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A systematic literature review on Web3 applications in trucking logistics: Impacts and emerging trends in logistics 5.0☆

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ABSTRACT

Web3 technologies, representing the next generation of a decentralised and user-centric Internet, offer innovative solutions to enhance adaptability, sustainability, and resilience in logistics systems aligned with the principles of Logistics 5.0. This study conducts a Systematic Literature Review (SLR) following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology, analysing peer-reviewed journal articles published between 2018 and 2024 and retrieved from Scopus, Web of Science Core Collection, IEEE Xplore, and ACM Digital Library. The review specifically focuses on trucking logistics, a sector characterised by high fossil-fuel dependency, operational fragmentation, and significant environmental impact. The findings reveal that Artificial Intelligence and Internet of Things technologies dominate current implementations, mainly supporting fleet management, route optimisation, accident prevention, and risk assessment. In contrast, blockchain applications remain limited, and metaverse-based solutions are largely exploratory and confined to training scenarios. Key research gaps include the scarcity of integrated Web3 solutions, the limited consideration of human-centric Logistics 5.0 dimensions, and the lack of large-scale empirical validation in real-world trucking operations. Based on the analysis, this paper proposes a conceptual framework that maps Web3 technologies to trucking logistics areas, investment priorities, and Logistics 5.0 objectives, offering actionable guidance for Logistics Service Providers transitioning from Logistics 4.0 to Logistics 5.0.

1. Introduction

The logistics business is undergoing a transformative phase driven by the convergence of technological innovation and sustainability objectives (Logistics: What It Means and How Businesses Use It, *n.d.*). In this work; Logistics 5.0 is defined as the evolution of Logistics 4.0 that extends beyond automation and digitalisation to integrate human-centricity; sustainability; and system resilience; in alignment with the Industry 5.0 vision proposed by the European Commission (Union, P. O. of the E, 2021). Logistics 4.0; rooted in Industry 4.0; primarily emphasises cyber-physical systems; data integration; and process automation within supply chains. At the core of this evolution is Logistics 5.0 (Boz & Pinto, 2023); a paradigm that integrates advanced technologies and sustainable practices to address complex operational; environmental; and societal challenges. This transition reflects an urgent need to adapt to the growing demands of e-commerce; heightened consumer expectations for eco-friendly operations; and increasingly stringent regulatory requirements. Logistics 5.0 promises to enhance operational adaptability; resilience; and sustainability; but its implementation presents significant challenges (Trstenjak et al., 2022). Logistics 5.0 builds upon this technological foundation while addressing social, environmental, and ethical dimensions. However, this evolution of industries is occurring in parallel with the technological advancement of the internet, which is currently undergoing a transition towards its next generation, Web3, which refers to a decentralised Internet paradigm enabled by technologies such as blockchain and smart contracts, artificial intelligence, the Internet of Things, and immersive environments, facilitating secure, interoperable, and user-controlled digital ecosystems, promising

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new technological advancements.

Logistics service providers (LSP's), particularly small and medium-sized enterprises (SME's), face numerous obstacles, including the integration of legacy systems, workforce skill deficits and data security concerns. Web3 next-generation technologies promise to transform business operations by addressing the core challenges of the Industry 5.0 transition (Ghobakhloo et al., 2023). However; the academic and practical understanding of how Web3 technologies can be systematically leveraged to facilitate Logistics 5.0 is limited. Existing research primarily focuses on individual technological applications without integrating them into a cohesive framework addressing the broader needs of the industry (Andres et al., 2024).

Within the context of Industry 4.0, supply chain management has been transformed through automation, cyber-physical systems, digital twins, and data-driven optimisation. Logistics 4.0 represents the operationalisation of these principles in transport, warehousing, and distribution, emphasizing connectivity and efficiency improvements. Logistics 5.0 extends this trajectory, aligning logistics operations with Industry 5.0 by embedding societal value creation, workforce empowerment, and environmental responsibility into supply chain decision-making. This framing directly positions the present review within the Industry 4.0 and supply chain management perspective while recognising the emerging shift towards human-centric and sustainable logistics systems.

This systematic literature review (SLR) focuses on trucking logistics, examining the transport and distribution of goods using lorries and land heavy goods vehicles (HGVs), most of which still operate with fossil fuel engines (Foytik & Robinson, 2019). This logistics industry segment represents a critical area for intervention; as it accounts for a significant portion of greenhouse gas emissions; operational inefficiencies and road congestion (Giuliano et al., 2021). Focusing on trucking logistics, this review aims to explore how Web3 technologies can address these pressing issues.

Despite these potential applications, the academic and practical understanding of how Web3 technologies can systematically transform trucking logistics remains limited. Existing research examines these technologies in isolation or within broader logistics contexts without delving into their specific implications for road-based distribution systems reliant on fossil fuels (Cortes-Murcia et al., 2022; Neagoe et al., 2024; Sahoo et al., 2024). This research seeks to consolidate existing knowledge, identify research gaps and explore the synergistic potential of Web3 technologies in facilitating the transition to Logistics 5.0 within the trucking sector.

This SLR bridges the knowledge gap by researching how Web3 technologies can facilitate the logistics industry's transition from Logistics 4.0, characterised by automation and digital efficiency, to Logistics 5.0, which prioritises resilience, sustainability, and human-centric operations. The objectives are:

1) Evaluate the role of Web3 technologies, examining in what context these technologies are used and supported at key focus in Logistics 5.0;
2) Identify use cases and applications and highlight practical implementations of Web3 technologies within trucking logistics operations to improve processes;
3) Propose a structured framework for developers to integrate Web3 technologies into the transition to Logistics 5.0.

The guiding main research question is: "What is the current state of applying Web3 technologies on trucking logistics for the transition to Logistics 5.0?". This question was divided into several Sub-Research Questions (SRQ) to shape the ground on this stage:

- SRQ1: "What are the technologies more associated with Web3?";
- SRQ2: "Which Web3 technologies are currently being applied in trucking logistics?";
- SRQ3: "What are the gaps between current Web3 applications and the transition to Logistics 5.0?";
- SRQ4: "Which Web3 applications should stakeholders invest in for Logistics 5.0, and what are their impacts?".

This SLR contributes to the body of knowledge by synthesising research on trucking logistics at the intersection of Web3 and Logistics 5.0, offering actionable insights for industry practitioners and decision-makers. In doing so, the paper seeks to equip the LSP's with tools and strategies to navigate an increasingly complex and dynamic global landscape for the next generation of the industry.

The structure of the paper is as follows: Chapter 2 provides the theoretical background of key topics for the development of this paper and identifies the technologies most associated with Web3. Chapter 3 presents the methodology for the SLR employed in this paper. Chapter 4 provides a content analysis of all reviewed articles based on the results. After extracting all information relevant to the objectives proposed in this research, chapter 5 presents the discussion of results and a

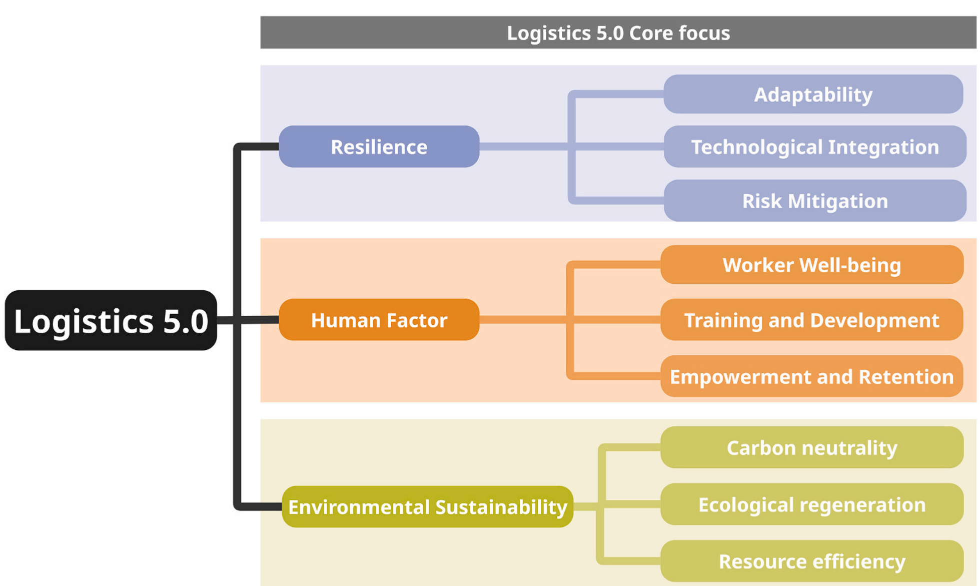

Fig. 1. Core focus components on Logistics 5.0 (authors' synthesis based on the systematic literature review).

conceptual framework illustrating the interactions between areas of trucking logistics and Web3 technologies that are most suitable for investment based on the desired goals. It also discusses the contributions of this paper to both academia and industry, as well as the literature gaps identified. Finally, chapter 6 presents the research's conclusions and outlines future research directions.

