

Conceptualizing logistics 5.0: a socio-technical paradigm for human-centric, sustainable and resilient supply chains

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Abstract

Purpose – Logistics 5.0 represents a shift from Logistics 4.0 by moving beyond a focus on efficiency and technology to also consider socioenvironmental impacts. This article reviews the current research on Logistics 5.0, examining its key dimensions to provide a clearer conceptual understanding and propose a structured agenda for future studies.

Design/methodology/approach – A comprehensive systematic literature review was conducted, resulting in a final sample of 42 peer-reviewed articles retrieved from the Scopus and Web of Science databases. The selected studies were analyzed using content analysis to identify, categorize and synthesize key themes, findings and research gaps.

Findings – It was identified that Logistics 5.0 is characterized by three interconnected dimensions: resilience, sustainability and human-centricity. Unlike Logistics 4.0, which focuses primarily on technology, Logistics 5.0 places greater emphasis on people and broader societal goals. It emphasizes worker well-being and human-machine collaboration, the use of digital technologies to support sustainability goals and the application of real-time data and simulations to improve supply chain resilience and adaptability.

Originality/value – This study advances the emerging field of Logistics 5.0 by clarifying its conceptual boundaries in relation to Logistics 4.0 and proposing an integrated socio-technical framework grounded in resilience, sustainability and human-centricity. It further contributes by introducing a five-level Logistics 5.0 Maturity Model to support the operationalization and assessment of Logistics 5.0 in organizational contexts. In addition, the study identifies theoretical and managerial gaps, which inform a structured multidisciplinary research agenda. The findings provide theoretical guidance for future research, practical support for organizations seeking to implement Logistics 5.0 and policy implications related to digital infrastructure and workforce reskilling.

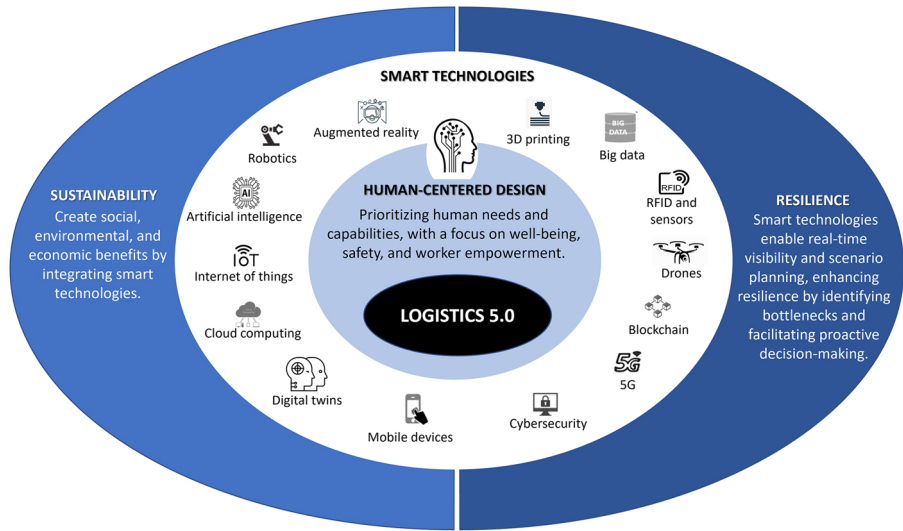
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Graphical abstract

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Paper type Literature review

1. Introduction

Industrial evolution has been marked by the development of new technologies that bring increased productivity and changes in the way people work (Leng *et al.*, 2022). Industry 1.0 was notable for its use of the steam engine, which resulted in a significant increase in productivity, while Industry 2.0 saw the emergence of electricity and the internal combustion engine, which led to the further development of industry (Maddikunta *et al.*, 2022; Nahavandi, 2019). The main contribution of Industry 3.0 was the adoption of information technologies to automate production processes, resulting in increased production efficiency (Maddikunta *et al.*, 2022; Nahavandi, 2019). Meanwhile, the strength of Industry 4.0 is the integration of advanced technologies, such as the Internet of Things (IoT), big data, cloud computing, artificial intelligence (AI) and blockchain, to improve industrial efficiency (Xu *et al.*, 2021). The industrial revolutions also transformed logistics operations, with the development of more efficient, reliable and flexible technologies and practices (Wang *et al.*, 2016).

Logistics 4.0, derived from Industry 4.0, was the result of advances in information and communication technologies and the introduction of cyber-physical systems (Nahavandi, 2019; Wang *et al.*, 2016). Through automation and digital integration, Logistics 4.0 significantly enhanced operational efficiency, traceability and decision-making capabilities. However, the growing complexity of global supply chains, combined with increasing environmental and social pressures, has exposed the limitations of purely technocentric and efficiency-oriented logistics models (Cimini *et al.*, 2022; Leng *et al.*, 2022).

Industry 5.0 has emerged from this context, proposing a restructuring of manufacturing and product delivery processes, aligning them not only to technical criteria but also to social and environmental needs. Unlike previous industrial revolutions, Industry 5.0 does not arise from entirely new disruptive technologies. Instead, it reflects a paradigmatic reorientation in the use of existing technologies. It represents a transition from a purely technocentric and hyper-efficiency-oriented model, characteristic of Industry 4.0, toward a sociotechnical approach. In this perspective, artificial intelligence, collaborative robotics

and digitalization are redefined to support human well-being, systemic resilience and environmental regeneration.

The three pillars underpinning this paradigm, namely sustainability, resilience and human-centricity, are widely discussed in the literature, yet their conceptual boundaries remain contested. Sustainability is framed as operational efficiency through reduced resource consumption (Elkington, 1998; Nicoletti and Appolloni, 2024) or as ecological regeneration grounded in circular economy principles (Ismail *et al.*, 2024). Similarly, resilience has been associated with both reactive recovery from disruptions (Ivanov, 2023a; Ivanov *et al.*, 2022) and proactive anticipation of future risks (Saldanha-Da-Gama, 2022). Human-centricity also encompasses distinct perspectives, ranging from worker safety and well-being to human-machine collaboration and cognitive augmentation (Cimini *et al.*, 2022; Grosse *et al.*, 2023; Lagorio *et al.*, 2024). These divergent interpretations highlight the absence of an integrated framework capable of articulating these dimensions within a coherent Logistics 5.0 paradigm.

As a holistic outcome of this integration, production and logistics systems become increasingly resilient, sustainable and human-centered (Ivanov, 2023b). Rather than operating as rigid structures, these advanced sociotechnical systems are designed to adapt rapidly to changes in demand and environmental conditions. They enable the delivery of personalized, high-quality products and services with reduced environmental impact, while leveraging human creativity in synergy with the precision and efficiency of intelligent machines (Maddikunta *et al.*, 2022).

Derived from the principles of Industry 5.0, the concept of Logistics 5.0 (L5.0) extends the socio-technical logic of the fifth industrial revolution to logistics and supply chain management contexts. Rather than introducing entirely new technologies, Logistics 5.0 redefines the purpose of digital technologies by aligning them with human well-being, resilience and sustainability objectives. Despite the growing interest in Logistics 5.0, the literature remains conceptually fragmented. Existing studies frequently approach Logistics 5.0 from isolated technological, sustainability or human-centered perspectives, without integrating these dimensions into a coherent socio-technical framework. Furthermore, the conceptual boundaries between Logistics 4.0 and Logistics 5.0 remain unclear, particularly regarding whether Logistics 5.0 represents a paradigmatic transformation or merely an extension of digitalization trends already associated with Industry 4.0.

