

Smart Logistics 5.0: Integrated Transportation Innovation for Global Supply Chain Efficiency

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ABSTRAK

Smart Logistics 5.0 merepresentasikan evolusi terkini dalam manajemen rantai pasok yang mengintegrasikan teknologi digital (IoT, edge computing, AI, blockchain, big data) dan otomasi fisik (robotika, kendaraan otonom, drone) dengan prinsip *human-centric*, keberlanjutan, dan ketahanan. Kajian literatur sistematis ini menelaah publikasi tahun 2020–2025 untuk memahami bagaimana inovasi transportasi terintegrasi multimoda meningkatkan efisiensi, transparansi, dan resiliensi rantai pasok global. Metode telaah menggunakan pencarian pada basis data utama (Scopus, Web of Science, Google Scholar) dengan kata kunci terkait *Industry 5.0*, *Smart Logistics*, *integrated transport*, *IoT*, *blockchain*, dan *autonomous logistics*, kemudian diseleksi berdasarkan kriteria inklusi yang jelas dan dianalisis secara tematik. Hasil kajian menunjukkan bahwa kombinasi IoT + edge computing meningkatkan visibilitas operasional dan orkestrasi real-time; AI dan analitik big data memperbaiki akurasi peramalan serta optimasi rute; sementara blockchain mendukung *traceability* dan otomatisasi administratif melalui *smart contracts*. Selain itu, integrasi transportasi multimoda (laut, darat, udara, rel) yang didukung platform digital terbukti mengurangi biaya *door-to-door*, mempercepat pengiriman, serta memperkuat adaptabilitas jaringan terhadap gangguan. Hambatan utama mencakup fragmentasi standar data, kebutuhan investasi awal, isu regulasi (terutama kendaraan otonom dan drone), serta kesenjangan keterampilan SDM. Berbeda dari kajian sebelumnya, penelitian ini menekankan peran inovasi transportasi multimoda dalam kerangka Smart Logistics 5.0 sebagai kunci transformasi rantai pasok global yang efisien, tangguh, dan berkelanjutan.

Kata kunci: Smart Logistics 5.0; Transportasi Terintegrasi; Rantai Pasok.

ABSTRACT

Smart Logistics 5.0 represents the latest evolution in supply chain management, integrating digital technologies (IoT, edge computing, AI, blockchain, big data) and physical automation (robotics, autonomous vehicles, drones) with human-centered principles, sustainability, and resilience. This systematic literature review examines publications from 2020–2025 to understand how multimodal integrated transport innovations improve efficiency, transparency, and resilience in global supply chains. The review methodology involved searches in major databases (Scopus, Web of Science, Google Scholar) using keywords related to Industry 5.0, Smart Logistics, integrated transport, IoT, blockchain, and autonomous logistics; records were then screened against clear inclusion criteria and analyzed thematically. Findings indicate that IoT combined with edge computing enhances operational visibility and real-time orchestration; AI and big data analytics improve forecasting accuracy and route optimization; and blockchain supports traceability and administrative automation via smart contracts. Furthermore, multimodal transport integration (sea, land, air, rail) enabled by digital platforms has been shown to lower door-to-door costs, accelerate deliveries, and bolster network adaptability to disruptions. Major barriers include fragmented data standards, high upfront investment needs, regulatory issues (notably for autonomous vehicles and drones), and workforce skills gaps. Distinct from earlier reviews, this study emphasizes the role of multimodal transport innovation within the Smart Logistics 5.0 framework as a key driver of a more efficient, resilient, and sustainable global supply chain.



Keywords: Integrated Transport; Smart Logistics 5.0; Supply Chain.

INTRODUCTION

The evolution of global industry over the past decade has signaled a significant paradigm shift in supply chain and logistics management. The increasing complexity of goods, services, and information flows, compounded by the uncertainty caused by the COVID-19 pandemic, geopolitical conflicts, and market volatility, has intensified the demand for logistics models that are smarter, more adaptive, and sustainable (Ivanov, 2022). Furthermore, regulatory pressures and consumer expectations for transparency and environmentally responsible practices have reinforced the urgency of transforming traditional logistics systems into integrated and resilient ecosystems (Araz et al., 2022).

