Secondary data were drawn from four categories: (a) Government of India sources, including Press Information Bureau releases, the Assessment of Logistics Cost in India, and National Logistics Policy documentation (DPIIT & NCAER, 2025; Press Information Bureau, 2026a, 2026b); (b) industry-body and market-research reports, including the CII-Knight Frank Multimodal Transportation and Logistics Summit report, KPMG India's pre-Budget analysis, and independent market-sizing studies of India's e-commerce and last-mile logistics segments (Business Standard, 2026; IMARC Group, 2026a, 2026b; KPMG India, 2026; Mordor Intelligence, 2026a, 2026b); (c) peer-reviewed journal articles indexed in Scopus and Web of Science addressing Industry 4.0/5.0 and Logistics 5.0 adoption barriers in India and comparable emerging economies (Discover Applied Sciences, 2025; MDPI Sustainability, 2025; Sahu & Gupta, 2022); and (d) verifiable public-domain corporate disclosures, technology-partner case studies, and financial filings pertaining to the two case organisations (AWS, 2026; Cargo Insights, 2024; India Remarks, 2026; TaxTMI, 2025).

5.3 Case Selection and Sampling Logic

The primary case organisation Delivery Ltd. was chosen for being (a) the India’s largest listed express-parcel and full-stack logistics technology company by volume market share, (b) a publicly listed entity with disclosure obligations that allow fact verification on the Bombay Stock Exchange and National Stock Exchange since May 2022, and (c) a firm with documented, technology-partner-verified deployments of AI- and machine-learning-based routing, generative-AI-based geocoding, and automated sortation (AWS, 2026; India Remarks, 2026; Pestel-Analysis, 2025). CONCOR was chosen intentionally as a contrasting case because it is (a) India’s largest rail-based, public sector multimodal logistics operator under the Ministry of Railways, (b) governed by a different governance, capital access and institutional mandate framework than a venture-backed private technology firm, and (c) has documented, independently reported AI and automation deployments at its flagship terminals (Cargo Insights, 2024; DCFmodeling.com, 2025; TaxTMI, 2025). This maximum-variation case

pairing was selected in an effort to test whether Logistics 5.0 adjacent capability building is contingent on ownership structure or more generally diffusing across organisational types. In accordance with Yin's (2018) logic of selecting cases that are critical, extreme, or revelatory for the phenomenon under study.

5.4 Proposed Primary-Data Instrument for Confirmatory Research

To enable future empirical validation of the barrier taxonomy derived in the Results section, this paper proposes a structured questionnaire comprising 32 items across eight constructs (technological readiness, financial constraints, human-capital/skill availability, infrastructural adequacy, regulatory/policy clarity, organisational/cultural readiness, cybersecurity risk perception, and sustainability commitment), each measured on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree), targeted at logistics/supply-chain managers, third-party logistics operators, and small-and-medium-enterprise owners across at least four Indian logistics clusters. Table 2 summarises the proposed sampling frame.

Table 2

Proposed Sampling Frame for Future Confirmatory Primary-Data Collection

Respondent Category	**Target Cluster(s)**	**Indicative Sample Size**	**Primary Analysis Technique**
Large/listed third-party logistics managers	National Capital Region, Mumbai-Pune	30-40	Descriptive statistics and qualitative interview coding
Small and medium enterprise logistics/transport owners	All four clusters	150-180	Exploratory factor analysis and interpretive structural modelling - DEMATEL barrier ranking
Public-sector logistics officials	Pan-India (CONCOR, state corporations)	20-30	Qualitative interview and document analysis
E-commerce/quick-commerce logistics managers	National Capital Region, Bengaluru, Chennai	30-40	Descriptive statistics and Likert-scale comparison

Note. Sample-size ranges reflect conventional item-to-response ratios for factor-analytic small-and-medium-enterprise technology-adoption research.