Recent studies have explored the technical aspects associated with key Logistics 5.0 technologies, as well as operational challenges such as high implementation costs, organizational resistance and deficiencies in technical training (Ahmed *et al.*, 2023; Grosse *et al.*, 2023; Ivanov, 2023a; Li *et al.*, 2023a). Another growing stream of research examines human-centricity in technological projects, addressing critical issues related to worker well-being, safety and job satisfaction (Cimini *et al.*, 2022; Grosse *et al.*, 2023; Lagorio *et al.*, 2024). Nevertheless, important theoretical tensions remain insufficiently explored in the literature. While some studies portray advanced digitalization as a mechanism for enhancing resilience, sustainability and worker empowerment, others emphasize risks associated with workforce displacement, employee surveillance, ethical concerns, technological dependence and increasing sociotechnical complexity. These contrasting perspectives highlight the need for a more integrated and critically grounded conceptualization of Logistics 5.0, capable of balancing technological, organizational, social and environmental dimensions.

The present study adopts a socio-technical perspective by recognizing that logistics transformation depends not only on technological capabilities but also on the interaction between organizational structures, human factors and sustainability objectives. This perspective is aligned with socio-technical systems theory (Carter and Rogers, 2008), which emphasizes that organizational performance emerges from the interaction between technological and social subsystems. Given these gaps, this study seeks to answer the following research question: “*How is Logistics 5.0 conceptualized in the current literature and what are the key dimensions associated with it?*”. To address this question, a systematic

literature review (SLR) was conducted based on 42 peer-reviewed articles published in international journals.

Drawing on the findings of the SLR, this study advances the Logistics 5.0 field through four interconnected contributions. First, it clarifies the conceptual boundaries between Logistics 4.0 and Logistics 5.0, highlighting the transition toward a socio-technical paradigm. Second, it synthesizes fragmented research streams into an integrated conceptual framework grounded in resilience, sustainability and human-centricity. Third, the study advances the operationalization of Logistics 5.0 by proposing a five-level maturity model that enables organizations to assess their current stage and guide their progression from technology-driven logistics toward socio-technical and regenerative logistics systems. Finally, beyond conceptual consolidation, the study uncovers critical theoretical and managerial gaps that constrain the implementation of Logistics 5.0 in organizational settings. These gaps informed the development of a structured and multidisciplinary research agenda to advance future empirical research and managerial practice.

This article is divided into six sections, including this introduction. The second section presents the concept of Industry 5.0. The third describes the method used to conduct the study. The fourth section contains the qualitative analysis of the articles investigated, presenting the concept, framework and dimensions of Logistics 5.0. The fifth section consolidates the research gaps identified in the literature. The last section brings the study's final considerations.

2. Theoretical foundations of Logistics 5.0

Industry 5.0 is a new approach to manufacturing, presented by the [European Commission \(2021\)](#). Rather than being a chronological continuation of, or alternative to, Industry 4.0, this new approach is an extension of its principles. This evolution is a response to emerging social trends and needs, such as the urgent demand for waste reduction and the quest to make supply chains less vulnerable ([Xu et al., 2021](#)).

According to [Ivanov \(2023a, b\)](#), Industry 5.0 refers to the integration of resilient, sustainable and human-centered technologies, organizational concepts and management principles aimed at designing and managing value-adding systems across ecosystems, supply chains and manufacturing and logistics operations. These systems are characterized by their efficiency, responsiveness, adaptability and human-centered orientation. One of the main distinctions between Industry 4.0 and Industry 5.0 lies in the focus the latter places on human beings in the production process. While Industry 4.0 has traditionally prioritized automation and operational efficiency, with comparatively less attention devoted to the well-being of workers and social sustainability ([Jafari et al., 2022](#); [Parhi et al., 2022](#); [Xu et al., 2021](#)), Industry 5.0 seeks to rebalance this logic by positioning human capabilities at the center of technological systems. This approach aims not only to improve quality of life and ensure healthier and safer working environments ([Cimini et al., 2022](#)) but also to strengthen collaboration between humans and machines, promoting the personalization of products and services more effectively ([Ivanov et al., 2022](#); [Xu et al., 2021](#)). [Table 1](#) summarizes the main differences between these two approaches, thus providing a comprehensive view of the evolution of manufacturing and technology.

The theoretical foundations of Industry 5.0 and Logistics 5.0 extend beyond recent technological discussions and are deeply rooted in classical socio-technical systems (STS) theory. STS theory is grounded in the foundational studies of [Trist and Bamforth \(1951\)](#) and the structural model of [Leavitt \(1965\)](#). This perspective argues that organizational effectiveness, safety and resilience depend on the joint and interdependent optimization of social subsystems (people, relationships and organizational structures) and technical subsystems (technologies, tools and operational processes) ([Leavitt, 1965](#); [Trist and Bamforth, 1951](#)). This perspective provides the conceptual basis for the human-centered

Table 1. Differences between Industry 4.0 and Industry 5.0

	Industry 4.0	Industry 5.0
Focus	Automation and efficiency	Human-centered, resilience and sustainability
Role of human beings	Focus on replacing human operators with automation, leading to unemployment in some areas	Aims to promote the creation of qualified jobs, where professionals work in collaboration with machines, thus seeking a more harmonious integration between humans and technology
Technologies	Industry 4.0 uses advanced technologies such as the Internet of Things, Big Data, cloud computing and artificial intelligence, blockchain and automation to improve industrial efficiency	In addition to the technologies adopted by Industry 4.0, Industry 5.0 emphasizes other specific technologies, such as bioinspired technologies and technologies geared to energy efficiency and renewable energies
Type of production	Industry 4.0 emphasizes mass production and large-scale automation, with robots playing a central role	The main focus of Industry 5.0 is mass customization, where humans play a guiding role in the work of robots, allowing for highly personalized products and services

Source(s): Adapted from [Jafari et al. \(2022\)](#), [Parhi et al. \(2022\)](#) and [Xu et al. \(2021\)](#)

orientation of Industry 5.0 by rejecting purely technocentric approaches and emphasizing that technological innovation should support human well-being and organizational sustainability.

These assumptions are further reinforced by the human factors and ergonomics literature, which demonstrate that neglecting workers' physical, cognitive and psychosocial demands may generate systemic failures, operational inefficiencies and occupational risks ([Davis et al., 2014](#); [Walker et al., 2008](#)). In logistics environments, these discussions have become increasingly relevant due to the growing implementation of collaborative robots, automation systems and intelligent interfaces. Accordingly, recent studies argue that advanced technologies should be designed to augment human capabilities rather than simply replace human labor ([Grosse et al., 2023](#); [Neumann et al., 2021](#); [Winkelhaus and Grosse, 2020](#)).

From a resilience perspective, the theoretical foundations of Industry 5.0 applied to logistics are rooted in supply chain resilience models, viable supply chain theory and digital supply chain transformation. Seminal contributions by [Sheffi and Rice Jr \(2005\)](#) and [Ponomarov and Holcomb \(2009\)](#) conceptualize resilience as the ability of supply chain networks to anticipate, absorb, adapt to and recover from disruptions while maintaining operational continuity. This debate gained prominence during the COVID-19 pandemic, which exposed vulnerabilities such as supplier dependence, transport disruptions and cascading failures across global logistics systems. Building on these classical perspectives, [Ivanov and Dolgui \(2019\)](#) emphasize that digital technologies and advanced analytics are essential to mitigate ripple effects and enhance system viability under uncertainty.

From a sustainability perspective, Industry 5.0 applied to logistics is grounded in sustainable supply chain management, circular economy and industrial ecology frameworks. Foundational studies by [Carter and Rogers \(2008\)](#) and [Linton et al. \(2007\)](#) highlight the integration of economic, environmental and social objectives in supply chain design and management. This discussion is expanded by circular economy literature ([Bals et al., 2022](#); [Geissdoerfer et al., 2017](#); [Genovese et al., 2017](#)), which emphasizes regenerative systems oriented toward resource efficiency, waste reduction and product life-cycle extension. Consequently, the integration of technological intelligence with circularity principles ensures value creation across economic, social and environmental dimensions while respecting planetary boundaries ([Genovese et al., 2017](#)). Although these theoretical streams are complementary, they prioritize different objectives. While resilience research often emphasizes continuity and adaptability under disruption, sustainability frameworks focus on long-term environmental and social outcomes, which may occasionally create tensions in managerial decision-making.