2. Theoretical background

This research examines the intersection of three key areas: Logistics 5.0, trucking logistics, and Web3 technologies. Together, they form the fields through which the evolution of the logistics sector is analysed, highlighting how emerging technologies and paradigms converge to shape sustainable, efficient, and human-centric practices. Logistics 5.0 emphasises integrating innovation with ecological and societal goals, while trucking logistics represents a vital operational domain within the logistics and supply chain industry in global production chains. Web3 technologies, meanwhile, offer the tools to drive this change, enabling decentralised, secure, and intelligent systems.

2.1. Logistics 5.0

Logistics 5.0 has gained traction in recent years as part of the broader discussion around the concept of Industry 5.0 (Jefroy et al., 2022) and the future of manufacturing and Supply Chains (SC). Industry 5.0 is itself described as a novel and continually evolving concept without a widely accepted; detailed definition (Maddikunta et al., 2022).

"Industry 5.0 recognises the power of industry to achieve societal goals beyond jobs and growth, to become a resilient provider of prosperity." - European Commission, 2021 (Union, P. O. of the E, 2021).

The first record of the use of the term Logistics 5.0, was made by "M. Trstenjak "(Trstenjak et al., 2022) in 2022; this concept has emerged as an extension of Industry 5.0 and Supply Chain 5.0; building upon the digitisation and automation trends of Logistics 4.0 (Logisticians: Occupational Outlook Handbook: U.S. Bureau of Labor Statistics, n.d.), while emphasizing the integration of human factors, resilience, and sustainability into logistics operations. This next generation of the logistics industry highlights the integration of human capabilities. It requires the integration of logistics systems, including transforming humans from a cost factor into an investment, enhancing their roles through formal education and training, and promoting human-machine collaboration to improve efficiency and innovation.

As shown in Fig. 1, Logistics 5.0's key focus components emphasise the importance of sustainability, particularly environmental impacts, the development and empowerment of human resources to improve overall operational efficiency, and the resilience and adaptability enabled by integrating advanced technologies within LSP's.

These focus components are interconnected and bolstered by advanced technologies, underscoring their collective role in transforming LSP into the next generation. Human orientation emphasises collaboration between workers and intelligent technologies, necessitating continuous skill development.

2.1.1. Resilience

According to Revilla, E., Acero, B., Sáenz, M.J. (Revilla et al., 2024); SC resilience responds to the adaptive capability of LSP to reduce the probability of facing sudden disruptions related to disturbances in the flows of materials; products or services. This is achieved by applying Industry 5.0 technologies; with collaborative principles serving as the foundation for enhancing visibility; agility; and flexibility; critical logistics capabilities during disruption recovery (Purvis et al., 2016; Vasiulis Ferreira Rodrigues et al., 2024). Furthermore, the integration of these logistics capabilities strengthens LSP resilience. In line with this, the work in India (Mandal et al., 2017) of highlights the importance of incorporating logistic capabilities towards positive influences on SCs' resilience.

2.1.2. Human factor

The transformation of the industrial sector since Industry 4.0 emerged has been based mainly on the increasing digitalisation and interconnection of technologies. In this context, concepts such as Operator 4.0 (Romero et al., n.d.) have appeared and are based on meeting their work needs using technology in their workplaces. However; according to Federica Menti; et al.(Menti et al., 2023); this promising perspective is wholly disconnected from the human factor point of view; even though technological developments have fundamentally changed their role in productive systems. Industry 5.0 covers human interaction by leveraging workers' expertise to collaborate with robust; smart and precise technologies (Singh & Kumar, 2024). This transformation requires constantly updating workers' knowledge (Kumari et al., 2024) to optimise their performance in the current position and develop the necessary skills to occupy the new positions created through the evolution of the business environment (Khan et al., 2024; Yang, Liu, et al., 2022).

2.1.3. Environmental sustainability

Environmental sustainability is another core focus of Logistics 5.0, combining environmental concerns with advanced technologies to reduce the ecological footprint of SC operations (Szeredi et al., 2024). This includes minimising greenhouse gas emissions; energy consumption; and material waste throughout all stages of the logistics cycle (Trstenjak et al., 2022). Key strategies implemented at both strategic and operational levels include the adoption of low-emission transport fleets, route optimisation through artificial intelligence, energy-efficient warehouse management, and real-time monitoring systems that facilitate predictive and environmentally responsible decision-making.

Although this core factor is primarily linked to the environmental dimension of sustainability, its implementation inherently influences the social and economic dimensions as well. Environmentally conscious logistics practices contribute to improved working conditions, including cleaner and safer work environments and bolster long-term economic resilience by lowering operational costs, enhancing risk management, and ensuring compliance with environmental regulations (Machado & Rodriguez, 2025).

Moreover, when examining the remaining core focus of Logistics 5.0, it becomes evident that these elements are intrinsically linked to the social and economic dimensions of sustainability. The Human Factor promotes worker well-being and inclusiveness, while the Resilience enhances system adaptability and long-term business continuity. Taken together, these interdependencies illustrate how Logistics 5.0 operates as an integrated and multidimensional framework, simultaneously advancing environmental, social, and economic sustainability dimensions.

The adoption of Logistics 5.0 principles necessitates sector-specific analysis to address operational particularities. In this context, trucking logistics emerges as a particularly relevant domain given its central role in freight distribution and the unique technical, regulatory, and organisational challenges it faces.

2.2. Trucking logistics

The logistics industry relies on four main modes of transportation: air, rail, water and road, each mode contributes unique advantages to the seamless movement of goods, often working in conjunction to optimise supply chains (Gohari et al., 2022). Trucking logistics, centred on the use of HGVs such as articulated lorries and Class 8 trucks, is an indispensable component of road freight operations. It encompasses the planning, execution, and management of goods transportation by road, forming the backbone of efficient SC operations.

Integrating Logistics 5.0 principles presents significant opportunities for trucking logistics, mainly through telematics and data-driven systems. One key technology enabling this transformation is the Controller Area Network Bus (CANBUS), a standardised protocol for

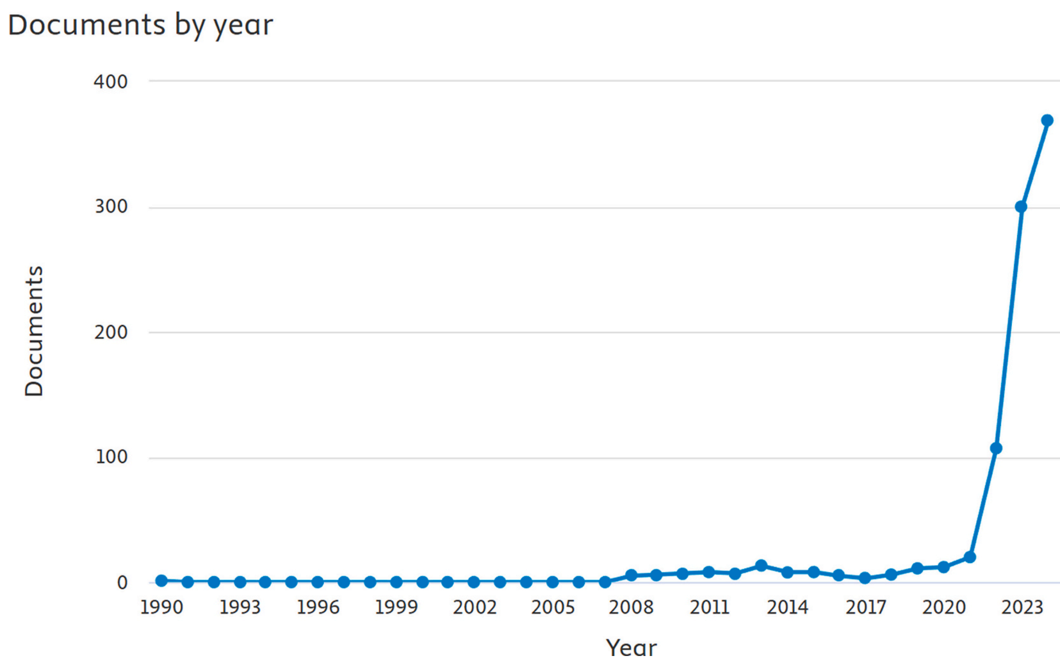

Fig. 2. Annual publication trends for Web3-related documents, 1974–2024 (data retrieved from Scopus). The line graph illustrates the temporal evolution of published documents addressing Web3 topics.

communication among a truck's Electronic Control Units (ECUs). CAN-BUS facilitates the seamless exchange of information between systems such as engine management, transmission and braking, ensuring the vehicle functions as a cohesive unit. By collecting and transmitting this