Recommended analysis techniques include exploratory factor analysis for construct validation, followed by interpretive structural modelling-DEMATEL or TOPSIS ranking to establish inter-barrier driving/dependence relationships, consistent with methods used in comparable Indian studies (Discover Applied Sciences, 2025; Sahu & Gupta, 2022). A minimum total sample of 230-290 valid responses is recommended. This instrument is presented as a research design contribution; the barrier rankings reported in the Results section are derived from triangulating already-published, independently collected empirical evidence rather than from a new primary survey conducted for this paper.

5.5 Analytical Approach, Validity, and Reliability

Quantitative secondary indicators were trend-analysed across available years and cross-validated across at least two independent sources; where sources diverged materially, both figures are reported as bounding estimates rather than resolved into a single point figure, in the interest of transparency. Qualitative barrier evidence from the reviewed studies was content-analysed and mapped onto eight a-priori categories derived from the Industry 5.0/Logistics 5.0 literature, producing a consolidated, frequency-weighted barrier ranking. Case-study evidence was triangulated across a minimum of three independent public sources per case to reduce single-source bias, consistent with case-study validity practice recommending multiple sources of evidence and traceable chains of evidence (Yin, 2018).

6. Results

6.1. Trend in India's Logistics Cost as a Percentage of Gross Domestic Product

Table 3 consolidates independently produced estimates of India's aggregate logistics cost as a share of gross domestic product. The wide historical range reflects differing methodologies, and the divergence between the DPIIT-NCAER and CII-Knight Frank figures for the same period is itself informative: it illustrates that logistics-cost measurement in India lacks a single settled methodology, a factor that itself complicates benchmarking of Logistics 5.0 return-on-investment cases for prospective adopters (Business Standard, 2026; DPIIT & NCAER, 2025).

Table 3

Trend in India's Logistics Cost as a Percentage of Gross Domestic Product Across Independent Studies

Estimate / Study	Reference Period	Logistics Cost (% of GDP)	Source / Methodology
Armstrong & Associates (ANN model)	2016	≈13%	Artificial neural network model applied across economies
CII-AVALON Consulting	2015	≈10.9% of GVA	Consulting estimate for CII
NCAER interim assessment	2021-22	7.8%-8.9%	Supply and Use Tables plus national accounts statistics
DPIIT-NCAER Assessment of Logistics Cost in India	2023-24	7.97%	Hybrid: primary survey of 3,500+ stakeholders plus MOSPI/RBI secondary data
CII-Knight Frank Report	FY 2025-26	10%-10.7%	Industry-body estimate; cumulative USD 360 billion infrastructure investment base

Note. Divergence between rows reflects genuine methodological differences (scope of cost components, GVA vs. GDP denominator, primary vs. purely secondary data) rather than a single error-corrected series. Adapted from DPIIT and NCAER (2025), Business Standard (2026), and The Statesman (2026).

6.2. E-Commerce and Last-Mile Market Growth

Table 4 summarises market-sizing evidence for India's e-commerce and last-mile logistics segments, drawn from independent market-research estimates. While absolute figures vary by methodology and forecast horizon, all sources concur on a double-digit compound annual growth trajectory driven by e-commerce and quick-commerce expansion, rising Tier-2/Tier-3 city penetration, and consolidation among leading logistics providers (IMARC Group, 2026a, 2026b; Mordor Intelligence, 2026a, 2026b).

Table 4
India E-Commerce and Last-Mile Logistics Market-Sizing Estimates

Market Segment	2025/26 Base Value	Forecast Value	CAGR	Key Driver Noted in Source
India last-mile delivery	USD 7.4-7.96 billion (2025-26)	USD 14.45-24.5 billion (2031-34)	≈12.7%-13.5%	Quick-commerce sub-15-minute delivery norms; Tier-2/3 GMV growth
India e-commerce logistics	USD 19.5 billion (2025)	USD 103.8 billion (2034)	≈20.4%	Digital penetration, automated warehousing, marketplace fulfilment
India e-commerce logistics (alternative estimate)	≈USD 10.2 billion (2026, implied)	USD 11.14 billion (2031)	≈8.98%	Transportation segment dominance (≈71% share)

Note. Ranges reflect differing market-research methodologies and forecast horizons. Adapted from IMARC Group (2026a, 2026b) and Mordor Intelligence (2026a, 2026b).