Taken together, these theoretical perspectives provide the foundations for the three core dimensions identified in Logistics 5.0. Human centricity is primarily rooted in socio-technical systems theory and human factors research (Lagorio *et al.*, 2024; Winkelhaus and Grosse, 2020); resilience derives from supply chain resilience and viability theories (Ivanov and Dolgui, 2019) and sustainability is grounded in sustainable supply chain management and circular economy principles (Elkington, 1998; Nicoletti and Appolloni, 2024). By integrating these perspectives, Logistics 5.0 can be understood as a socio-technical paradigm that seeks to balance technological advancement with human well-being, environmental responsibility and adaptive capacity in increasingly complex logistics systems.

3. Methodological procedures

Logistics 5.0 is an emerging and evolving concept, one lacking a universally accepted definition. Given this conceptual gap, a systematic literature review (SLR) was carried out, with the aim of mapping, identifying and critically analyzing the different theoretical perspectives extant in the academic literature on the subject. With its origins in the area of health, the SLR is notable as a structured and transparent methodology designed to systematize the search, evaluation and synthesis of scientific evidence, one which guarantees rigor and replicability in the treatment of sources (Tranfield *et al.*, 2003).

The choice of this method is justified, considering its ability to bring together diverse studies in a coherent analytical framework, allowing researchers to critically examine the state of the art and identify trends or conceptual divergences (Centobelli *et al.*, 2020). The present study used the structured methodology for SLR proposed by Ahrens and Heubeck (2025) and Cerchione *et al.* (2016), which establishes clear steps from the definition of search criteria to the interpretative analysis of data. This approach not only guaranteed transparency during the process but also ensured scientific validation of the results obtained, in line with the best practices for the critical syntheses of academic literature.

3.1 Search for material

In order to identify the literature pertinent to the topic under investigation, the SLR initially defined a research protocol (Table 2), in line with the methodological approach of Ahmad and Van Looy (2020). This procedure aimed at minimizing results bias.

The search was conducted in February 2025 using the Web of Science (WoS) and Scopus databases. These databases were selected because they are among the most comprehensive and widely recognized sources of peer-reviewed scientific literature, ensuring broad coverage and methodological rigor in the literature retrieval process (Pranckutė, 2021). The aim of the research was to identify studies related to Logistics 5.0 and associated 5.0 technologies in the logistics context. To this end, a search strategy combining relevant keywords was employed. The term “Logistics 5.0” was associated with other terms commonly used to refer to 5.0 technologies, such as “Industry 5.0” and “Society 5.0”. This combination was complemented with terms inherent to the logistics sector, such as “logistics,” “supply chain,” “warehouse” and “transportation”. The searches covered the “title, keywords, and abstract” fields of the studies: a common strategy for identifying relevant research in academic databases.

3.2 Selection and evaluation of the articles

The selection criteria for articles demanded that those studies considered were strictly related to the logistics area and comprehensively addressed the topic of Logistics 5.0. This included studies investigating advanced technologies, automation, digitalization and innovations in logistics and also considered the interconnection with the principles of sustainability, resilience and prioritizing the human element in operations. The initial search resulted in 231 articles. To ensure methodological rigor, following the recommendations of Cassaro *et al.* (2025), the quality appraisal procedure included only peer-reviewed journal articles,

Table 2. Research protocol – SLR

Stage	Phase	Activity
1. Search for material	Research question	How is Logistics 5.0 conceptualized in the current literature and what are the key dimensions associated with it?
	Databases Research strategy – Combination of keywords Research fields Eligibility of the studies	<i>Scopus and Web of Science</i> (“logistics 5.0”) OR [(“industry 5.0” OR “society 5.0”) AND (“logistics” OR “supply chain” OR “warehouse” OR “transportat*”)] Title, abstract and keywords Theoretical or empirical studies addressing the dimensions and concepts of Industry 5.0 applied to logistics operations
2. Selection and evaluation of the articles	Inclusion criteria	Peer-reviewed study (editorial, article and review), available in the databases selected, written in English or Portuguese
	Exclusion criteria	Studies that correspond to book chapters, conference and seminar papers. Studies that do not explore Logistics 5.0 from an organizational perspective
	Screening	Filter 1: Reading of the titles Filter 2: Reading of the keywords and abstract Filter 3: Reading of the introduction and conclusion Filter 4: Reading of the entire article
3. Analysis and synthesis of the results	Descriptive analysis	Distribution of the articles by year of publication, periodical and articles most cited
	Qualitative analysis	Concept of Logistics 5.0 and dimensions of Logistics 5.0
Source(s): Prepared by the authors (2025)		

excluding conference papers and other non-peer-reviewed publications. After removing duplicate and non-relevant records, the sample was reduced to 143 articles. Subsequently, the titles, keywords and abstracts were screened to assess their alignment with the research question. This process resulted in the exclusion of 88 articles, yielding a final sample of 42 studies.

3.3 Data analysis

The analysis was conducted using the content analysis technique, with the aim of systematizing and categorizing key information extracted from the studies selected. Content analysis enables the material selected to be explored and divergences and convergences between studies to be found (Bardin, 2008). The process sought to identify, in a structured way, the central objective of each study, the methodological description used, the main results and contributions to the field and the suggestions proffered for future research.

Concurrently, the aim was to map out which dimensions of Logistics 5.0 were addressed across the studies and how these dimensions were explored: by such means, a critical understanding of the interaction between technological innovations and contemporary logistics practices could be reached. To ensure accuracy and organization, the data was compiled within a structured database, developed with the use of Excel software, facilitating the cataloguing, cross-referencing and systematic visualization of the information collected. Such a methodological approach enables not only the qualitative synthesis of the elements investigated but also the identification of patterns and thematic gaps relevant to the advancement of knowledge in the area.

4. Theoretical framework: conceptualization and pillars of Logistics 5.0

As pointed out in the literature (Jafari *et al.*, 2022; Trstenjak *et al.*, 2022), the migration to Industry 5.0 requires a systemic restructuring of current business models. These models, traditionally anchored in the unilateral maximization of profitability, contrast with the human-centered and ecological principles of Industry 5.0, which advocate the three-dimensional harmonization of economic efficiency, social equity and environmental preservation (Ivanov *et al.*, 2022; Li *et al.*, 2023a). In this context, Logistics 5.0 emerges as a strategic paradigm capable of operationalizing these principles within supply chains, simultaneously promoting operational optimization, cost reduction, customer satisfaction and the mitigation of negative externalities (Li *et al.*, 2023a). This transformation is driven by the adoption of smart technologies aimed at increasing transparency and connectivity across supply chains, which are necessary factors for the consolidation of more efficient, resilient and environmentally responsible operations (Ivanov *et al.*, 2022).

Although Logistics 5.0 derives directly from the foundational principles of Industry 5.0, its practical application within supply chains establishes a field of study with distinctive characteristics and substantially different challenges (Ivanov and Dolgui, 2019). While Industry 5.0 focuses predominantly on the intra-organizational environment and the redesign of manufacturing spaces, Logistics 5.0 extends this perspective to the external and global supply chain environment, encompassing highly dynamic and often uncontrollable variables, such as international logistics infrastructure, climate conditions, natural ecosystems and the simultaneous interaction of multiple networked actors (Fox *et al.*, 2025; Li *et al.*, 2023b).

One of the main theoretical distinctions between Logistics 5.0 and Industry 5.0 lies in the explicit incorporation of the biological dimension into organizational and operational analyses (Fox *et al.*, 2025; Li *et al.*, 2023b). While Industry 5.0 is primarily focused on human-machine interactions within controlled manufacturing environments (Jafari *et al.*, 2022; Trstenjak *et al.*, 2022), Logistics 5.0 recognizes that logistics activities directly interact with natural ecosystems and biomes. The expansion of logistics infrastructure, such as roads, warehouses, ports and distribution centers, can generate environmental impacts including habitat loss, ecosystem degradation, biodiversity reduction and changes in natural dynamics (Fox *et al.*, 2025). Therefore, Logistics 5.0 adopts a broader perspective in which supply chain operations must be managed not only from technological and economic viewpoints, but also considering their effects on environmental and biological systems.