Within this context, the concept of Smart Logistics 5.0 emerges as an extension of the digital transformation initiated under Industry 4.0, with renewed emphasis on human-centricity and sustainability. Unlike the previous paradigm, which primarily emphasized automation and technical efficiency, Logistics 5.0 places human-machine collaboration, service personalization, and environmental stewardship at the core of operational strategy (Araz et al., 2022; Azarian et al., 2022). Technologies such as the Internet of Things (IoT), artificial intelligence (AI), blockchain, digital twins, and physical automation (robotics, autonomous vehicles, and drones) serve as the principal enablers that facilitate real-time visibility, route optimization, and end-to-end multimodal orchestration (Onyshchuk et al., 2025; Sundari et al., 2025).

The adoption of these digital technologies has been shown to significantly enhance operational efficiency through inventory optimization, demand forecasting, and the reduction of delivery delays (Bhargava et al., 2022; Cecil, 2024). The integration of multimodal transport, supported by collaborative platforms and the digitalization of trade documentation, addresses system fragmentation and accelerates cross-border flows, thereby reducing both costs and lead times on key routes (Cecil, 2024; Kurniawan, 2024). Beyond economic benefits, the combination of modal shifts (e.g., from road to rail or sea) and optimized routing also holds potential to reduce the carbon footprint of the transport sector, provided that appropriate incentive policies are implemented (Kazim & Baskaran, 2025).

Operationally, international supply chains in the era of globalization and digitalization face substantive challenges related to efficiency, speed, transparency, and adaptability to disruptions, alongside persistent issues of system and modal fragmentation (Cecil, 2024). To overcome these challenges, the literature underscores the critical role of digital technologies including IoT, AI, blockchain, and digital twins in improving visibility, refining demand prediction, and optimizing routing and inventory management, thereby reducing operational costs and shipment delays (Cecil, 2024; Onyshchuk et al., 2025).

A global supply chain constitutes a network of activities, organizations, individuals, information, and resources engaged in the production and distribution of goods and services from initial suppliers to end consumers across national boundaries. Within this network, processes such as design, production, marketing, distribution, and after-sales services are coordinated internationally, either through direct ownership or strategic partnerships (outsourcing/offshoring). Global supply chains represent a defining feature of globalization, enabling firms to access new markets, technologies, and resources efficiently while enhancing the speed and flexibility of product delivery worldwide (Schlegelmilch, 2022).

At the operational infrastructure level, the integration of multimodal transport, facilitated by collaborative platforms and the digitalization of trade documents, minimizes cross-border barriers and accelerates inter-country logistics processes (Cecil, 2024; Kurniawan, 2024). To confront systemic disruptions such as pandemics, conflicts, or extreme weather events, logistics organizations are urged to strengthen resilience through network flexibility, strategic stockpiling, and multi-stakeholder coordination. Lessons from humanitarian logistics underscore the importance of procedural innovation, data standardization, and operational preparedness as key elements of response readiness (Bui et al., 2020; Kovács & Sigala, 2020). In this regard, AI and big data analytics enhance predictive capability and response speed, while blockchain technology strengthens end-to-end accountability and transparency, though governance and privacy concerns remain key implementation challenges (Daraojimba et al., 2024).

Logistics 5.0 expands the digital transformation agenda by incorporating human-centricity, service personalization, and sustainability as core operational priorities (Jafari et al., 2022). Technologies such as IoT and sensor networks provide real-time data for monitoring goods' conditions and predictive maintenance, enabling faster and more accurate operational decisions (Sundari et al., 2025). Simultaneously, the integration of AI, blockchain, and big data analytics enhances supply chain visibility, accelerates response mechanisms, and supports both risk management and environmental objectives (Hirna, 2025).