The scale of this demand growth is directly relevant to Logistics 5.0 adaptation: consolidation activity, most notably Delhivery's 2025 acquisition of a controlling stake in Ecom Express, which immediately combined roughly 35% of third-party parcel flows, signals that technology scale, rather than price competition alone, is increasingly expected to determine competitive leadership in Indian logistics, reinforcing the bifurcation dynamic discussed further in the Discussion section (Mordor Intelligence, 2026a).

6.3. Consolidated Barrier Taxonomy

Table 5 synthesises barrier evidence across four independent Indian empirical studies spanning general manufacturing small and medium enterprises, the textile and clothing sector, and the logistics/supply-chain-specific technology-adoption literature. Barriers are grouped into seven categories consistent with the Logistics 5.0 conceptual pillars identified above.

Table 5
Consolidated, Cross-Study Barrier Taxonomy for Industry 4.0/5.0 and Logistics 5.0 Adoption in India

Barrier Category	Representative Evidence	Approx. Reported Incidence / Ranking
Financial / cost	High implementation and capital cost cited as the leading obstacle in logistics-sector small and medium enterprise technology adoption (ResearchGate, 2025)	≈70% of surveyed small and medium enterprises cite high implementation cost as a major barrier
Human capital / skill gap	Skill shortage ranked among the top three barriers in both general-	≈55% of small and medium enterprises report skill shortages as a

	manufacturing and textile-sector Industry 4.0 studies; fear of unemployment identified via multi-criteria ranking (Discover Applied Sciences, 2025; Sahu & Gupta, 2022)	constraint
Organisational / cultural resistance	Resistance to change most pronounced in traditional, family-run, and legacy-process firms (ResearchGate, 2025)	≈40% of small and medium enterprises report organisational resistance
Infrastructural (IT/connectivity)	Poor information-technology infrastructure identified as a root-cause driver barrier via DEMATEL analysis, amplifying downstream barriers (Discover Applied Sciences, 2025)	Ranked as most influential causal barrier in textile-sector DEMATEL study
Cybersecurity	Cybersecurity risk ranked among top-five barriers; small and medium enterprises delay Internet of Things/cloud adoption due to resource constraints and lack of in-house expertise (Discover Applied Sciences, 2025; ResearchGate, 2025)	Top-2 ranked barrier in textile-sector DEMATEL analysis
Regulatory / policy clarity	Historic ambiguity in logistics-cost measurement complicated policy benchmarking until the 2022 National Logistics Policy mandated a standard framework (DPIIT &	Addressed only from FY 2025-26 onward via DPIIT-NCAER framework

	NCAER, 2025)	
Supply-chain integration / interoperability	Difficulty integrating fragmented, multi-tier supplier and transporter networks flagged as a distinct barrier cluster (Discover Applied Sciences, 2025)	Identified as a distinct top-5 barrier in textile-sector study

Note. Financial and human-capital barriers are the most consistently reported obstacles across sectors and studies, while infrastructural inadequacy functions as a structural root cause that intensifies the other barriers.

6.4. SWOT Synthesis of Indian Logistics 5.0 Readiness

Table 6 synthesises the preceding indicators into a SWOT framework summarising India's aggregate readiness for Logistics 5.0 adaptation.

Table 6

SWOT Synthesis of India's Aggregate Logistics 5.0 Adoption Readiness

Strengths	**Weaknesses**
Large, rapidly growing e-commerce demand base (≈9%-20% CAGR); strong policy scaffolding (National Logistics Policy, PM GatiShakti, Unified Logistics Interface Platform); demonstrated large-player technology capability (AI routing, generative-AI geocoding)	High implementation cost and skill shortages reported by a majority of small and medium enterprise logistics operators; truck utilisation productivity roughly one-third of developed-economy benchmarks; unsettled logistics-cost measurement methodology
Opportunities	**Threats**
Planned multimodal logistics parks and Dedicated Freight Corridor expansion could extend digital-physical infrastructure to underserved regions; large-player platform capability could be extended to small and medium enterprises as shared infrastructure	Ecosystem bifurcation between technology-native large players and small-and-medium-enterprise-dominated informal sector; cybersecurity exposure rising with data-platform integration; regional infrastructure disparity (Eastern India lagging)

Note. Derived by the authors from the Results section.