Furthermore, the operational environment of Logistics 5.0 differs substantially in terms of complexity. While industrial production systems tend to operate in structured and relatively controllable environments (Ivanov, 2023a), Logistics 5.0 is characterized as a highly complex cyber-physical-social system, simultaneously encompassing different countries, markets, cultures and economic structures (Li *et al.*, 2023a; Wang *et al.*, 2024). In this context, coordination among multiple independent actors, including suppliers, logistics providers, customs authorities and consumers, requires new mechanisms of governance, transparency and trust (Li *et al.*, 2023a; Wang *et al.*, 2024).

Based on the findings of the SLR and the theoretical foundations discussed previously, a conceptual framework and a clear definition of Logistics 5.0 were developed. *Logistics 5.0 represents an intelligent, adaptable and collaborative ecosystem, driven by data and focused on human centricity and sustainability, which integrates advanced digital technologies to create shared value and promote the resilience of logistics operations and supply chains.*

Figure 1 presents the proposed framework, which synthesizes the key dimensions and underlying principles of the Logistics 5.0 concept. The technical subsystem (logistics technologies) provides the technological backbone for the automation and digitalization of logistics, integrating warehouse management systems, collaborative robots, autonomous vehicles, IoT-enabled tracking, digital twins, AI-based routing and last-mile innovations such as drones and augmented reality, alongside cybersecurity, blockchain and predictive analytics (Dornelles *et al.*, 2023; Lagorio *et al.*, 2024). These technologies enhance visibility, efficiency and control across logistics operations.

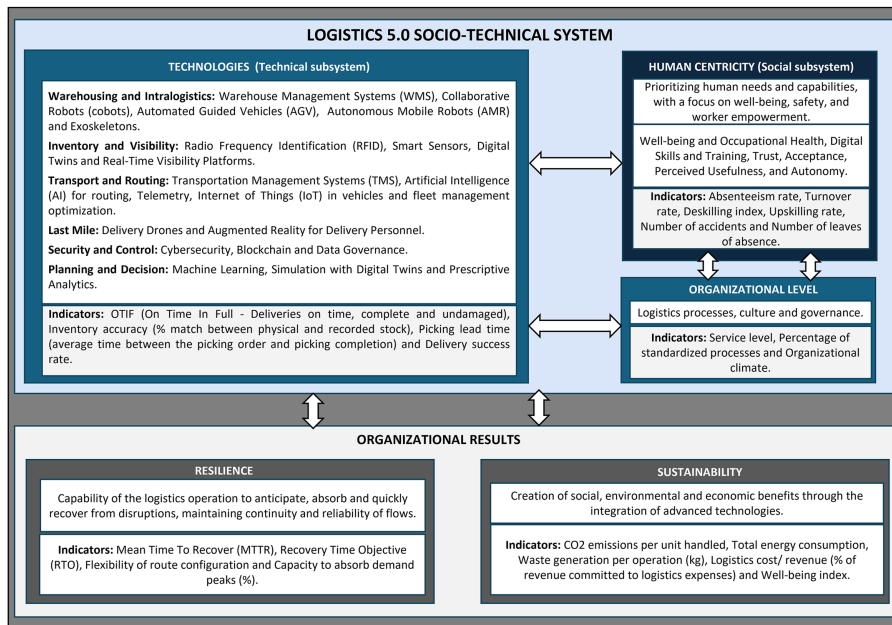


Figure 1. Conceptual framework for Logistics 5.0. Source: Prepared by the authors (2026)

The organizational level acts as a mediating layer between technological and social subsystems, encompassing governance structures, organizational culture, process standardization and managerial practices (Grosse *et al.*, 2023; Thylén *et al.*, 2023). It determines how technologies are deployed and how human-centric principles are translated into operational routines (Lagorio *et al.*, 2024). Consequently, the same technological infrastructure may generate different outcomes depending on the organizational context in which it is implemented (Adriaensen *et al.*, 2023; Thylén *et al.*, 2023).

The social subsystem (human centrality) emphasizes that technology creates value only when aligned with worker well-being, skills and perceptions. It includes occupational health (physical, cognitive and psychosocial), digital skill development and behavioral dimensions such as trust, acceptance, autonomy and perceived usefulness (Grosse *et al.*, 2023; Sakthi Nagaraj and Jeyapaul, 2021). In this sense, human credentials act as both an enabler and a constraint for technological implementation. Within the proposed framework, human-centrality is not treated as an outcome of digital transformation but as a prerequisite for achieving resilience and sustainability. Technology creates value only when supported by adequate skills, well-being, trust and active worker participation.

The framework assumes that resilience and sustainability are emergent outcomes resulting from the interaction between technological capabilities, organizational arrangements and human-centered practices. In this perspective, the interaction among these subsystems generates two key outcomes: resilience and sustainability. Resilience refers to the system's ability to anticipate, absorb and recover from disruptions (Ahmed *et al.*, 2023a,b; Ismail *et al.*, 2024; Ivanov, 2023a, b), while sustainability reflects the balance of economic, environmental and social performance through responsible technological integration (Anitha and Parthiban, 2025; Kamruzzaman *et al.*, 2025; Pereira *et al.*, 2023). In this sense, human-centrality functions as an enabling condition. Without well-being, adequate training and active participation, the adoption of technology is likely to generate stress, skill loss, and resistance. These effects can undermine both resilience, as less motivated workers respond less

effectively to disruptions, and social sustainability, due to higher absenteeism and employee turnover.

However, these outcomes involve important dependencies and trade-offs. Greater automation and efficiency can strengthen resilience but may reduce human autonomy or increase job strain if human-centricity is neglected (Pasparakis *et al.*, 2023). Similarly, sustainability initiatives may require operational redundancies or slower processes that can temporarily reduce efficiency. Conversely, strong human-centricity improves adaptability, learning and long-term sustainability but may limit full automation or increase implementation costs (Ivanov, 2023a; Priyadarshini *et al.*, 2024). Thus, achieving Logistics 5.0 requires balancing technological optimization, human well-being and system-level robustness rather than maximizing any single dimension in isolation.

4.1 Resilience and Logistics 5.0

Resilience is perceived as the multidimensional ability to face challenges and guarantee the continuity of logistics operations (Ivanov *et al.*, 2022). Resilient supply chains adapt and recover in the face of increasing global volatility: marked by pandemics, natural disasters, geopolitical crises and fluctuations in demand (Hsu *et al.*, 2024a, b; Ismail *et al.*, 2024; Ivanov, 2023a). In Logistics 5.0, resilience involves the use of technologies to create logistics systems that are agile, flexible and prepared for changes in market and business environments. These systems are designed not only to adapt to changes in such environments but also to incorporate lessons learned from adversity, strengthening their preparedness for future events (Ismail *et al.*, 2024). Achieving this adaptive capacity requires an integrated approach that transcends purely technological solutions, instead recognizing that resilience emerges from the interaction between digital capabilities, organizational learning structures and supply chain network design (Ivanov, 2023a; Zare *et al.*, 2025).

Digitalization enables data to be collected and shared in real time throughout supply chains, providing visibility with respect to the flow of materials, products and information. This helps speed up the identification of bottlenecks and company responsiveness, ensuring that operations continue to flow as efficiently as possible (Yu and Sun, 2024). The decentralization of production helps to increase the flexibility of operations and reduce dependence on single suppliers (Ivanov, 2023b). Decision-making based on historical data, combined with the identification of patterns, is essential to prevent supply-chain interruptions (Bhargava *et al.*, 2022; Jafari *et al.*, 2022).