This emerging paradigm situates multimodal transport integration within an adaptive and human-centered digital ecosystem: systems no longer rely solely on automation but instead position humans at the center of decision-making, innovation, and service personalization (Kurniawan, 2024). Supported by collaborative digital platforms, Smart Logistics 5.0 enables route optimization, real-time monitoring, and data-driven decision-making that accelerate delivery, reduce operational costs, and promote green logistics practices through modal shift and fleet electrification (Bhargava et al., 2022; Kazim & Baskaran, 2025).

Nevertheless, the success of this transformation largely depends on institutional and infrastructural readiness. Government policy support, investment capital availability, consistent data standards, and a collaborative culture throughout the supply chain are crucial prerequisites (Lu et al., 2005). Therefore, although Smart Logistics 5.0 presents a promising framework for achieving more adaptive, efficient, and sustainable supply chains, its global implementation continues to face significant challenges from digital infrastructure limitations to cross-jurisdictional regulatory inconsistencies necessitating systematic inquiry to formulate effective adoption strategies (Winkelhaus & Grosse, 2020).

METHOD

This study employed a narrative literature review using a systematic and purposive thematic approach. The literature search was conducted across major academic databases (Scopus, Web of Science, and Google Scholar) as well as gray literature from key industry organizations (e.g., Maersk/IBM, Deloitte, KPMG) covering the period from January 1, 2020, to June 30, 2025. The keywords used included variations and combinations of the following terms: *"Smart Logistics 5.0," "Industry 5.0," "IoT logistics," "blockchain supply chain," "autonomous vehicles logistics," "multimodal logistics," "digital control tower,"* and other related expressions.

The inclusion criteria were as follows: (a) peer-reviewed publications or relevant industry reports; (b) a focus on technology and/or modal integration within the supply chain context; (c) published between 2020 and 2025; (d) written in English or

Indonesian; and (e) presenting empirical findings, conceptual models, or comprehensive reviews. The exclusion criteria included short editorials without analytical content, documents not available in full text, and publications outside the designated time frame. Following the identification and screening phases, the selected studies were analyzed using thematic synthesis. Each article was coded according to its technological category (IoT, AI, blockchain, or physical automation), modal integration aspects, reported outcomes (efficiency, transparency, resilience, and sustainability), and implementation challenges. The synthesis process involved cross-study comparison of empirical results and the construction of a structured narrative that elucidates the key contributions, thematic patterns, and remaining research gaps in the field.

RESULT AND DISCUSSION

In general, Smart Logistics refers to logistics management that employs advanced technologies, such as the Internet of Things (IoT), big data, cloud computing, and artificial intelligence (AI) to automate and optimize operations, thereby enhancing efficiency, transparency, and continuity across the supply chain. According to Andres et al. (2024), Smart Logistics 5.0 represents the latest innovation in transportation integration, emphasizing efficiency, sustainability, and human-centricity within global supply chains. This concept leverages advanced technologies including IoT, AI, blockchain, and cyber-physical-social systems (CPSS) to establish a logistics ecosystem that is interconnected, adaptive, and responsive to dynamic market conditions. The integration of multiple transport modes is supported by real-time data, optimization algorithms, and automation systems, enabling effective route management, fleet monitoring, predictive maintenance, and data-driven decision-making that collectively improve operational efficiency and reduce costs (Bhargava et al., 2022).

1. Concept and Evolution of Smart Logistics 5.0

Smart Logistics is generally defined as logistics management that is automated and optimized through advanced technologies such as IoT, big data, and information technology to enhance operational efficiency, transparency, and supply chain continuity. This concept has evolved from the Logistics 4.0 paradigm, which focused on the application of Industry 4.0 technologies, toward Smart Logistics 5.0, which prioritizes human-centricity, sustainability, and resilience (Hsu et al., 2024). The transition to Smart Logistics 5.0 marks a shift from the emphasis on efficiency and automation (Logistics 4.0) toward human-machine collaboration, service personalization, and the strengthening of sustainability and supply chain resilience (Szeredi et al., 2024).