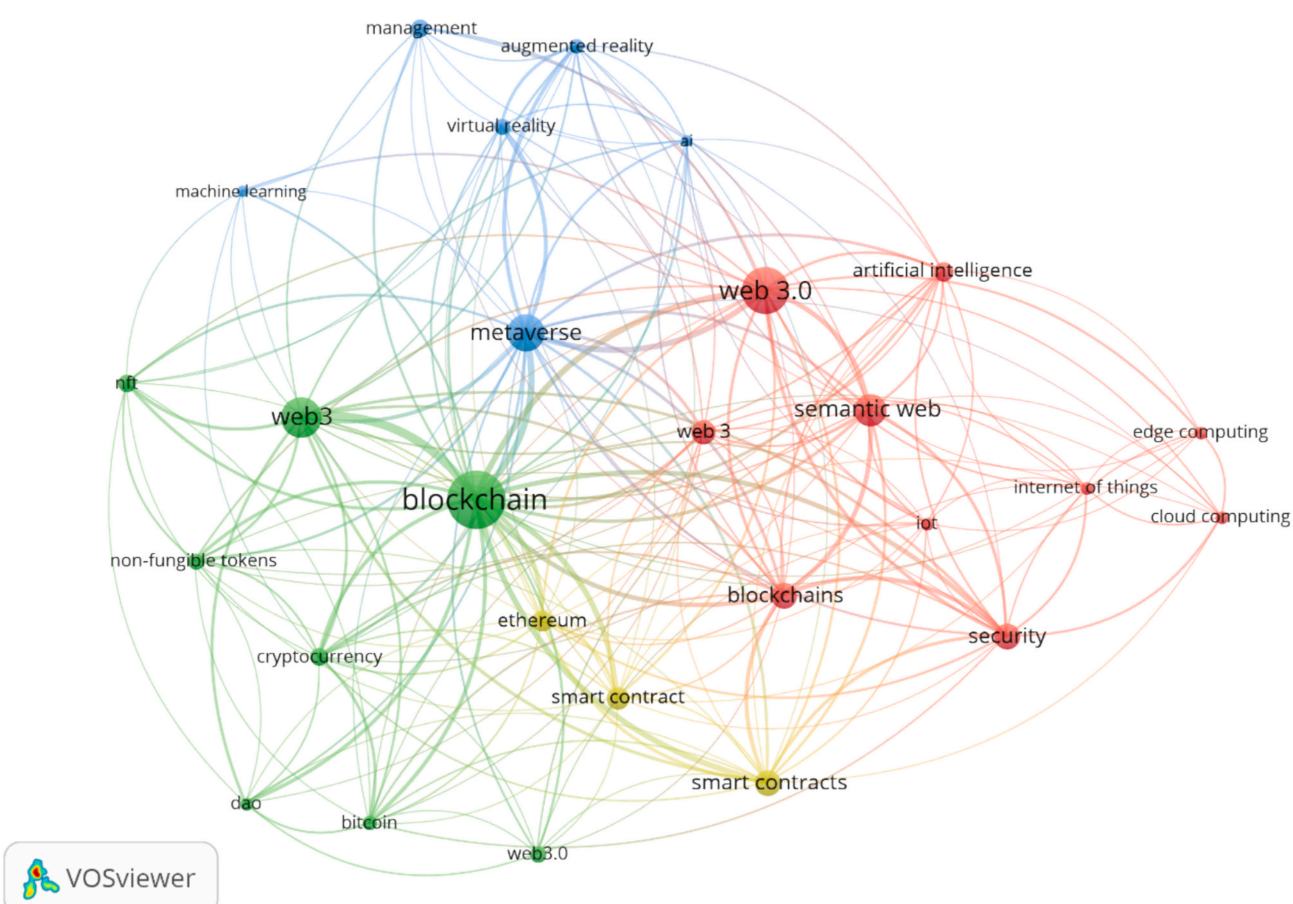

Fig. 3. Keyword cluster visualization of Web3-related topics generated by VOSviewer, illustrating four thematic clusters: blockchain technologies, information technologies, smart contracts/Ethereum, and metaverse applications.

data in real-time, telematics systems allow fleet managers to monitor critical metrics such as engine performance, fuel consumption and braking efficiency (Said et al., 2016). CANBUS data plays a vital role in this process; serving as the foundation for real-time monitoring and data storage that facilitates informed decision-making (Pimple, 2018; Salehpoor et al., 2022).

Understanding the road and trucking logistics industry requires recognition of four principal functional areas: freight brokerage, warehousing and distribution, transportation management, and last-mile delivery. Each logistics area plays a different role in the overall trucking logistics industry.

2.2.1. Freight broker

This area of logistics act as intermediaries between shippers and carriers, facilitating the movement of goods by connecting those who require transportation services with those who provide them. Play a role in optimising capacity utilisation and minimising empty miles, thereby enhancing overall industry efficiency (Road Freight Explained: Understanding Its Function in Logistics, n.d.).

2.2.2. Warehousing and distribution

Warehousing and distribution involve the storage, management, and delivery of goods. It encompasses activities such as inventory management, order fulfilment, and cross-docking. Efficient centres are essential for maintaining product availability and minimising lead times in the supply chain (Warehousing and Distribution: Understanding the Difference, n.d.).

2.2.3. Transportation management

This area concentrates on optimising the movement of goods from origin to destination. It encompasses route planning, scheduling, and vehicle allocation to ensure efficient and timely freight delivery (Advantages of Road Freight Services, n.d.).

2.2.4. Last-mile delivery

This marks the final stage of the delivery process, in which goods are transported from a distribution centre or transport hub to the end consumer (The Role of Trucking in the Supply Chain Worldwide, n.d.).

2.3. Web3 technologies

Web3, also known as Web 3.0, represents the next evolution of the Internet (Bruwer & Rudman, 2015) characterised by decentralisation and enhanced user control. It means the next evolution of the World Wide Web; building upon the foundations of earlier generations while introducing new technologies and concepts (Murray et al., 2023). Fig. 2 illustrates the annual publication trends for Web3-related documents from 1974 to 2024, based on data retrieved from the Scopus database (www.scopus.com). The analysis reveals that academic interest in Web3 became more prominent in 2008, with exponential growth observed over the last five years.

The propagation of this concept can be explained through Satoshi Nakamoto's work (Nakamoto, n.d.) and the first publication about Bitcoin's creation. While Web3 is strongly associated with blockchain technology, the concept extends far beyond this technology. Indeed, Web3 remains a broad and emerging concept that needs a precise definition, making its formulation both variable and volatile.

To identify the technologies employed within Web3 ecosystems, a scoping literature search was conducted in the Scopus database in November 2024. The search query ("web 3" OR "web3" OR "web 3.0") was applied to account for variant spellings of the term, yielding 2079 documents. For a better search of keywords within the corpus, a Visualization of Similarities (VOS) analysis was performed for the construction and visualization of bibliometric networks. Fig. 3 shows the cluster-related topics with Web3, created by VOSviewer software (VOSviewer - Visualizing scientific landscapes, n.d.), after filtering out keywords that were out of context or poorly indexed. In the graphical analysis, it is possible to observe four clusters of 4 different colours: (1) the green cluster that concentrates on blockchain technologies and their uses, such as Cryptocurrency or Non-fungible Tokens (NFT); (2) the red cluster linked to Information Technologies (IT) more related to traditional web, such as cloud or edge computing, Internet of Things (IoT), Artificial Intelligence (AI), and a strong focus on security for the next generation of the internet; (3) the yellow cluster functions as an intersection between the green cluster (Blockchain) and the red cluster (IT), focusing on smart contracts and the leading associated blockchain network, Ethereum; (4) the last cluster, in blue, focuses on metaverse technology and all its inclusions, such as virtual reality, augmented reality, which are strongly linked to human-machine interaction, with notable connections to AI and machine learning.

The emergence of the semantic web concept in the results is particularly noteworthy. This extension of the current World Wide Web aims to provide well-defined meaning to information, enabling both humans and machines to understand and process web content more effectively (Al-Feel et al., 2009). Often referred to as Web 3.0; it represents a significant evolution from Web 2.0; focusing on data integration and interoperability (Kumar, 2016).

Through the application of cluster analysis, it was possible to identify and consolidate equivalent concepts related to Web3 technologies, thereby refining the selection of keywords for the SLR currently under research. Five core Web3 technologies were identified:

- Blockchain: a distributed ledger technology that enables secure, transparent, and immutable recording of transactions across decentralised networks. It provides cryptographic verification mechanisms and consensus protocols that eliminate the need for centralized intermediaries whilst ensuring data integrity and auditability;
- Artificial Intelligence and Machine Learning: computational techniques that enable systems to learn from data, identify patterns, and make autonomous decisions with minimal human intervention. These technologies encompass supervised, unsupervised, and reinforcement learning approaches for predictive analytics, Optimisation, and intelligent automation;
- Internet of Things: A network of interconnected physical devices embedded with sensors, actuators, and communication capabilities that enable real-time data collection, monitoring, and remote control. IoT systems facilitate seamless integration between the physical and digital worlds through continuous data streaming and device-to-device communication;
- Semantic Web: Technologies that structure and annotate data to enable machine-readable interpretation and reasoning. Based on ontologies and linked data principles, the Semantic Web facilitates automated data integration, interoperability across heterogeneous systems, and intelligent information retrieval;
- Metaverse: Immersive virtual environments that leverage extended reality technologies (virtual reality, augmented reality, and mixed reality) to create persistent, shared digital spaces. These platforms enable enhanced visualization, simulation, collaborative interaction, and experiential learning through three-dimensional digital representations.

Through this analytical process, we address SRQ1 and establish the technological framework that underpins the remainder of the study.

3. Review methodology

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is a widely recognised framework for conducting systematic reviews and meta-analyses in a transparent and reproducible manner (Page et al., 2021). The primary goal of this methodology is to ensure that these reviews are comprehensive and accurate, providing a clear explanation of how the review was conducted and its findings.