In addition, strategies such as optimizing transport routes, efficient inventory management and anticipating fluctuations in demand have proved fundamental to improving logistics performance (Ahmed, Tazim *et al.*, 2023). Data security and reliability play a crucial role in preventing data manipulation and guaranteeing the integrity of information, strengthening supply chain operations (Bhat *et al.*, 2022). Tools such as fuzzy optimization and dynamic simulations, including the use of digital twins, mean that assessing the robustness of supply chains in different scenarios and supporting the development of contingency plans are possible (Ivanov, 2023a; Yu and Sun, 2024). Using RFID to track inventory improves visibility and efficiency, minimizing delays and interruptions (Ahmed *et al.*, 2023). Finally, immersion in virtual environments has emerged as a promising solution for optimizing training and solving complex problems in supply chain management (Chidozie *et al.*, 2024).

However, literature increasingly recognizes that resilience cannot be achieved through technology alone. Organizational governance, decision-making structures and learning capabilities play a critical role in determining whether digital tools effectively support disruption management (Sang and Hung, 2024; Thylén *et al.*, 2023). Even highly digitalized supply chains may remain vulnerable when organizations lack coordination mechanisms, clear responsibilities or the capacity to translate data into timely decisions (Lagorio *et al.*, 2024).

Despite the growing relevance of resilience in Logistics 5.0, the literature highlights significant theoretical tensions in its management. The main contradiction emerges between resilience and sustainability; the traditional resilience strategies, based on redundancy, conflict with sustainability goals aimed at reducing waste and emissions (Ivanov, 2023a). Simulation studies reinforce this perspective by showing that highly responsive recovery actions, such as emergency air freight, ensure operational continuity but significantly increase CO₂ emissions (Ivanov, 2023a). Thus, resilience in Logistics 5.0 must go beyond short-term responses and incorporate long-term sustainable adaptation strategies.

Another structural tension arises from the digitalization and hyperconnectivity of supply chains. Although these networks enhance efficiency and visibility, highly interconnected digital systems also increase systemic vulnerability by enabling the rapid propagation of failures across multiple layers of the network, a phenomenon known as the ripple effect (Lei *et al.*, 2023). At the same time, the purely technocentric approach inherited from Industry 4.0 has been strongly questioned (Karmaker *et al.*, 2023). The COVID-19 pandemic demonstrated that strictly automated systems struggle to cope with unprecedented disruptions, where historical data and algorithmic forecasts become insufficient (Ahmed *et al.*, 2023; Chatterjee and Chaudhuri, 2024). This finding underscores that resilience in Logistics 5.0 must integrate human judgment, organizational flexibility and adaptive learning alongside technological sophistication (Ismail *et al.*, 2024; Ivanov, 2023b).

4.2 Sustainability and Logistics 5.0

Logistics 5.0 is proving its worth as a paradigm capable of creating sustainable value, while harmonizing economic, social and environmental dimensions. By incorporating advanced technologies, such as big data, collaborative robotics and blockchain, the approach enables circular logistics systems to be built that are capable of reducing environmental impacts and promoting operational efficiency (Pereira *et al.*, 2023). Thus, the integration of innovation and sustainability redefines not only processes (Schallmo *et al.*, 2025) but also the human experience at work, aligning business competitiveness with ethical and ecological principles. However, the literature increasingly argues that sustainability in Logistics 5.0 should not be interpreted as a linear or conflict-free process, since attempts to solve environmental or operational problems often generate new tensions, unintended consequences or competing priorities across economic, technological and biological dimensions (Priyadarshini *et al.*, 2024).

From a social sustainability perspective, collaborative robotics and intelligent systems are conceptually associated with worker empowerment, improved ergonomics and safer working conditions. By automating repetitive or hazardous tasks, technologies such as cobots, Automated Guided Vehicles (AGVs), IoT and AI systems may reallocate workers to more strategic and cognitively oriented activities (Dornelles *et al.*, 2023; Vijayakumar and Sobhani, 2023). In parallel, real-time data analysis means that customizing professional training programs is possible, fostering employee inclusion (Grosse *et al.*, 2023). Nevertheless, empirical studies demonstrate that many organizations continue to implement these technologies primarily through technocentric and efficiency-oriented approaches, prioritizing labor substitution and operational performance over worker development and well-being (Dornelles *et al.*, 2023). This gap between conceptual promise and organizational practice reveals that technology adoption alone is insufficient to achieve human-centricity and improve social sustainability without parallel investments in organizational culture, change management and worker participation in system design (Adriaensens *et al.*, 2023; Cimini *et al.*, 2022; Lagorio *et al.*, 2024).

From an economic perspective, Logistics 5.0 optimizes supply chain processes through integrated digitalization, enabling cost reduction and increased decision-making agility. Technologies such as big data analytics and artificial intelligence support predictive analysis of transportation routes and demand patterns, reducing waste and increasing logistical precision

(Nicoletti and Appolloni, 2024). Enhanced supply chain visibility through digital integration allows for more strategic and data-informed decisions. Circular economy principles combined with additive manufacturing (3D printing) promote innovation and new business models while reducing material costs (Ismail *et al.*, 2024). The transition to renewable energy sources, despite requiring substantial initial capital investment, guarantees long-term economic benefits through reduced carbon footprints and enhanced corporate reputation (Dwivedi *et al.*, 2023).

In the environmental field, Logistics 5.0 prioritizes ecological neutrality through intelligent energy management systems and reverse logistics: essential strategies for the circular economy (Li *et al.*, 2023a). The strength of additive manufacturing lies in enabling localized and on-demand production, thereby reducing inventories, excessive transport and waste (Ivanov, 2023a). In addition, route optimization through AI algorithms reduces fuel consumption and emissions, while traceability via blockchain ensures ethical practices throughout supply chains (Nicoletti and Appolloni, 2024; Wang *et al.*, 2024). The integration of digital tools not only maximizes operational efficiency but also reinforces corporate responsibility, ensuring that economic advances coexist with social equity and environmental preservation (Wang *et al.*, 2024).

However, critical trade-offs and design paradoxes complicate these economic advantages. Although additive manufacturing and consolidated product designs reduce transportation costs and emissions, they simultaneously limit repairability and reuse potential, creating a tension between logistical efficiency and circular economy principles (Priyadarshini *et al.*, 2024). Most significantly, technologies enabling transparency and circular operations (blockchain, digital twins and renewable energy systems) require substantial initial capital investments that hinder adoption, particularly among small and medium-sized enterprises (SMEs) with constrained resources (Ismail *et al.*, 2024; Parhi *et al.*, 2022). Simultaneously, consumer demand for sustainable and transparent supply chains remains disconnected from consumers' willingness to pay the price premiums required to support these systems (Priyadarshini *et al.*, 2024; Wang *et al.*, 2024).

Furthermore, the existing literature suggests that logistics solutions designed to be sustainable and digitally enabled may also generate unintended socio-environmental externalities. While electric vehicles and highly digitalized e-commerce systems are promoted as sustainable alternatives due to their potential to reduce carbon emissions and improve operational efficiency, studies indicate that lithium extraction for battery production may cause ecological degradation and biodiversity loss in mining regions (Fox *et al.*, 2025; Hsu *et al.*, 2024a, b). Similarly, the expansion of e-commerce and home delivery systems increases packaging consumption, transportation intensity and waste generation, contributing to additional environmental impacts (Fox *et al.*, 2025; Hsu *et al.*, 2024a, b). Taken together, these tensions indicate that sustainability in Logistics 5.0 should not be understood as a straightforward outcome of digitalization (Fox *et al.*, 2025; Hsu *et al.*, 2024a, b). Rather, it emerges from the continuous balancing of economic, environmental, social and technological objectives across complex supply chain ecosystems (Fox *et al.*, 2025; Nicoletti and Appolloni, 2024).