For example, Wang (as cited in Azarian et al., 2022) proposed Logistics 4.0 to enhance the intelligence and automation of logistics through IoT, robotics, and AI. In contrast, Smart Logistics 5.0 integrates artificial intelligence and digital technologies with human-machine collaboration to address the growing demand for customization and to foster socio-economic resilience. Hsu et al. (2024) emphasize that the successful implementation of Industry 5.0 depends on government support and the development of human-centered manufacturing and logistics models as key success factors. Several studies also highlight the importance of government backing, infrastructure development, and standardization as major enablers of this transformation. Moreover, Smart Logistics 5.0 aims to achieve the “6S” goals (Safety, Security, Sustainability, Sensitivity, Service, and Smartness) which collectively

strengthen the competitiveness and adaptability of the logistics industry in the global era (Hsu et al., 2024).

2. The Role of Key Technologies

a. IoT and Big Data

The Internet of Things (IoT) and big data are two complementary technologies, with IoT generating large volumes of data through connected sensors and devices, while big data provides methods for efficiently storing, managing, and analyzing that information (Bansal et al., 2020). Their integration enables smart applications in various domains such as smart cities, transportation, agriculture, environmental management, and industry by facilitating real-time monitoring, predictive analysis, automated decision-making, and enhanced service quality (Hajjaji et al., 2021).

IoT allows real-time tracking of assets and goods throughout the supply chain. According to Taj et al. (2023), IoT can automate and digitize supply chain management (SCM) processes to achieve maximum operational efficiency and cost reduction. IoT collects big data from sensors and delivery devices (e.g., GPS, RFID, telematics) to support tracking, tracing, and inventory management. Big data analytics then processes this information to optimize routing and demand forecasting, improving both visibility and operational predictability (Taj et al., 2023). Kurniawan (2024) demonstrates that real-time data systems and IoT in multimodal logistics significantly enhance operational coordination and crisis response, thereby improving efficiency and the resilience of integrated logistics networks.

b. Artificial Intelligence (AI)

Artificial Intelligence and machine learning play crucial roles in intelligent decision-making across procurement, scheduling, and resource optimization. The integration of AI into SCM substantially improves demand forecasting, inventory management, and operational decision-making, while Industry 5.0 emphasizes human-AI collaboration for customization and problem-solving. AI also optimizes resource utilization and reduces environmental footprints, supporting sustainable logistics practices. Thus, AI not only boosts operational efficiency but also strengthens supply chain resilience against disruptions (Samuels, 2024).

In Smart Logistics 5.0, AI serves as a core enabler of integrated transport innovation, enhancing efficiency, transparency, and global supply chain resilience. AI is applied in route optimization, demand prediction, inventory control, and predictive maintenance, significantly reducing delivery time, logistics costs, and equipment failure risks. Studies indicate that AI implementation in logistics can reduce delivery times by up to 25%, decrease stock-out incidents by 40%, and cut equipment failures by 35% (Mishra & Pradhan, 2025).

c. Blockchain

Blockchain technology plays a vital role in Smart Logistics 5.0 by providing a decentralized and immutable ledger system that enhances transparency, traceability, and data security across the logistics supply chain. With blockchain, every transaction or goods movement can be recorded in real-time and verified

by all relevant parties without intermediaries, reducing fraud, data errors, and administrative costs. The implementation of smart contracts further automates logistics processes such as payments and shipment tracking, expediting workflows and minimizing delays (Ran et al., 2024).