6.5. Interpretation of Results

Read together, the preceding results suggest a paradox characteristic of India's Logistics 5.0 transition: macro-level cost, infrastructural, and demand indicators are improving or expanding rapidly under sustained state investment and consumer-driven growth, yet the micro-level, firm-specific barriers that determine whether individual logistics operators can actually adopt human-centric, AI-augmented working models remain largely unaddressed by infrastructure spending or demand growth alone. This is consistent with the two-track infrastructure-versus-capability gap noted by KPMG India (2026), which observes that despite FASTag and Unified Logistics Interface Platform digitisation, trucks still lose six to eight hours per trip to manual interventions and ports still see three to four days of dwell time against a global norm of one to two days, implying that digital-physical integration at the operational, as opposed to policy, layer is the binding constraint for Logistics 5.0 readiness.

6.6. Case Study I: Delhivery Ltd. (Private, Technology-Native Third-Party Logistics Provider)

6.6.1. Company Background

Delhivery Ltd., headquartered in Gurugram, Haryana, was founded in 2011 and has grown from a hyperlocal delivery start-up into India's largest listed express-parcel and full-stack logistics technology

company, describing its mission as building the operating system for commerce (Pestel-Analysis, 2025; World Economic Magazine India, 2025). The company was listed on the Bombay Stock Exchange and National Stock Exchange in May 2022, and by FY2025 reported services revenue of ₹8,931.9 crore and full-year profitability, with a network spanning more than 18,700 pin codes, 24 automated sort centres, 94 gateways, and 2,880 direct delivery centres, and a reported express-parcel volume market share exceeding 20% (India Remarks, 2026). In April 2025, Delhivery further consolidated its market position by acquiring a 99.4% stake in Ecom Express for ₹1,410 crore, a transaction that industry analysis suggests immediately combined roughly 35% of third-party parcel flows under the enlarged entity (Mordor Intelligence, 2026a).

6.6.2. Logistics 5.0-Adjacent Capabilities

1. Delhivery's operating model illustrates several building blocks consistent with the Logistics 5.0 paradigm rather than pure Logistics 4.0 automation.
2. Predictive, AI-based routing and capacity planning: proprietary logistics software directs parcel-level routing decisions and hub capacity planning, with the company reporting measurable improvements in delivery-time efficiency attributed to AI-optimised routing (India Remarks, 2026).
3. Generative-AI infrastructure for address geocoding: to resolve last-mile address ambiguity, Delhivery deployed a fine-tuned, self-hosted large language model, a variant of Llama 3.2, on Amazon Elastic Kubernetes Service, achieving 160-millisecond inference latency at throughput of up to 8,000 requests per minute, and reducing model-serving costs by approximately 80% relative to third-party application-programming-interface-based alternatives (AWS, 2026).
4. Automated sortation and warehouse robotics: deployment of automated sort centres and robotics-enabled order processing, with independently reported productivity gains in order-processing throughput (World Economic Magazine India, 2025).
5. Human-machine collaborative workforce model: despite extensive automation, Delhivery continues to operate a large direct and gig workforce, variously reported between roughly 57,000 and 92,000 personnel depending on classification, indicating that automation has been deployed to augment rather than fully displace human logistics labour (India Remarks, 2026).

6.6.3. Persistent Challenges Even for a Leading Adopter

Notably, even as an above-median technology adopter, Delhivery's own disclosed operating challenges mirror several barriers identified in the Results section: fuel-price volatility and cost-sensitive margins constrain investment capacity; intense competitive pressure from Blue Dart Express, DTDC Express, and Mahindra Logistics limits pricing power for technology cost recovery; and fluctuating volumes tied to retail/e-commerce consumption cycles complicate capacity-planning investments in automation (India Remarks, 2026; Mahindra Logistics, 2026). Industry data also indicate that EBITDA margins for pure-play last-mile logistics operators have compressed to roughly 4%-6%, underscoring the thin margin base against which any technology investment must be justified (Mordor Intelligence, 2026a).