4.3 Human-centricity and Logistics 5.0

Unlike traditional automation approaches, Logistics 5.0 emphasizes collaboration between humans and machines to enhance productivity while maintaining worker well-being (De Lombaert *et al.*, 2023). Human-centricity has emerged as a pillar, guiding the integration of digital technologies into supply chains in order to leverage human intelligence, improve user experience and optimize processes (Adel, 2022). Based on a socio-technical perspective, Logistics 5.0 seeks to balance technical elements, such as tools, systems and automation technologies, with social dimensions, including interpersonal dynamics, worker capabilities and human needs (Lagorio *et al.*, 2024). This perspective recognizes that the interaction

between people and technology is critical to operational performance, requiring adaptive designs that prioritize physical and cognitive capabilities (Mondal and Samaddar, 2021). Consequently, the design of logistics systems involves adapting interfaces, reducing workloads and creating safe environments, with a view to harmonizing efficiency and mental health (Adriaensen *et al.*, 2023; Cimini *et al.*, 2022; Lagorio *et al.*, 2024).

The implementation of smart technologies such as cobots, Global Positioning System (GPS), Radio Frequency Identification (RFID), AGVs, IoT and deep learning algorithms illustrates this integration. Cobots, for example, take over repetitive or dangerous tasks, such as picking and palletizing, mitigating occupational risks and relieving the physical and mental pressures workers face (Oran *et al.*, 2022). The use of GPS and RFID improves material traceability and operational safety. In addition, AGVs combined with IoT and AI perform high-risk activities, thus reallocating workers to strategic and less strenuous functions (Adriaensen *et al.*, 2023; Cimini *et al.*, 2022; Lagorio *et al.*, 2024). Deep learning algorithms already contribute to predictive stock management and the identification of risks in real time, raising safety and precision standards (Xie and Yao, 2023).

Despite the anthropocentric discourse that underpins Logistics 5.0, the literature reveals important theoretical and practical tensions regarding the role of workers in increasingly automated logistics environments. The conceptual perspective of integrating advanced technologies with worker empowerment, collaboration and well-being frequently conflicts with the empirical reality of organizational implementation (Grosse *et al.*, 2023; Adriaensen *et al.*, 2023). The assumption that increasing technological sophistication and automation necessarily lead to sustainable operational performance has also been questioned. Studies in ergonomics and human factors demonstrate that systems designed exclusively around technical efficiency may generate hidden long-term organizational costs associated with fatigue, stress, absenteeism, turnover and operational errors caused by workers' physical and cognitive exhaustion (Grosse *et al.*, 2023; Adriaensen *et al.*, 2023). These findings suggest that productivity gains achieved through automation are not inherently sustainable when human limitations and well-being are neglected.

Simultaneously, Logistics 5.0 challenges traditional assumptions regarding autonomy, trust and control in human-machine interaction. Classical organizational theories generally associate higher worker autonomy with greater satisfaction and lower cognitive load (Pasparakis *et al.*, 2023). However, recent studies on human-robot collaboration show that operators may experience higher satisfaction and lower mental burden when following rather than directly controlling intelligent systems (Pasparakis *et al.*, 2023).

This paradox suggests that human-centricity should not be interpreted simply as maintaining human control over every operational decision but rather as designing systems capable of balancing cognitive demands, safety, collaboration and trust (Adriaensen *et al.*, 2023; Grosse *et al.*, 2023; Pasparakis *et al.*, 2023). However, this balance becomes more difficult as Logistics 5.0 relies on AI and advanced decision-support systems whose operational logic is not always fully understandable to workers, reducing transparency and potentially weakening trust in automated decisions and creating a fundamental contradiction in which workers are expected to trust and collaborate with systems whose reasoning is not fully accessible to them. These challenges are intensified in small and medium-sized enterprises, where limited financial resources, low managerial maturity and shortages of skilled labor often hinder the implementation of human-centered innovations (Zare *et al.*, 2025).

Taken together, these challenges demonstrate that human-centricity in Logistics 5.0 extends the simple coexistence of humans and machines. It requires governance structures, organizational practices and technological designs that simultaneously promote trust, autonomy, well-being and meaningful human participation (Adriaensen *et al.*, 2023; Grosse *et al.*, 2023; Pasparakis *et al.*, 2023). Thus, Logistics 5.0 is better understood as a socio-technical ecosystem in which human capabilities and digital technologies evolve in a complementary and mutually reinforcing manner (Figure 2).

KEY DIMENSIONS OF LOGISTICS 5.0

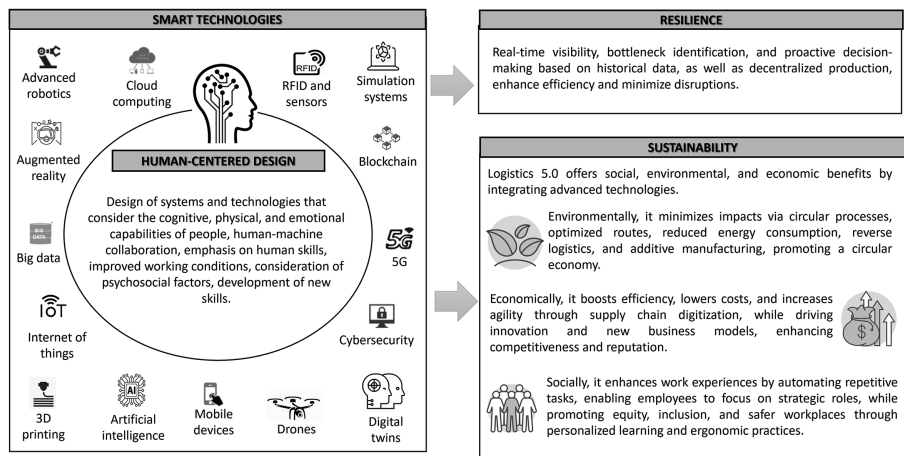


Figure 2. Key pillars of Logistics 5.0. Source: Prepared by the authors (2026)

4.4 Logistics 5.0 maturity model

Based on the SLR conducted in this study, it is observed that logistics maturity models, particularly those associated with the evolution from Logistics 4.0 to 5.0, still present a high level of conceptual abstraction and limited practical applicability. In addition, there is a lack of an integrated structure capable of consistently connecting human, environmental and operational resilience dimensions across the different evolutionary stages of intralogistics and transportation. In response to this gap and with the aim of enabling the operationalization of the proposed Logistics 5.0 framework, a five-level maturity model was developed (Table 3), allowing for a gradual progression between technological, sociotechnical and regenerative stages.

Level 1, Manual Logistics, is characterized by fully manual operations without digital integration, with internal transportation performed by conventional forklifts and intensive human effort (Grosse et al., 2023; Pasparakis et al., 2023). Processes rely on paper-based records and verbal communication, resulting in low visibility, rigid workflows and limited responsiveness to demand changes (Helm et al., 2024; Trstenjak et al., 2022). Human indicators include high absenteeism and work-related injuries due to physical strain and fatigue among operators and drivers performing transportation with conventional forklifts and intensive human effort (Adriaensen et al., 2023; Grosse et al., 2023; Pasparakis et al., 2023). From a sustainability perspective, there is high paper consumption and significant fossil fuel waste driven by inefficient fleets and static routing practices (Trstenjak et al., 2022). In terms of resilience, the stage is marked by high picking and delivery error rates, long cycle times and an inability to respond to demand peaks or transportation disruptions (Helm et al., 2024; Ivanov, 2023a,b).

Level 2, Basic Digitalization, introduces initial digital technologies such as RFID and GPS, enabling partial traceability of assets and transport vehicles, along with virtual training environments (Trstenjak et al., 2022). Although internal transport remains largely manual, route monitoring and flow visibility begin to improve. This stage reduces operational errors but increases cognitive load and occupational stress due to performance monitoring without greater worker autonomy (Grosse et al., 2023; Pasparakis et al., 2023). Sustainability improvements include reduced paper use, basic fuel consumption tracking and early adoption of green warehousing practices such as packaging recycling (Trstenjak et al., 2022).