According to Deloitte (2021), blockchain adoption improves supply chain transparency and traceability while reducing administrative expenses. By digitizing documents (e.g., bills of lading, customs records), blockchain ensures consistent and auditable access to information for all parties. This enhances process transparency and mitigates fraud risks. Similarly, Idrissi et al. (2024) assert that supply chain traceability and flexibility can only be achieved through the integration of advanced technologies such as blockchain.

d. Autonomous Systems and Robotics

Autonomous systems and robotics play a central role in Smart Logistics 5.0 by providing high efficiency, speed, and operational precision. Autonomous Delivery Robots (ADRs), self-driving vehicles, and drones are increasingly used to address last-mile delivery challenges, reduce costs, optimize time, and lower emissions and labor dependency (Guerreiro et al., 2025). Within logistics facilities, autonomous robots perform tasks such as goods handling, route planning, and human-machine collaboration, supported by AI and advanced sensors to enhance adaptability and safety (Bernardo et al., 2022).

Ibiyemi and Olutimehin (2024) report that autonomous vehicles significantly increase logistics efficiency by enabling continuous operations with minimal human error, potentially improving supply chain efficiency by up to 30%. Likewise, drone integration in goods distribution reduces labor costs and accelerates delivery by 30%, cumulatively lowering operational costs and increasing service speed.

3. Integration of Transportation Modes

Smart Logistics 5.0 also emphasizes connectivity among various transportation modes, including sea, land, air, and rail. The concept of intelligent transportation focuses on unifying these different modes to create an integrated system that is both efficient and well-coordinated (Sari et al., 2023). For example, Kurniawan (2024) highlights that a multimodal approach (road, rail, sea, air) supported by digital infrastructure and IoT enhances the agility of logistics networks. In times of crisis, the multimodal model offers a more adaptive response compared to single-mode systems (Kurniawan, 2024). IoT and AI are utilized to manage the logistics process from first-mile to last-mile, streamline modal transitions, and monitor delivery conditions along the route, thereby reducing bottlenecks and delays. This cross-modal integration, supported by real-time information systems, improves overall cost and time efficiency in delivery operations.

Technologies such as digital twinning and V2X (vehicle-to-everything) connectivity enable data integration across transportation modes, scenario simulation, and automated decision-making for route optimization and resource utilization (Han et al., 2024). Studies also indicate that integrating internal and external transportation systems through intelligent algorithms can reduce logistics costs by up to 16.8% and

increase customer satisfaction (Bhargava et al., 2022). Therefore, Smart Logistics 5.0 establishes a multimodal transportation system that is integrated, collaborative, and responsive to market dynamics as well as environmental challenges (Han et al., 2024).

4. The Impact of Innovation on Efficiency, Transparency, and Resilience

Various technological innovations and intermodal integrations have collectively proven to enhance supply chain performance. According to Samuels (2025), the combination of digital technologies not only improves operational efficiency, such as demand prediction accuracy and inventory reduction, but also strengthens the resilience of supply chains against disruptions (Samuels, 2024). Transparency is enhanced through end-to-end tracking enabled by IoT and blockchain, ensuring full visibility over the movement of goods (Taj et al., 2023).

Logistics cost efficiency is improved through route optimization and modal integration; for instance, the use of standardized containers and intermodal synergy (such as ship-truck-rail combinations) minimizes reloading and waiting time. In terms of resilience, digitally supported multimodal structures enable rapid rerouting in response to disruptions caused by severe weather, traffic congestion, or geopolitical crises (Kurniawan, 2024). Overall, this review shows that Smart Logistics 5.0 through IoT, AI, blockchain, big data, and autonomous systems advances global supply chains toward faster, more transparent, adaptive, and sustainable operations.

Over the past five years, the literature consistently indicates that the implementation of Smart Logistics 5.0 relies on the combination of digital technologies and physical automation to accelerate, streamline, and strengthen global supply chains. This study emphasizes the role of digital multimodal transport integration as the core of Smart Logistics 5.0. Beyond improving cost and time efficiency, Smart Logistics 5.0 enhances the adaptability of supply chains to cross-border disruptions such as pandemics, geopolitical conflicts, and climate-induced disturbances. The integration of land, sea, air, and rail modes, supported by digital control towers, edge computing, and real-time information systems, allows for rapid rerouting and synchronized cross-border capacity management. This demonstrates that Smart Logistics 5.0 is not merely a technological evolution but a global strategy for achieving sustainable, resilient, and human-centered supply chain efficiency in an increasingly complex era of international trade.