6.6.4. Case Implications

The Delhivery case demonstrates technical feasibility: Logistics 5.0-adjacent capabilities are achievable within the Indian operating environment given sufficient scale, capital access, and in-house technical talent. However, the same case also reveals that these capabilities are concentrated among a small number of well-capitalised, technology-native firms operating at national scale, while the broader ecosystem, comprising thousands of small and medium enterprise transporters, warehousing operators, and regional third-party logistics providers that collectively handle a large share of India's freight movement, continues to face the financial, skill, and infrastructural barriers documented in the Results section.

6.7. Case Study II: Container Corporation of India (Public-Sector, Rail-Based Multimodal Operator)

6.7.1. Company Background

Container Corporation of India Limited is the largest rail-based multimodal logistics operator in India. It was established in 1988 as a public sector undertaking under the Ministry of Railways. It operates a network of more than 60 inland container depots and container goods stations connecting ports with industrial and inland distribution centres (Cargo Insights, 2024). The export-import traffic accounts for over 80% of the company’s business, with the remaining being domestic multimodal transport, which connects almost 47,000 containers across cargo clusters throughout the country. The company has reported revenue of approximately ₹4,800 crore for FY2023-24. The company has transformed into a diversified conglomerate with 16 group entities,

including subsidiaries and joint ventures, under its new leadership, and has developed 15 greenfield multimodal logistics parks (Cargo Insights, 2024; DCFmodeling.com, 2025).

6.7.2. Logistics 5.0-Adjacent Capabilities

Despite its public-sector, infrastructure-legacy character, Container Corporation of India has undertaken a documented digital transformation programme with several Logistics 5.0-adjacent elements.

1. AI-based Terminal Management Systems: an AI project launched at the flagship Tughlakabad terminal introduced centralised business and front-office applications that automate gate movements, optimise yard planning, and track container locations with three-dimensional accuracy, resulting in faster gate entry and exit, automated job-order creation, and real-time container-location monitoring (Cargo Insights, 2024).
2. Know Your Container Location system: a real-time cargo- and train-tracking initiative that extends digital visibility across the rail-road network (Cargo Insights, 2024).
3. Warehouse occupancy and space-utilisation dashboards: real-time views of warehouse occupancy across a 40-lakh-square-foot secure warehousing footprint support better space management and operational efficiency (TaxTMI, 2025).
4. International multimodal integration: a memorandum of understanding on the International North-South Transport Corridor with Russian Railways illustrates cross-border multimodal digital-physical integration consistent with the resilience pillar of Logistics 5.0 (Cargo Insights, 2024).

6.7.3. Persistent Challenges Distinctive to the Public-Sector Case

The transformation trajectory of Container Corporation of India also reveals barriers distinctive to its public-sector, infrastructure-legacy character rather than the financial-capital constraints dominant in the Delhivery case: governance and procurement cycles typical of public sector undertakings can slow technology deployment relative to venture-backed private competitors; the company's core rail-based asset model requires continued dependence on Ministry of Railways infrastructure decisions that lie partly outside its direct operational control; and workforce transition toward AI-augmented terminal operations must be managed within public-sector service and employment frameworks that differ materially from the more flexible, gig-inclusive workforce models observed at private third-party logistics providers. These distinctions matter for Logistics 5.0 policy design because they indicate that a single, one-size-fits-all adoption-support programme is unlikely to address the differing institutional constraints faced by private-technology-native firms versus public-sector infrastructure operators.

6.7.4. Cross-Case Comparative Analysis

Table 7 synthesises the two case studies against a common set of Logistics 5.0 readiness indicators, alongside a stylised small-and-medium-enterprise-scale comparator drawn from the barrier taxonomy reported in the Results section, an illustrative composite based on cited survey evidence rather than a third individually named case.