Table 3. Logistics 5.0 maturity model

Level	System description	Human indicators	Sustainability indicators	Resilience/ Operational indicators
Level 1 – Manual Logistics	Fully manual operations without digital integration. Internal transport relies on conventional forklifts and physical handling. Low visibility and high operational rigidity	Absenteeism rate and Lost Time Injuries associated with physical strain, heavy lifting and occupational fatigue	High paper consumption for operational documents and significant fossil fuel waste due to static and inefficient routing	High picking and last-mile delivery error rates, long cycle times and lack of flexibility to absorb demand peaks or disruptions
Level 2 – Basic Digitalization	Introduction of partial digital traceability through RFID and GPS. Internal transport remains predominantly manual, with initial asset and route monitoring	Increased cognitive load and occupational stress due to performance monitoring without corresponding operational autonomy	Reduction in paper usage and early adoption of green warehousing practices, including basic fuel consumption monitoring	Information latency between data capture and system updates and initial reduction in inventory and shipment losses
Level 3 – Logistics 4.0	Automation through AGVs, IoT and AI-based tactical decision-making. Automated material transport and increased digital integration. High technological dependency	Turnover rate associated with operational pressure and mismatch between human capacity and automation pace (phantom profits effect)	Reduced energy consumption and emissions through fleet electrification and IoT-based warehouse optimization	Exposure to ripple effect vulnerability and system-wide downtime during automation failures
Level 4 – Sociotechnical Transition (Toward Logistics 5.0)	Human-machine integration through collaborative robots and digital twins. Intelligent transport systems with dynamic routing and simulation-based optimization	Job satisfaction in human-robot interaction and upskilling rate of the workforce	Green transport adoption with electric vehicles and route optimization considering both energy consumption and carbon footprint	Near-miss rate reduction enabled by intelligent monitoring systems (e.g. IVA, smart spaghetti mapping and digital twins for bottleneck prediction)
Level 5 – Logistics 5.0 Ecosystem	Fully integrated cyber-physical-social system with AI-driven autonomous operations, Human Digital Twins (HDTs) and electric autonomous transport. Predictive, self-optimizing, zero-emission logistics	Dynamic ergonomic risk is monitored via HDTs, enabling adaptive task allocation and real-time worker well-being management	Full circularity based on the 9R framework and Net Zero operations supported by renewable energy and biosocial-technical impact metrics	Sustainable resilience index reflecting predictive self-adaptation capacity using AI, blockchain and distributed manufacturing for disruption recovery

Resilience is still constrained by information latency, although initial reductions in losses and shipment deviations can be observed (Ivanov, 2023a; Ivanov and Dolgui, 2019).

Level 3, Logistics 4.0, is characterized by the adoption of AGVs, IoT and AI for tactical decision-making, including autonomous material handling and transportation (Lei *et al.*, 2023; Li *et al.*, 2025). Additive manufacturing complements supply flows, reducing manual activities and increasing operational accuracy and efficiency (Priyadarshini *et al.*, 2024). Although this stage improves energy performance and reduces waste, it also creates a high dependence on digital technologies and greater vulnerability to system failures (Hsu *et al.*, 2024a, b; Ivanov, 2023a; Nicoletti and Appolloni, 2024). Human indicators include the phantom profits rate, which measures the extent to which productivity gains achieved through automation are offset by hidden costs related to turnover, absenteeism and workforce exhaustion caused by the pace imposed by robots and algorithms (Grosse *et al.*, 2023; Adriaensen *et al.*, 2023). Sustainability indicators focus on reductions in warehouse energy consumption and lower local emissions resulting from the replacement of combustion-powered equipment with lithium-battery technologies (Trstenjak *et al.*, 2022; Hsu *et al.*, 2024a). From a resilience perspective, this stage is characterized by vulnerability to the ripple effect, measured through system downtime during disruptions (Ivanov, 2023a; Lei *et al.*, 2023). To maintain operational continuity during shortages or unexpected events, organizations often rely on unsustainable responses, such as emergency air freight, which significantly increases carbon emissions (Ivanov, 2023a; Lei *et al.*, 2023).

Level 4, Sociotechnical Transition toward Logistics 5.0, represents the progressive integration of humans and machines, replacing rigid automation with collaborative robots and intelligent systems also applied to internal transportation (Dornelles *et al.*, 2023; Grosse *et al.*, 2023). The use of digital twins enables continuous simulation and optimization of logistics flows, supporting dynamic routing and improving operational safety (Ivanov, 2023a). This stage reduces repetitive tasks for workers while improving environmental and operational performance through route optimization and lower internal emissions (Trstenjak *et al.*, 2022). Human indicators include job satisfaction in human–robot interaction and reskilling rates, reflecting workforce adaptation to collaborative environments and new digital competencies (Grosse *et al.*, 2023; Koreis *et al.*, 2023; Pasparakis *et al.*, 2023). Regarding sustainability, there is an expansion of green transport through electric vehicles and route optimization based not only on time efficiency but also on energy consumption and carbon footprint reduction (Hsu *et al.*, 2024a, b; Ivanov, 2023a). In terms of operational resilience, emphasis is placed on the prevention of near misses through intelligent monitoring systems, including sensor-based tracking, computer vision and digital models for bottleneck prediction (Helm *et al.*, 2024; Ivanov, 2023a; Ivanov and Dolgui, 2019).

Level 5, Logistics 5.0, refers to a fully integrated cyber-physical-social ecosystem in which internal transportation is performed by AI-coordinated electric autonomous vehicles (Chen *et al.*, 2024; Li *et al.*, 2025). Advanced digital twins and real-time analytics ensure continuous flow optimization while dynamically adapting operational pace to human well-being, creating a truly human-centered environment (Li *et al.*, 2025). This model is characterized by zero emissions, high resource circularity and strong predictive resilience against disruptions (Anitha and Parthiban, 2025; Ivanov, 2023a). Human indicators are based on dynamic ergonomic and cognitive risk monitoring using sensors and digital human models, enabling automatic task adjustment and reinforcing a cognitively supported work system in which humans remain the primary strategic decision-makers (Dornelles *et al.*, 2023; Li *et al.*, 2025). In sustainability, the model emphasizes full circular economy integration, covering reduction, reuse and recycling strategies, as well as the assessment of biosocial impacts to ensure that logistics expansion does not generate negative environmental or public health effects (Anitha and Parthiban, 2025; Fox *et al.*, 2025). Regarding resilience, the sustainable resilience index reflects the system's ability to anticipate, absorb and reconfigure in response to disruptions by combining zero-emission transport, localized and decentralized production and secure

traceability technologies, enabling rapid responses to global disruptions without compromising environmental integrity (Ivanov and Dolgui, 2019; Wang *et al.*, 2024).

5. Research agenda

This section presents a research agenda based on the gaps identified in the analyzed studies. Table 4 highlights underexplored areas in the current literature and outlines directions for future research to advance the field.

5.1 Regulatory and ethical issues

The implementation of Logistics 5.0 raises a number of ethical and regulatory questions. The collection of vast amounts of data, fundamental to the operation of such technologies, equally

Table 4. Summary of the research agenda

Theme	Research questions
Regulatory and ethical issues	How can the security and privacy of user data be guaranteed, given the considerable amount of location information and the use of digital platforms?
Public policies and regulations	Are there ethical and psychological limits to the use of digital technologies? Which public and regulatory policies are most effective in promoting the adoption of emerging technologies in supply chains? How can public policies foster the creation of technological infrastructure to support the digital transformation required by Logistics 5.0 in emerging countries? How can governments collaborate with private companies to develop integrated and connected logistics ecosystems in line with Logistics 5.0 principles?
Biopsychosocial impact	How does the perception of vigilance affect operator stress, motivation, job satisfaction and mental health? How can increased human-machine interaction in Logistics 5.0 influence employee engagement, motivation and the perception of purpose? How can Logistics 5.0 promote a more inclusive and collaborative work environment?
People management	How does effective human resources management contribute to the adoption of Logistics 5.0? How does Logistics 5.0 impact the definition of roles and responsibilities in logistics teams, especially with the use of autonomous technologies and artificial intelligence? What main socio-emotional skills are required of workers who operate in highly automated logistics environments and supply chains? How can employee resistance to new technologies and methods be mitigated during a transition to Logistics 5.0?
Outsourcing and stakeholder engagement	How can the decentralization inherent in the outsourcing of logistics services hinder the application of the principle of human centrality in the context of Logistics 5.0? What new outsourcing models are emerging with Logistics 5.0? What are the main challenges for outsourcing activities in the context of Logistics 5.0, and how can they be mitigated?
Organizational barriers	What strategies can be employed to ensure the organizational commitment required for digital transformation in Logistics 5.0? What tensions and trade-offs emerge among the objectives of Logistics 5.0, and how can organizations manage them in managerial decision-making? What organizational capabilities are essential for a successful implementation of Logistics 5.0?