The Internet of Things (IoT) and edge computing function not only as tracking tools but also as enablers of real-time operational orchestration, which is crucial for sensitive commodities. The performance of these technologies is typically measured by location accuracy, response time, and the degree of product damage reduction, yet challenges remain in achieving interoperability standards and device security. Furthermore, artificial intelligence (AI) and big data analytics enhance demand forecasting accuracy, route optimization, and predictive maintenance, often assessed using indicators such as mean absolute percentage error (MAPE), on-time in full (OTIF), and inventory days of supply. However, data limitations, algorithmic bias, and insufficient technical skills hinder broader adoption.

Meanwhile, blockchain and smart contracts have shown promise in expediting document verification and increasing transparency in logistics transactions, though they face obstacles related to privacy, network governance, and adoption among

smaller players. Physical automation, including warehouse robots, autonomous vehicles, and drones, has demonstrated improvements in throughput, order fulfillment accuracy, and cost efficiency per kilometer. Nevertheless, regulatory barriers, workplace safety issues, and inadequate energy infrastructure remain key implementation challenges. Moreover, integrating land, sea, air, and rail transport modes through digital control towers has proven effective in reducing logistics costs and CO₂ emissions per ton-kilometer, although schedule synchronization and transloading costs continue to pose significant difficulties.

Policy and regulatory factors also play a crucial role in either accelerating or slowing down the adoption of Smart Logistics 5.0. Proactive regulations, such as regulatory sandboxes for autonomous vehicles and digital customs systems, have facilitated faster technological adoption, whereas cross-border legal fragmentation and data protection concerns often serve as barriers. Sustainability has also become a central focus, as transport electrification and increased use of environmentally friendly modes contribute to emission reductions. However, high initial investment costs and the risk of greenwashing require fiscal incentives and carbon pricing mechanisms to promote broader adoption. Consequently, Smart Logistics 5.0 can be understood as an interconnected ecosystem of technology, policy, and business strategy that not only prioritizes cost efficiency but also enhances transparency, resilience, and sustainability within global supply chains.

Conceptually, the transformation direction of Smart Logistics 5.0 can be summarized through the strategic framework of the “6S”: Safety, Security, Sustainability, Sensitivity, Service, and Smartness. This framework emphasizes that the success of Smart Logistics 5.0 should not be measured solely by cost efficiency or delivery speed but also by the system’s ability to maintain operational safety, protect data and digital infrastructure (security), ensure environmental sustainability, respond sensitively to customer needs and market dynamics (sensitivity), deliver high-quality end-to-end service, and demonstrate intelligent adaptability to global disruptions (smartness). Therefore, the 6S serves as a comprehensive benchmark for assessing how effectively Smart Logistics 5.0 can realize an efficient, resilient, and sustainable global supply chain.

CONSLUSIONS

Recent literature indicates that Smart Logistics 5.0 is an evolution of Logistics 4.0 that introduces the dimensions of human-centricity, sustainability, and resilience within global supply chains. This concept emphasizes not only automation but also human-machine collaboration and transportation mode integration as forms of innovative, interconnected mobility. The key technologies IoT and edge computing for real-time orchestration, AI and big data for forecasting and route optimization, blockchain for traceability and contract automation, and autonomous systems such as robotics, self-driving vehicles, and drones have been proven to enhance efficiency, increase transparency, and strengthen supply chain resilience.

Multimodal integration across sea, land, air, and rail modes plays a crucial role in reducing logistics costs, accelerating delivery times, and improving the adaptability of networks to global disruptions. Therefore, Smart Logistics 5.0 can be understood as an integrated framework that synergizes digital technologies, physical automation, and

multimodal strategies to optimize global supply chain efficiency. Moving forward, the development of supportive policies, data standardization, green investment incentives, and workforce reskilling programs will be essential prerequisites to fully realizing the potential of Smart Logistics 5.0.

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