Table 1
Identified keywords for tracking Logistics and Web3.

Main Category ('AND' Operator)	Sub-Keywords ('OR' Operator)	Limitations ('AND' Operator)
Logistics	"logistic*"; "logistics service provider"; "logistics 5.0"; "smart logistics";	Timeline 01/01/2018 to 31/12/2024
Trucking	"CANBUS"; "Class 8 trucks"; "heavy-duty vehicle"; "lorries"; "road transport"; "telematics"; "truck*";	Articles/ Journals
Web3	"ai"; "artificial intelligence"; "blockchain"; "internet of things"; "iot"; "machine learning"; "metaverse"; "semantic web"; "web 3"; "web 3.0"; "web3";	English language

3.1. Search strategy and eligibility criteria

A literature review was conducted using four different integrated research databases: Scopus, Web of Science Core Collection (WoSCC), IEEE Xplore and ACM Digital Library (ACM DL). This research was conducted through December 2024. The selection of these databases aims to provide a comprehensive overview of current academic trends, particularly in engineering projects and industry use cases.

The keywords were identified based on the objectives and research questions and extracted from the subject's theoretical background. Keyword search employs three search techniques: (1), using double quotation marks for an exact match in phrase searches; (2), the use of the asterisk (*) as a common wildcard symbol that enables to find variations of a root word by acting as a placeholder for any number of characters following the root and (3), leveraging boolean operators (OR/AND) to combine diverse sets of keywords and find results that fulfil the established parameters.

The results were required to encompass articles published between January 1st, 2018, and December 31st, 2024. This timeframe was chosen to capture publications that emerged after the introduction of the Logistics 5.0 concept and the significant increase in works related to Web3. For this review, only full articles/journals were considered. Grey literature, reviews, conference papers, workshops, books, editorials and works not written in English were excluded.

Table 1 provides a representation of the main categories under investigation, along with the respective keywords for the search queries in the databases listed and the limitations in filtering.

While other studies are being conducted on this topic, it is essential to examine published research to identify the persisting weaknesses and opportunities in this area. As part of the initial exclusion criteria for this research, (1) literature reviews were not included to prevent duplicate findings. The primary objective of this SLR is to deliver an original synthesis of primary research and case studies from the specified period. Incorporating secondary sources such as reviews could result in double-counting findings, and no existing review met the criteria and scope of this research. The review mainly focuses on the trucking logistics industry and its various components, so the exclusion criterion (2) directs the analysis towards articles specifically related to this field, which includes the planning, management, storage, and execution of goods transport by trucks. Articles addressing other transportation modes (e.g., rail, maritime, or air freight) or related topics such as traffic management, urban mobility, or passenger transport are also excluded unless they directly impact trucking logistics operations. These exclusion criteria ensure that the analysis stays closely aligned with the focus of identifying weaknesses and opportunities specific to trucking logistics.

Exclusion criterion (3) is a refinement of criterion (2). In contrast, criterion (2) ensures that articles unrelated to trucking logistics are excluded, and criterion (3) further narrows this scope by excluding articles concentrating on electric and/or autonomous vehicles within trucking logistics. Although such articles fall within the broader domain of trucking, they are excluded due to the limited adoption of these technologies in current industry practices, representing only 0.3% of operations in the USA, 2.3% in the EU, and 5.7% in China (Why electric lorries are better than ever — and still not selling, n.d.). This decision reflects the work's focus on identifying weaknesses and opportunities within conventional trucking logistics systems, where these emerging technologies do not yet play a significant role. It explicitly targets the transition to Logistics 5.0 from traditional LSP's, which predominantly rely on fossil fuels.

The eligibility inclusion criterion encompasses all articles identified through the systematic search queries conducted as part of the search strategy. Any article retrieved from the applied keywords and search combinations was included in the initial dataset, provided it did not meet any of the previously outlined exclusion criteria. By refraining from imposing additional restrictions at this stage, the research aimed to capture diverse perspectives, methodologies, and findings relevant to the field. The inclusion process focuses on methodological rigour, facilitating a thorough analysis of existing trends, challenges, and opportunities related to the application of Web3 in trucking logistics.

Table 2
Summary of papers retrieved from integrated each research database.

	Scopus	WoSCC	IEEE Xplore	ACM DL
Number of Articles	100	97	63	0
Duplicates	78			
Total	182			

3.2. Study selection

The initial papers were selected using Covidence, an online tool that facilitates the systematic review process (Covidence - Better Systematic Review Management, n.d.). This platform assists researchers in managing and organising their reviews more efficiently by providing features for importing references, screening studies, extracting data and conducting risk-of-bias assessments. The process is structured into six distinct steps:

1) Import references from the mentioned databases, Scopus (Scopus | Abstract and citation database | Elsevier, n.d.); WoSCC (Document Search - Web of Science Core Collection, n.d.); IEEE Xplore (IEEE Xplore, n.d.); and ACM Digital Library (Advanced Search, n.d.);
2) Screen articles with the help of Covidence, which provides quick access to screen titles and abstracts. Articles are categorised as either relevant or irrelevant. When an article is deemed irrelevant, it is assigned to one of the exclusion criteria defined;
3) Full-text review, following the initial screening, upload and examine the complete texts of the chosen studies;
4) Data extraction, after it is collected from the articles using customisable forms. Covidence enables multiple reviewers to ensure accuracy and resolve selection conflicts;
5) Risk of bias assessment, where the risk is evaluated in the studies using standardised tools;
6) Export data, after the review is finalised, the list of studies for the systematic review is extracted and the PRISMA flow diagram is generated.

3.3. Data collection and synthesis

After defining the review methodology, studies were searched in integrated research databases. Table 2 presents the number of articles extracted from each database, as well as the total number of studies after duplicates have been identified.

Fig. 4 illustrates a graph depicting the trend of annual scientific production, showing a clear upward trajectory in the subject being

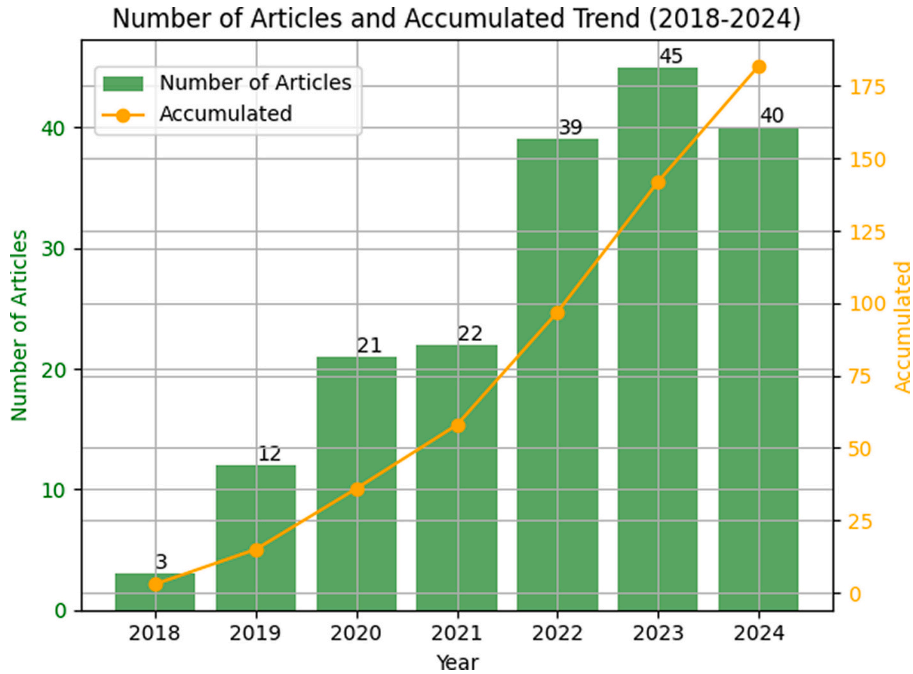

Fig. 4. Annual scientific production trend from 2018 to 2024.

studied.

4. Content analysis

The PRISMA flow diagram (Fig. 5) summarises the article selection process. Database searching identified 260 articles; after removing 78 duplicates, 182 articles remained for screening.

During the title and abstract screening, 49 articles were excluded based on title and abstract review, as they were clearly outside the scope of this SLR, and five articles were excluded because it was not possible to extract them fully. The full-text screening of 132 articles was conducted to assess eligibility, resulting in the exclusion of 54 articles for reasons such as being a literature review ($n = 6$), outside the scope of trucking logistics ($n = 34$), and electric and/or autonomous vehicles ($n = 14$).

Ultimately, 74 articles met the inclusion criteria and were included in the qualitative synthesis. A detailed overview of the full-text articles is provided in Appendix A.

4.1. Study characteristics

The review encompassed 74 articles selected according to the inclusion criteria outlined above. Table 3 presents key characteristics of each study: type, logistics area, Web3 technologies, data source, objectives, and solution type. Articles were classified using non-mutually exclusive categories, as studies often addressed multiple characteristics simultaneously.

Among the 74 articles analysed, 60% are empirical studies, and 54% are focused on practical or real-world applications. This result demonstrates that empirical research plays a significant role in the literature, offering evidence-based findings that enhance the theoretical discussions presented in this SLR. Additionally, 8% of the articles included case studies, offering specific examples of Web3 implementations, although these were primarily focused on broader Supply Chain contexts rather than Trucking Logistics.