Source(s): Prepared by the authors (2026)

raises concerns about privacy and security (Roring and How, 2022). In addition, the use of algorithms in automated decisions widens the debate about impartiality and transparency since mismanaged systems can result in structural biases (Fatima et al., 2022; Wang et al., 2016). At the same time, a lack of clear regulation on the use of personal data creates uncertainty for both users and organizations, increasing risks such as the violation of privacy and information misuse (Fatima et al., 2022). It is noteworthy that analyses of these challenges often neglect organizational factors such as company size, hierarchical structure and geographical context: elements that directly influence the implementation of Logistics 5.0. Thus:

Gap 1. Research has overlooked how organizational characteristics influence the management of ethical, privacy and security challenges in Logistics 5.0.

5.2 Public policies and legislation

The transition to Logistics 5.0 involves structural challenges inherited from previous stages, such as the absence of a favorable political ecosystem and deficiencies in infrastructure: factors that had already compromised supply chain efficiency during the Logistics 4.0 implementation (Lei et al., 2023). Such obstacles reinforce the importance of government measures aimed at modernizing systems and creating regulatory frameworks adapted to technological innovations. At the same time, replacing human functions with intelligent systems, while enhancing operational efficiency, increases the risk of structural unemployment, requiring proactive public policies for professional retraining and job realignment (Cimini et al., 2022; Grosse et al., 2023). Future research should prioritize two interconnected issues. First, investigating how investment in digital infrastructure and tax incentives can accelerate the adoption of sustainable technologies, ensuring resilience in production chains. Second, analyzing the multidimensional effects of Logistics 5.0 on the labor market (from the polarization of skills to the need for continuous training programs) ensures that technological advancement does not widen social inequalities. Thus:

Gap 2. There is limited understanding of which policy instruments and public-private initiatives are most effective in supporting Logistics 5.0 adoption and workforce adaptation.

5.3 Biopsychosocial impact

Although Logistics 5.0 has the potential to create safer and more efficient working environments, it brings with it complex challenges linked to human-machine interaction. Advanced automation and the integration of intelligent tools, for example, may result in workforce redundancy and a consequent need for retraining: a scenario that has direct repercussions on the psychological health of employees. Thus, technologies designed to optimize processes can simultaneously trigger resistance from workers, especially when such technologies are perceived as intrusive within the workplace or when implementation disregards the need for gradual adaptation and adequate training (Dornelles et al., 2023; Grosse et al., 2023). Thus, it is suggested that studies be carried out not only to investigate the operational gains of Logistics 5.0 but also to examine its intangible impact on organizational climate, interpersonal relations and employee engagement (Thylén et al., 2023). Thus:

Gap 3. The biopsychosocial effects of Logistics 5.0 technologies on workers' well-being, engagement and workplace relationships remain insufficiently explored.

5.4 People management

The transition to Logistics 5.0, marked by automation and AI, requires a profound reconfiguration of roles and skills in the context of supply chains (Koreis et al., 2023). Such transformation calls for in-depth studies on how emerging technologies are redesigning occupational roles, especially in supervisory activities. At the same time, there is a need to develop specific skills, such as the mastery of advanced technological tools and data interpretation, which are essential for aligning professionals with the demands of the new

digital age (Modgil *et al.*, 2023). In this context, future studies should investigate and systematize the skills that are essential for a transition to Logistics 5.0 (Koreis *et al.*, 2023; Modgil *et al.*, 2023). Thus:

Gap 4. The skills, roles and human resource practices required to support workforce adaptation during the transition to Logistics 5.0 are still unclear.

5.5 Outsourcing

Outsourcing is recognized as a strategy that provides flexibility and scalability, allowing companies to adapt their operations quickly to market demands, thereby reducing costs and sharing the risks associated with digital transformation. However, outsourcing logistics services can involve significant challenges, such as the fragmentation of control over working conditions, compromising the principle of human-centeredness (Dwivedi *et al.*, 2023). From a sustainability point of view, integrating practices such as reducing carbon footprints and recovering supply chain resources requires strategic alignment and effective collaboration with outsourcing partners (Dwivedi *et al.*, 2023). To overcome these limitations, future studies could investigate management mechanisms that strengthen strategic partnerships throughout supply chains, enabled by Logistics 5.0 principles and technologies. Thus:

Gap 5. Limited research has examined how outsourcing arrangements can support human-centricity, sustainability and stakeholder collaboration in Logistics 5.0.

5.6 Organizational barriers

The adoption of logistics technologies requires strategic alignment and collective engagement at all hierarchical levels. However, a lack of support from top management and employee resistance to technological and methodological changes are critical challenges to their successful implementation (Dwivedi *et al.*, 2023). Such factors not only hinder the adoption of innovation but also compromise the integration of principles such as sustainability and human-centricity – two key pillars of Logistics 5.0. Additionally, managerial decision-making may be challenged by tensions arising from trade-offs and unintended consequences among the objectives of Logistics 5.0 (Ivanov, 2023a; Priyadarshini *et al.*, 2024). Future studies could therefore explore these tensions, as well as the organizational capabilities, such as an adaptive culture, change management practices and workforce development, that are essential for enabling this transformation and helping companies overcome structural and cultural obstacles. Thus, the following research gap was identified:

Gap 6. The organizational capabilities and change management mechanisms required to overcome barriers and manage tensions associated with Logistics 5.0 adoption remain underexplored.

6. Final considerations

Logistics 5.0 has established itself as a transformative milestone, overcoming the technocentric vision of Logistics 4.0 by integrating resilience, sustainability and human-centricity. This study, based on an analysis of 42 articles, has shown that Logistics 5.0 is not limited to the incremental evolution of digital tools but represents a paradigmatic reorientation, where operational efficiency coexists with socio-environmental imperatives. Its three interdependent axes redefine the relationship between humans, technologies and ecosystems, promoting adaptive, regenerative and socially just supply chains.

The findings of this study provide theoretical, practical and policy implications. From a theoretical perspective, this research advances the Logistics 5.0 literature by developing an integrated conceptualization of the phenomenon and proposing a socio-technical framework that synthesizes its core dimensions and guiding principles. In addition, it identifies several knowledge gaps and presents a research agenda to support future scholarly developments in the field. From a practical perspective, the study offers guidance for the implementation of

Logistics 5.0 by proposing a Logistics 5.0 Maturity Model and identifying opportunities for organizations and professionals to enhance logistics operations and supply chain performance. From a policy perspective, the findings highlight the importance of governmental support through investments in digital infrastructure, workforce reskilling and enabling regulatory frameworks to facilitate the transition toward Logistics 5.0.

The limitations of this study should be acknowledged. The SLR was restricted to articles published in English and Portuguese and indexed in the Scopus and WoS databases, which may have excluded relevant contributions from other sources. Future research should focus on empirically validating the proposed conceptual framework and maturity model, as well as examining their applicability across different industries and geographical contexts. Ultimately, a multidisciplinary agenda involving engineering, social sciences and public policy is essential for advancing Logistics 5.0 from an emerging concept to a widely adopted paradigm for 21st-century supply chains.

Data statement

Data available within the article or its [supplementary materials](#).

Supplementary material

The supplementary material for this article can be found online.

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