Table 7

Cross-Case Comparison of Logistics 5.0 Readiness Indicators

Indicator	**Delhivery Ltd. (Private, Listed 3PL)**	**CONCOR (Public-Sector, Rail Multimodal)**	**Typical Small and Medium Enterprise Operator (Composite)**
AI/ML deployment	Advanced (predictive routing, generative-AI geocoding)	Emerging (AI-based Terminal Management System at flagship terminal)	Minimal to none reported
Automation / robotics	Automated sort centres, robotics-	Automated gate/yard operations at select terminals	Largely manual operations

	enabled processing		
Real-time visibility	Proprietary tracking system	Know Your Container Location real-time tracking	Limited or informal tracking
Capital access	Listed entity; access to public equity/debt markets	Government-backed; subject to public capital allocation cycles	Constrained; ≈70% cite cost as major barrier
Workforce model	Large direct and gig workforce (≈57,000-92,000)	Structured public-sector employment; transition governance required	Small, often family-run workforce; skill shortage ≈55%
Principal constraint type	Margin compression, competitive intensity, fuel-cost volatility	Procurement/governance cycles; dependence on rail infrastructure completion	Cost, skill, and cybersecurity barriers

Note. Composite small-and-medium-enterprise column derived from ResearchGate (2025) survey evidence, not an individually verified case.

The comparison indicates that Logistics 5.0-adjacent capability building is diffusing across both private and public-sector organisational forms in India, but through different mechanisms and subject to different binding constraints, while the small and medium enterprise segment that numerically dominates the industry remains constrained by the more fundamental cost, skill, and cybersecurity barriers identified in the Results section. This supports the bifurcation hypothesis introduced in the Introduction and elaborated below.

7. Discussion

7.1. Technological and Financial Barriers

Consistent with prior Industry 4.0 adoption research in India, the cost of acquiring and integrating artificial intelligence, Internet of Things, and automation technologies remains the most frequently cited obstacle, disproportionately affecting small and medium enterprises that lack the balance-sheet capacity of listed players such as Delhivery or the differently structured capital access available to public-sector operators such as Container Corporation of India (ResearchGate, 2025; Sahu & Gupta, 2022). Given that logistics margins in India remain thin and volume-sensitive, technology investment is frequently deprioritised relative to working-capital needs.

7.2. Human Capital and Organisational Culture

The Logistics 5.0 paradigm's human-centricity is, paradoxically, one of its harder adoption barriers in the Indian context: it requires not merely automating tasks but redesigning work to combine human judgement with machine intelligence, which demands a workforce skilled in data literacy and human-machine collaboration, a capability gap that existing vocational and logistics-management education in India has not yet closed at scale, consistent with the skill-shortage findings reported across the reviewed studies (Discover Applied Sciences, 2025; Sahu & Gupta, 2022). The gig-economy dimension adds a further layer of complexity: algorithmic dispatch and performance management must be designed to support, rather than merely extract efficiency from, a large, often precarious delivery workforce, if the human-centricity pillar of Logistics 5.0 is to be meaningfully realised rather than nominally invoked.

7.3. Infrastructural and Regulatory Constraints

India's truck utilisation productivity gap, an Indian truck reportedly covering 250-300 kilometres per day against 700-800 kilometres for a comparable United States truck and over 500 kilometres for a Chinese truck, illustrates that physical and process infrastructure continues to constrain the throughput gains that Logistics 5.0 digital tools are designed to enable; digitisation without complementary physical-infrastructure and fleet-consolidation reform yields only partial benefit (KPMG India, 2026).

7.4. Cybersecurity and Data Governance

As logistics data increasingly flows across multiple stakeholders via platforms such as the Unified Logistics Interface Platform, cybersecurity risk exposure rises correspondingly; resource-constrained small and medium enterprises' tendency to defer digital adoption over cybersecurity concerns therefore risks becoming self-reinforcing, since firms that adopt more slowly also invest less in the security capability needed to adopt safely (Discover Applied Sciences, 2025; ResearchGate, 2025).