The data source category represents the origin of information used in the applications developed by the studies. Out of 48 articles specifying data sources, telematics/vehicle data (23%) and GPS data (19%) emerged as dominant contributors, reflecting their critical role in enabling Web3 applications such as Blockchain-based tracking and decentralised fleet management. Smart sensors (17%) and environmental/external data (15%) also featured prominently, showcasing their utility in enhancing operational transparency and efficiency. However, some articles did not specify their data sources, limiting insights into the technological foundations of specific applications.

The Studies Goals category highlights the primary objectives pursued by the reviewed articles in improving logistics operations. Waste minimisation (38%) and risk assessment (31%) were the most frequently targeted goals, underscoring the focus on sustainability and resilience within logistics systems. Accident prevention (10%), performance improvement (15%), and management enhancements (7%) were also addressed, reflecting diverse priorities across different logistics areas.

4.2. Outcomes analysis

The 74 articles were analysed across three dimensions: Logistics 5.0 focus areas (Table 4), logistics domains (Fig. 6), and Web3 technologies employed (Fig. 7). Table 4 illustrates the distribution of articles across the various focuses and sub-focuses of Logistics 5.0, with individual articles often addressing multiple categories. Table 5 presents the distribution of enabling technologies identified across the reviewed literature.

Resilience emerged as the dominant focus, accounting for 57\% of articles and centering on strategies to enhance operational efficiency and business adaptability within the logistics industry. Sustainability represented 34\% of articles, examining technological applications that reduce LSPs' environmental impact, reflection of growing industry attention to ecological footprints in recent decades. Conversely, the human-centric focus was least explored, comprising only 9\% of articles. This limited coverage reflects its novelty as a distinguishing feature of Logistics 5.0 compared to its predecessor, Logistics 4.0. Nevertheless, the human factor remains essential, as Logistics 5.0 seeks balanced integration across all dimensions: LSP growth and resilience, environmental sustainability, and the human capabilities that underpin every aspect of logistics operations.

Fig. 6 illustrates the distribution of articles across trucking logistics domains, revealing the primary research focus areas within the industry. Transportation management emerges as the most extensively examined area, representing 65.8% of the total articles reviewed. This emphasis

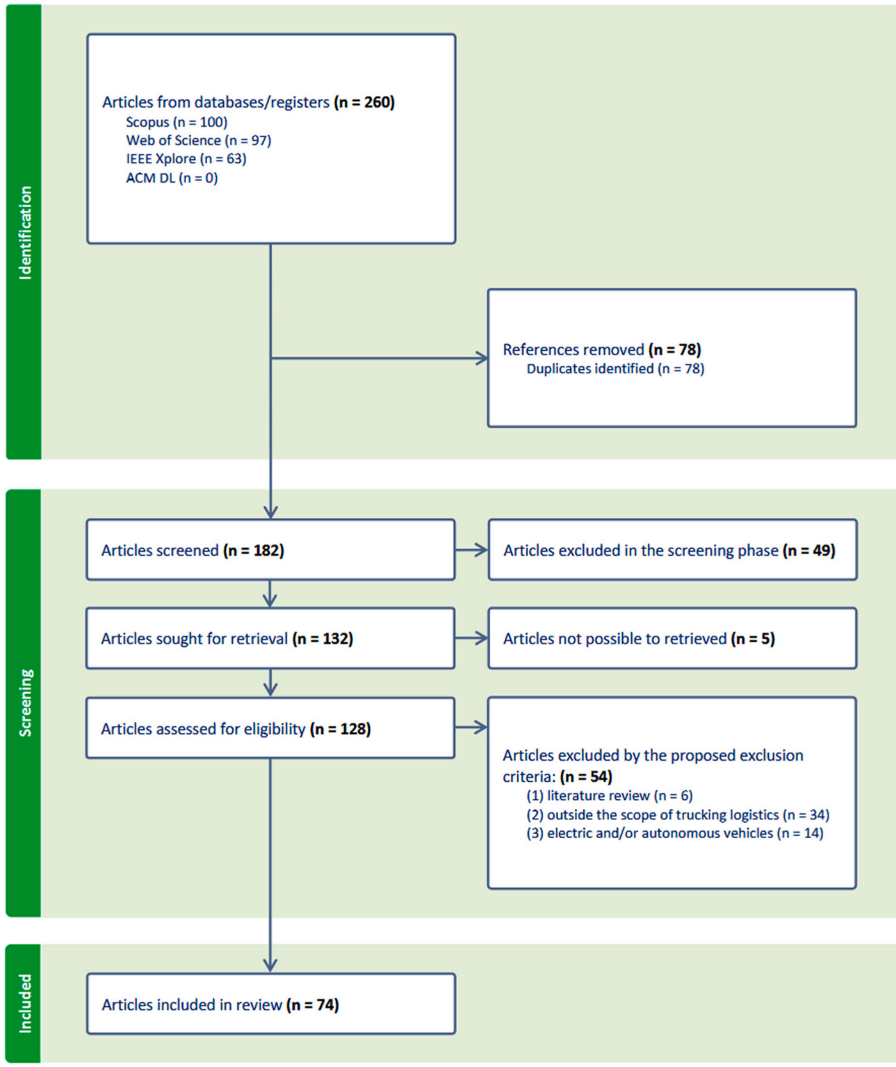

Fig. 5. PRISMA flow diagram illustrating the process of study identification, screening, eligibility assessment, and inclusion in the systematic review.

Table 3
Summarising the characteristics of the studies included in the review.

Characteristics		Studies, N (%)
Study Type	Applied research studies	24 (32%)
	Empirical study	44 (60%)
	Theoretical/Conceptual	6 (8%)
Data Source (n = 48)	Customer	3 (6%)
	Driving	3 (6%)
	Environmental or external	7 (15%)
	GPS	9 (19%)
	Smart sensor	8 (17%)
	Telematics / Vehicle	11 (23%)
	Traffic	4 (8%)
	Video or images	3 (6%)
Studies Goals	Accident prevention	7 (10%)
	Improve performance	11 (15%)
	Management	5 (7%)
	Risk assessment	23 (31%)
	Waste minimisation	28 (37%)
Solution type	Case study	6 (8%)
	Framework and model	22 (30%)
	Practical/Real-world application	40 (54%)
	Simulation	6 (8%)

can be attributed to the essential role that carrier management plays in optimising the efficiency and effectiveness of trucking operations. Research in this domain frequently addresses fleet management, route optimisation, fuel efficiency and driver performance.

Following this, warehousing and distribution are the second most significant areas with 17.8%, involving the storage, handling and movement of goods from warehouses to their final destinations. Research in warehousing and distribution addresses various challenges, including inventory management, warehouse layout optimisation and the integration of automation technologies.

In contrast, freight brokerage comprises only 11% of the articles reviewed. Research in this area typically examines the role of technology in streamlining brokerage operations, the effects of regulatory changes and the development of efficient matching algorithms.

Finally, last-mile delivery accounts for less than 6% of the articles reviewed, indicating a significant research gap given its increasing importance in e-commerce and urban logistics. This relatively limited focus on last-mile delivery within the existing literature underscores the necessity for more thorough research to tackle the challenges and opportunities present in this vital aspect of logistics (Kaewpuang et al., 2023; Lan et al., 2022; Ng et al., 2019; Tsang et al., 2021).

Across the reviewed trucking-logistics literature, AI is the most prevalent enabling technology (48 studies). Most AI contributions fall under machine learning (31 studies), primarily targeting operational prediction and risk-related tasks (e.g., dwell-time prediction, safety/risk scoring, scheduling, and emissions or consumption forecasting). A

Table 4
Relationship between Web3 technologies employed and the characteristic parameters of Logistics 5.0.

Logistics 5.0		References	N (%)
Human Factor	Worker well-being	(Correll, 2024; Loske & Klumpp, 2021; Wang et al., 2024)	3 (4%)
	Training and development	(Khan et al., 2023; Ribeiro et al., 2021; Zhang et al., 2021)	3 (4%)
	Empowerment and Retention	(Dutta et al.; 2023)	1 (1%)
Environmental Sustainability	Carbon Neutrality	(Ahmed & Roorda, 2022; Basso et al., 2024; Ding et al., 2023; Emadikhiav et al., 2024; Hopkins & Hawking, 2018; Juvvala & Sarmah, 2021; Li, Zhao, et al., 2024; Lo & Shih, 2021; Morsali & Kianfar, 2024; Ng et al., 2019; Rajak et al., 2024; Wang et al., 2023; Yin et al., 2024; Zalzal & Hatzopoulou, 2022)	14 (19%)
	Ecological Regeneration	(Chopra, 2020; Pan et al., 2021; Pernestål et al., 2021; Tsang et al., 2021; Zhao et al., 2020)	5 (7%)
	Resource Efficiency	(Alacam & Sencer, 2021; Chen et al., 2021; Dib et al., 2023; Dutta et al., 2023; Gong et al., 2021; Lan et al., 2022; Negueroles et al., 2024; Pérez-González et al., 2024; Yang, Lan, et al., 2023; Yu et al., 2021; Zhang et al., 2021)	11 (15%)
Resilience	Adaptability	(Abdulrashid et al., 2024; Chen, 2023; da Silva et al., 2023; De Beer & Joubert, 2024; Kong et al., 2022; Lee et al., 2022; Schöning & Kruse, 2023; Tsang et al., 2021; Umer et al., 2024; Xiao et al., 2020; Yang et al., 2024, b; Zhang & Liu, 2021)	13 (17%)
	Technological integration	(Bagloee et al., 2019; Cerquitelli et al., 2020; Chen et al., 2021; Choudhury et al., 2023; Correll et al., 2023; Hopkins & Hawking, 2018; Lee & Lee, 2021; Li, Tok, et al., 2024; Liu & Li, 2023; Lu et al., 2018; Mahalakshmi Priya et al., 2019; Negueroles et al., 2024; Tahfim & Chen, 2024; Yang, Wang, et al., 2022; Zhao et al., 2020)	15 (20%)
	Risk Mitigation	(Abdulrashid et al.; 2024; Carvalho et al.; 2024; Chen et al.; 2024; Duan et al.; 2022; Dutta et al.; 2023; Heinbach et al.; 2022; Ho et al.; 2022; Hussain et al.; 2024; Kaewpuang et al.; 2023; Lan et al.; 2022; Liang et al.; 2022; Pan et al.; 2021; Piendl et al.; 2019; Shahmardan & Sajadieh; 2020; Taghavi et al.; 2023; Tahfim & Chen; 2024; Tomasoni et al.; 2024; Xu et al.; 2024; (Yang et al., 2023); Yu et al.; 2021; Yuan et al.; 2023; Zhao et al.; 2024)	24 (32%)

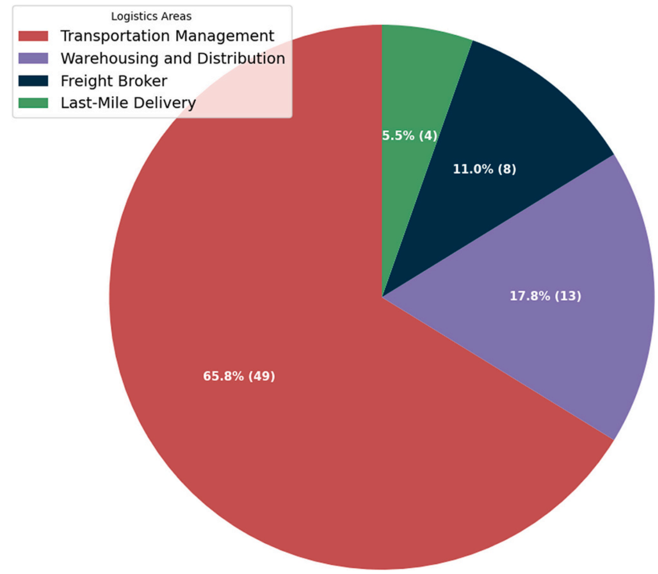

Fig. 6. Distribution of studies across logistics areas as represented in the literature.

second cluster applies deep learning (11 studies), typically for higher-dimensional pattern recognition and sequence learning problems (e.g., trajectory-based modelling, time-series forecasting, and detection tasks). A smaller subset is classified as Big Data analytics (3 studies), and one study explores quantum neural networks for logistics decision support (R. Correll et al., 2023). Two additional studies report AI usage but do not disclose model architectures; these were coded as AI (unspecified) during extraction.

IoT is the second most common technology (30 studies) and is used mainly to capture and operationalize real-time fleet and shipment signals. Reported implementations include edge computing (8 studies), smart sensors (19 studies) for monitoring vehicle and cargo conditions, and telematics data pipelines (3 studies) supporting driver behaviour analytics and predictive maintenance.

Blockchain remains comparatively underrepresented (8 studies). Where adopted, it is used primarily for smart-contract automation (6 studies), for example, enforcing business rules, automating settlement/insurance, and enabling platform-based coordination, and less frequently for decentralised storage / integrity protection (2 studies), typically in combination with IoT data streams.

Lastly, metaverse technology exhibits the least research engagement, with only three articles: one article applying Virtual Reality (VR) for workforce training before field deployment (Ribeiro et al., 2021) and two articles employing digital twins (Lee & Lee, 2021; Negueroles et al., 2024).

The data presented in Fig. 7 summarises the usage frequency of Web3 technologies identified across the reviewed articles. This analysis directly addresses SRQ2; it should be emphasised that the adoption of these technologies is not mutually exclusive, as several articles report the concurrent use of multiple technologies within the same context. All technologies previously referenced in this research are exclusively integrated into the Web3 paradigm, with no articles addressing the semantic web.

4.3. Logistics areas and logistics 5.0: comparative insights Web3 technologies

Analysing the articles that implemented freight brokers, 40% (4/10) of these articles implemented AI-based solutions. Another 30% (3/10) incorporated a IoT system, and a further 30% (3/10) employed some kind of blockchain application.

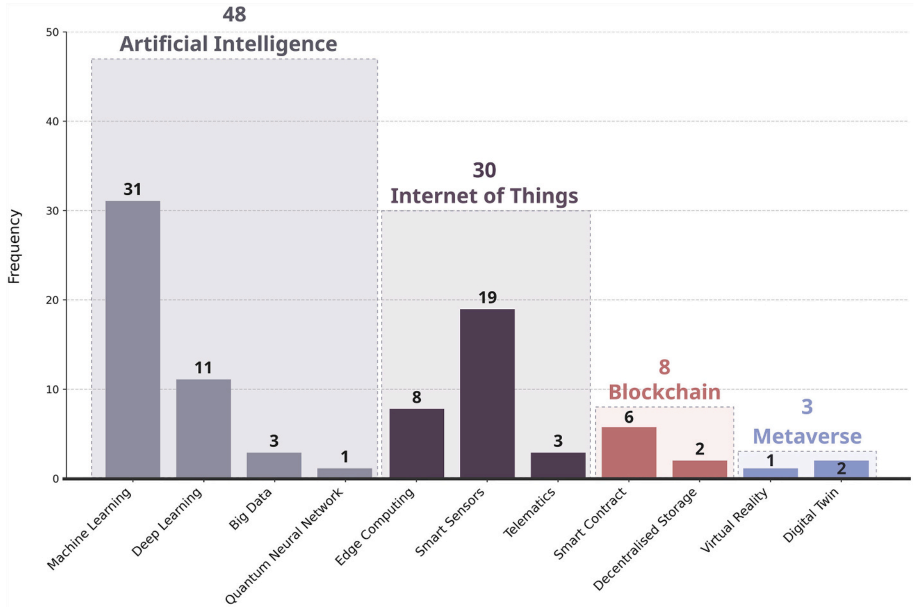

Fig. 7. Distribution of studies by Web3 technology categories and specific technologies, inside Artificial Intelligence, Internet of Things, Blockchain, and Metaverse.

Table 5
Distribution of enabling technologies in the reviewed trucking-logistics literature ($n = 74$).

Technology family	Total studies (count)	Main sub-categories (count)	Typical trucking-logistics applications (examples)	Reporting notes / gaps
Artificial Intelligence (AI)	48	Machine Learning (31); Deep Learning (11); Big Data analytics (3); Quantum neural networks (1); AI unspecified (2)	Prediction (TSR, dwell time, demand), driver risk/safety analytics, scheduling and routing, emissions/fuel modelling, maintenance/diagnostics, platform intelligence	Frequent model transparency gaps (features, hyperparameters, validation protocols). Several papers report "AI" without architecture details (coded as *AI unspecified*).
Internet of Things (IoT)	30	Smart sensors (19); Edge computing (8); Telematics pipelines (3)	Real-time fleet visibility; cargo/condition monitoring; driver behaviour capture; predictive maintenance; risk scoring via in-vehicle/edge analytics	Limited interoperability discussion.
Blockchain	8	Smart contracts (6); Decentralised storage / integrity protection (2)	Freight marketplaces, automated settlement/insurance, traceability and auditability, data integrity for IoT streams	Few empirical deployments in trucking contexts; limited evaluation of performance/scalability and governance.

The application of AI in freight brokerage is prominently featured in several articles. One article uses Long Short-Term Memory (LSTM) models to predict customer purchase cycles, integrating AI with blockchain to enhance data security and build a comprehensive customer database. This approach promotes intelligent logistics and reduces transportation costs by leveraging predictive analytics (Choudhury et al., 2023). Similarly; a real-world application (Chen et al., 2024) employs Graph Neural Networks (GNNs) and LSTM networks to model spatial and temporal dependencies from large-scale GPS trajectory data; improving post-loan default prediction for truck loans. This article highlights the role of AI in risk assessment and decision-making within freight brokerage. Another real-world application (Xiao et al., 2020) focuses on predicting short-term route-specific Truckload Spot Rates (TSR) using a lagged coefficient Weighted Matrix-Based multiple linear Regression (Lag-WMR) model, with variable selection by the Light Gradient Boosting (LGB) method. This empirical study underscores the importance of AI in optimising freight brokerage by providing accurate rate predictions based on real-world data.