7.5. The Bifurcation Challenge

Perhaps the most distinctive challenge specific to Logistics 5.0, as opposed to Logistics 4.0, adaptation in India is the risk of a two-speed ecosystem, now evidenced not only by the Delhivery case but by the cross-case comparison above: large, technology-native private firms and modernising public-sector operators are both advancing toward human-machine collaborative, AI-augmented operations, while the numerically dominant small and medium enterprise and unorganised-sector logistics operators remain constrained to Logistics 2.0/3.0-era practices. Because Logistics 5.0's resilience and sustainability objectives are network-level properties, this bifurcation itself constitutes a systemic barrier to realising Logistics 5.0 benefits at the national supply-chain level, independent of any single firm's technology readiness. Consolidation activity such as Delhivery's acquisition of Ecom Express may further concentrate technology capability rather than diffuse it, unless deliberately counteracted by shared-infrastructure or platform-access policies (Mordor Intelligence, 2026a).

7.6. Regional Disparity

Market-sizing evidence indicates that East India lags in last-mile logistics performance due to road-density deficits and patchy connectivity, even as the Eastern Dedicated Freight Corridor improves rail linehaul economics between Kolkata and Delhi; by contrast, South and West India benefit from denser policy and infrastructure investment (Mordor Intelligence, 2026a). This regional unevenness implies that Logistics 5.0 adaptation is unlikely to proceed at a uniform national pace and that policy design must explicitly account for lagging regions rather than assuming diffusion from metro success cases.

7.7. Proposed Logistics 5.0 Readiness Roadmap for India

Building on the cross-case and barrier analysis presented above, this paper proposes a three-phase, time-bound roadmap for accelerating inclusive Logistics 5.0 adaptation across the Indian supply chain industry, summarised in Table 8.

Table 8

Proposed Phased Roadmap for Logistics 5.0 Readiness in the Indian Supply Chain Industry

Phase	Indicative Timeframe	Priority Actions	Target Barrier Addressed
Phase 1: Foundation	0-2 years	Standardise recurring logistics-cost/technology-adoption surveys; extend onboarding support to small and medium enterprises; launch human-machine collaboration modules within Skill India	Regulatory clarity; infrastructural (IT) baseline; human capital
Phase 2: Diffusion	2-4 years	Link multimodal logistics park incentives to throughput/digital-integration outcomes; pilot shared-platform access from large third-	Financial/cost; supply-chain integration; sustainability

		party logistics providers to regional operators; expand electric-vehicle subsidy schemes beyond Tier-1 metros	
Phase 3: Consolidation	4-7 years	Institutionalise cybersecurity-investment co-funding for small and medium enterprises; complete priority multimodal logistics park/Dedicated Freight Corridor segments; establish national human-machine work-design standards for gig/platform logistics labour	Cybersecurity; infrastructural (physical); human-centricity

Note. Roadmap developed by the authors based on the barrier taxonomy and case findings reported above.

7.8. Policy and Managerial Implications

7.8.1. Implications for Policymakers

1. Extend platforms such as the Unified Logistics Interface Platform and Logistics Data Bank 2.0 with subsidised onboarding support and simplified application programming interfaces specifically designed for small-and-medium-enterprise-scale logistics operators, lowering the technical and cost threshold for participation.
2. Link multimodal logistics park development incentives to throughput and digital-integration outcomes rather than land development alone, to ensure infrastructure investment translates into usable digital-physical capability for smaller operators (KPMG India, 2026).
3. Institutionalise a recurring, standardised logistics-cost and technology-adoption survey, building on the DPIIT-NCAER framework, at two- to three-year intervals to track Logistics 5.0 readiness longitudinally.
4. Incorporate logistics-specific human-machine collaboration modules into vocational and skill-development programmes, such as Skill India, to close the workforce-readiness gap identified above.
5. Design regionally differentiated support, such as electric-vehicle subsidy extension and connectivity investment, to address the East-West and metro/non-metro disparity identified above, rather than assuming uniform national diffusion.

7.8.2. Implications for Industry and Firm-Level Managers

1. Pursue phased, modular technology adoption, beginning with route-optimisation software before capital-intensive automation, to manage the cost barrier without foregoing near-term efficiency gains.
2. Invest in reskilling programmes framed explicitly around human-machine collaboration rather than automation-driven headcount reduction, to mitigate the fear-of-unemployment barrier identified in the literature (Sahu & Gupta, 2022) and to build the workforce trust that Logistics 5.0's human-centric model requires.
3. Larger third-party logistics providers such as Delhivery, and public-sector operators such as Container Corporation of India, could

extend platform access to smaller regional logistics operators on a shared-infrastructure basis, addressing the bifurcation challenge while creating new business-to-business or public-value revenue and service streams.

4. Prioritise cybersecurity investment in parallel with, not subsequent to, digital adoption, given evidence that security concerns and adoption delay are mutually reinforcing (Discover Applied Sciences, 2025).

7.8.3. Limitations and Future Research

This study's principal limitation is its reliance on secondary-data triangulation and a two-case embedded comparison rather than a newly collected, large-sample primary survey; while the barrier rankings synthesised in the Results section are drawn from multiple independent, methodologically rigorous Indian studies, they were not collected specifically around the Logistics 5.0 construct, since most reviewed studies address Industry 4.0 more generally, with only partial overlap onto Logistics 5.0's explicit human-centricity and sustainability dimensions. Market-sizing figures also vary considerably across market-research providers depending on segment definitions and forecasting methodology, and should be read as indicative ranges rather than precise point estimates. Additionally, the two organisations examined, while purposively selected for maximum variation in ownership structure, do not capture the small and medium enterprise segment directly through primary fieldwork; the composite comparator in the cross-case table is drawn from cited secondary survey evidence rather than an individually verified case.

Future research should operationalise the primary-data instrument proposed in the Method section across a stratified, multi-cluster Indian sample, apply interpretive structural modelling-DEMATEL or fuzzy analytic hierarchy process techniques to establish causal barrier hierarchies specific to Logistics 5.0, and extend the case-study approach to a genuine multi-case design that includes at least one directly studied small-and-medium-enterprise-scale regional transporter alongside the large-player and public-sector cases examined here, to empirically test the bifurcation hypothesis advanced above. Future work should also examine the worker-experience dimension of algorithmic dispatch management in India's gig logistics workforce, and evaluate the differential regional pace of Logistics 5.0 adoption using sub-national data disaggregated at the state or logistics-cluster level.

8. Conclusion

India's supply chain industry stands at an inflection point: sustained policy investment and rapid e-commerce-driven demand growth have meaningfully reduced macro-level logistics costs and improved India's global logistics competitiveness ranking, yet the firm-level transition toward Logistics 5.0's human-centric, AI-augmented, sustainability-oriented operating model remains constrained by financial, skill, infrastructural, cybersecurity, and cultural barriers that fall disproportionately on the small and medium enterprise segment. The comparative case analysis of Delhivery and Container Corporation of India demonstrates that Logistics 5.0-adjacent capabilities are technically achievable within India's operating environment across both private and public-sector organisational forms, but also that such capability currently resides in a small number of well-capitalised or strategically prioritised organisations, raising a distinct systemic risk of ecosystem bifurcation. Closing this gap will require the phased, sequenced interventions proposed above: extending digital infrastructure access, redesigning workforce skilling around human-machine collaboration, addressing regional disparity directly, and deliberately connecting large-platform capability to the smaller operators who collectively constitute the bulk of India's logistics workforce and freight volume.

8.1. Declarations

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of Interest: The authors declare no conflict of interest.

Data Availability: This study is based entirely on publicly available secondary sources cited in the References section; no new primary dataset was generated. The proposed survey instrument is available from the corresponding author on reasonable request.

Author Contributions: To be completed by authors (e.g., conceptualisation, methodology, formal analysis, writing-original draft, writing-review and edit

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