The implementation of IoT technologies in freight brokerage is explored in two articles, (Heinbach et al., 2022) and (Pernestål et al., 2021). The use case (Heinbach et al., 2022) designs a shared Freight Service Intelligence Platform (FSIP) that incorporates mobile telematics; including sensors for tracking position; temperature; humidity and other conditions of freight transport assets. This use of IoT aims to enhance the prevention of accidents and improve the overall efficiency of freight operations. On the other hand; another case study (Pernestål et al., 2021) develops future scenarios for road freight transport by integrating AI and IoT technologies. It includes connected vehicles equipped with sensors to monitor and transmit data about their condition and performance, as well as environmental, traffic flow, and infrastructure sensors.

Blockchain technology is another critical area of focus in freight brokerage articles. Implementing blockchain for data integration ensures data security and facilitates the collection of timely information (Chen et al., 2021. This integration supports the development of intelligent logistics systems and reduces transportation costs. The article from S. Alacam and A. Sencer (Alacam & Sencer, 2021) developed an application using blockchain to improve collaboration among shippers and carriers by implementing smart contracts on a blockchain network; aiming to eliminate brokers while preserving their organisational roles. This approach fosters transparency and trust in the trucking industry. Other proposed development; (Choudhury et al., 2023) assesses the feasibility of a blockchain-based trucking platform, exploring features such as smart contracts, digital signatures and decentralised key management, and emphasises the potential of blockchain to create a secure and efficient trucking marketplace, addressing challenges such as data security and stakeholder collaboration.

Notably, none of the reviewed articles implemented metaverse technologies in the context of freight brokerage. This indicates a

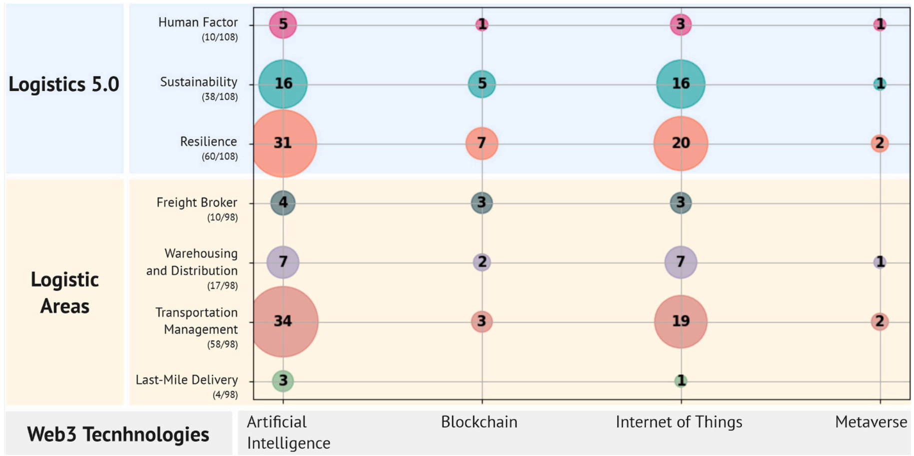

Fig. 8. Bubble matrix graph illustrating the relationship between Web3 technologies implemented, logistics areas, and Logistics 5.0 parameters. Bubble size represents the frequency or intensity of implementation across different logistics domains.

potential area for future research, as the metaverse could offer innovative solutions for virtual collaboration, training and simulation in logistics operations. Fig. 8 comprehensively summarises the comparative analysis of web technologies used across the various logistic areas.

5. Discussion

The findings presented in the previous section address the research questions formulated at the outset of this review, culminating in the decision to construct a conceptual framework to synthesise and present the results of this SLR. This approach was chosen for its ability to provide a structured and coherent representation of the insights derived from the analysed articles, offering an explicit mapping between logistics areas, Web3 technologies, and improvement goals. Conceptual frameworks are particularly valuable in SLR's as they bridge fragmented knowledge, integrate diverse perspectives, and facilitate critical discussion by organising findings into a unified model accessible to both researchers and practitioners (Peterson et al., 2018). The purpose and scope of the discussions:

- To guide stakeholders (e.g., LSP's, management, developers) in identifying relevant Web3 technologies for targeted operational improvements;
- To highlight gaps in scalability, adaptability, and cross-context validation for future research.

5.1. *Concept framework: a synthesis of SLR findings*

The results obtained from the SLR are synthesised into a concept framework, which addresses SRQ4 by providing a structured understanding of how Web3 technologies can be applied in Trucking Logistics to achieve specific goals and contribute to the principles of Logistics 5.0. This framework serves as a theoretical model, supported in empirical evidence from the analysed articles, to guide LSP's in identifying relevant technologies, their areas of application, and their alignment with the broader focus areas of Logistics 5.0.

The concept framework (Fig. 9) comprises four main components: logistics area, goals, Web3 technologies, and Logistics 5.0 focus.

It aggregates and organises insights from the literature to help stakeholders navigate the complex relationships between these components. Specifically, it maps existing research findings to demonstrate how Web3 technologies developed or proposed in prior articles address particular logistics areas (e.g., fleet management, warehouse operations) and their associated improvement goals (e.g., accident prevention, waste minimisation, stakeholder management). Additionally, it emphasises how these applications correspond with one or more of the core focus areas of Logistics 5.0 - sustainability, human factors, and resilience.

The development of this framework followed a systematic process based on the findings of this SLR. First, articles were categorised according to the logistics areas they address and the goals they pretend to achieve. Next, the Web3 technologies proposed in these articles were identified and mapped to their respective logistics applications. Finally, an analysis was conducted to determine how these applications contribute to advancing the principles of Logistics 5.0. For instance, articles proposing solutions for transportation management or enhancing performance are linked to the resilience focus and often use IoT as the most frequently used technology.

The discussion of SLR's investigation of this visual and synthesised representation serves multiple purposes. For practitioners, particularly LSP's in trucking logistics, it offers a decision-making tool to guide investments in Web3 technologies by linking them to specific improvement goals within their operations. Stakeholders can identify which logistics area they aim to enhance, select the corresponding goal (e.g., improving performance or minimising waste), and determine which Web3 technologies are most relevant for achieving that goal. Additionally, by linking these applications to Logistics 5.0 principles, the framework provides a roadmap for transitioning towards more sustainable, human-centric, and resilient logistics systems. For researchers, this framework highlights gaps in the existing literature by identifying logistics areas or goals that have been underexplored in the context of Web3 applications. It also provides a structured foundation for future empirical articles that seek to validate these findings in practical settings. Similarly, developers can utilise this framework to determine which applications require further investigation or refinement based on their potential impact on logistics operations.

As part of this framework, 14 distinct applications have been identified, each representing a specific combination of a logistics area, a targeted improvement goal, and one or more Web3 technologies proposed in the reviewed articles. The following sections provide a detailed explanation of these 14 applications, offering technical insights into their functionality and implementation. Each application is contextualised within its respective logistics area, linked to its intended improvement goal and associated with the Web3 technologies that enable its operation.

1) To prevent accidents on freight brokers, develop a Freight Service Intelligence Platform (FSIP). For starters, it is essential to delineate the key requirements articulated by stakeholders, including

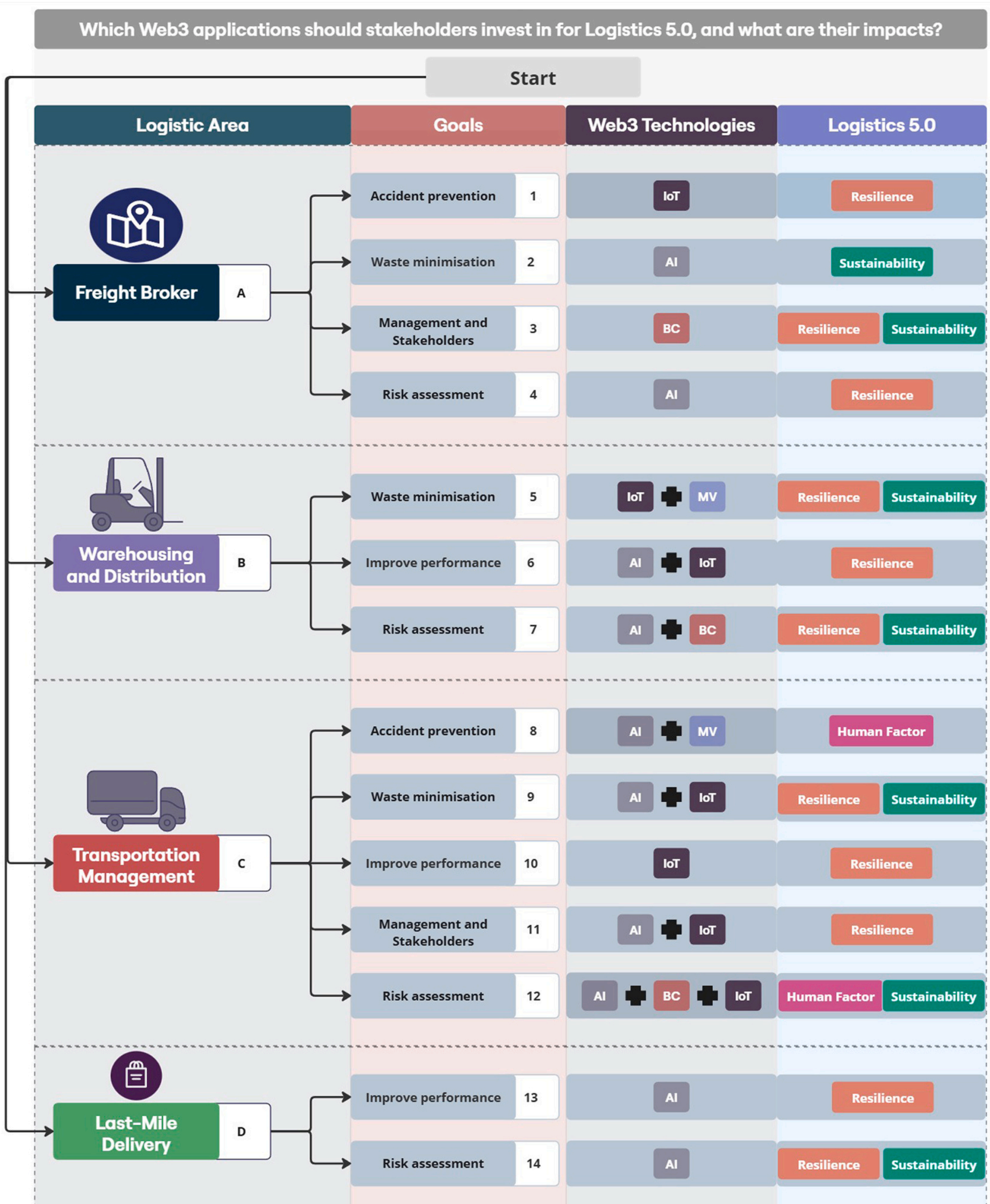

Fig. 9. Conceptual framework illustrating Web3 technologies recommended for investment across different logistics areas, aligned with specific improvement objectives and their contributions to the principles of Logistics 5.0. Note: AI - Artificial Intelligence; BC - Blockchain; IoT - Internet of Things; MV - Metaverse.

elements such as real-time tracking and environmental monitoring. Integrating telematics with various sensors is pivotal for comprehensively tracking parameters, including geographical positioning, temperature, humidity and other pertinent conditions affecting freight transport assets. Subsequently, developing a user-centric platform must prioritise characteristics such as scalability, security and interoperability with pre-existing systems in the industry (Heinbach et al., 2022);

2) To minimise waste on freight brokers, invest in customer purchase cycles. Initiate the process by gathering extensive and detailed data from e-commerce platforms and physical retail operations. This data should encompass critical aspects such as customer transaction records, consumption patterns, preferred payment methods and categorisation of products. Employing Long Short-Term Memory (LSTM) models will facilitate a comprehensive analysis of this data to forecast future purchase cycles accurately. Furthermore, integrating Decision Support Systems (DSS) alongside predictive analytics can significantly enhance decision-making frameworks within the organisation (Chen et al., 2021; Pernestål et al., 2021);

3) To assist management with freight brokers and assess the feasibility of a blockchain-based platform to improve collaboration between shippers and carriers, eliminating brokers while still maintaining their organisational roles. Develop a system architecture integrating smart contracts, digital signatures and decentralised key management to create a transparent, secure and efficient marketplace. Collect data from trucking operations, including load requirements and capacity availability, and qualitative insights from expert interviews and surveys (Alacam & Sencer, 2021; Choudhury et al., 2023; Yang, Bian, et al., 2024);

4) To improve risk assessment on freight brokers, comprehensive data must be gathered from an online freight exchange (OFEX) platform, including truckers, shippers, orders, and TSR data. The light gradient boosting (LGB) method for variable selection is employed to pinpoint the most relevant features. Subsequently, a lagged coefficient weighted matrix-based multiple linear regression (Lag-WMR) model will be utilised for accurate predictions (Xiao et al., 2020);
5) To minimise waste in the warehousing and distribution area, start by enhancing the traceability of food products through RFID sensors that capture data such as temperature and humidity. Gather and process data, including GPS coordinates and environmental conditions, to improve logistics operations and minimise food waste. Develop a smart indoor parking system using BLE beacons to monitor the location of vehicles, enhancing accuracy and reducing delays. Implement a digital twin framework for real-time logistics simulation, employing GPS sensors and IoT data to anticipate potential risks and ensure precise module arrival times (De Beer & Joubert, 2024; Dib et al., 2023; Lee & Lee, 2021; Zhao et al., 2020);
6) To improve warehouse and distribution performance, start minimising makespan in truck scheduling at a cross-docking centre using heuristic and RL-SA algorithms. Employ sensors to gather information on environmental conditions (temperature, humidity, vibration) and operational data (handling duration, batch quantity) to monitor the deterioration rates of perishable products. Apply Deep Q-networks (DQN) with Prioritised Experience Replay (PER) to optimise steel plate shuffling and truck loading sequencing. For dynamic rescheduling of truck appointments, utilise algorithms such as Decision Trees (DT) and real-time data from GPS and RFID technologies (da Silva et al., 2023; Shahmardan & Sajadieh, 2020; Xu et al., 2024);
7) To improve performance in warehousing and distribution, develop a cross-docking implementation model using blockchain to enhance transaction negotiations and operational scheduling with smart contracts, distributed ledgers and asymmetric encryption. Predict warehouse dwell time for trucks by employing LSTM models and self-attention mechanisms, tackling sparse data challenges with a multi-source adaptation module. Implementing a Blockchain with an AI application enhances quality management and consumer confidence in perishable supply chain logistics through smart contracts, ensuring data integrity, transparency and traceability (Carvalho et al., 2024; Liu & Li, 2023; Zhao et al., 2024);
8) To prevent accidents in transportation management, start by enhancing load safety assessments using AI to minimise risks and penalties. Develop a VR simulation platform to train truck drivers, personalise driver assistance systems and improve trust in Advanced Driver Assistance Systems (ADAS). Utilise GPS data to accurately identify truck rest stops for planning and regulatory purposes. Evaluate commercial truck accident risks by analysing vehicle trajectory and in-vehicle monitoring data to identify key risk factors and develop predictive models for proactive safety management. Collect and analyse data from various sources, including real-time tracking and tracing data, telematics systems and multimodal interaction data from driving sessions to improve overall safety and efficiency in transportation management (Loske & Klumpp, 2021; Wang et al., 2024; Xiao et al., 2020);
9) To minimise waste in transportation management, develop a model such as DeepPlan (Wang et al., 2023) to optimise urban road planning using real-time traffic data; thereby minimising logistics costs and carbon dioxide emissions. Establish a scalable system for real-time truck characterisation to support freight modelling and policymaking. Gather and analyse data on customer demands; truck capacities; CO2 emissions and vehicle specifications. Employ ML classifiers to predict truck driver turnover events and refine vehicle transportation routes through IoT data (Correll et al., 2023; Ding et al., 2023; Emadikhiav et al., 2024; Gong et al., 2021; Hussain et al., 2024; Juvvala & Sarmah, 2021; Kong et al., 2022; Li, Tok, et al., 2024; Lo & Shih, 2021; Pérez-González et al., 2024; Rajak et al., 2024; Tahfim & Chen, 2024; Umer et al., 2024; Wang et al., 2023; Yang, Lan, et al., 2023; Yu et al., 2021; Zalzal & Hatzopoulou, 2022);
10) To improve transportation management performance, develop integrated dynamic vehicle routing with time windows, leveraging IoT technologies and Big Data Analytics (BDA) to respond efficiently to fluctuating customer demands. By dividing dynamic time windows into smaller static intervals and applying advanced optimisation techniques such as tabu search, the system significantly enhances route planning, reduces travel distances, and increases vehicle utilisation. Real-time sensor data from telematics and camera-based technologies enable continuous monitoring of vehicle performance and driver behaviour, supporting predictive maintenance, eco-driving, and proactive safety measures (Chen, 2023; Hopkins & Hawking, 2018);
11) To implement an application for transportation management to enhance management and stakeholder engagement, begin by proposing an IoT-enabled solution for risk assessment in the auto-insurance industry. Utilise big data and hierarchical modelling to improve predictive performance and operational efficiency. Gather driving data using GPS, onboard diagnostics (OBD) and in-vehicle cameras. Employ fine-granular driving data and crash reports to evaluate risks. To ascertain the most effective approach, compare the performance of various predictive models, including neural networks, logistic regression, support vector machines and random forests (Ho et al., 2022);
12) To implement an application for transportation management focused on risk assessment, begin by developing a ML model to forecast greenhouse gas emissions from road transport, utilising social, economic and emissions data. Enhance fuel efficiency by analysing data from telemetric fleet data. Employ blockchain for immutable data storage, ensuring data integrity and transparency, and implement smart contracts for automated claims processing. Utilise IoT devices such as GPS for real-time positioning, RFID tags for monitoring waste levels and sensors for environmental conditions. Apply AI techniques such as decision trees, XGBoost and Neural Networks to improve predictive performance and risk assessment (Ahmed & Roorda, 2022; Chopra, 2020; Dutta et al., 2023; Khan et al., 2023; Morsali & Kianfar, 2024; Negueroles et al., 2024; Yin et al., 2024; Zhang et al., 2021);
13) To improve performance on last-mile delivery, implement an AI application for optimising delivery routes and reducing costs, and propose a two-echelon city dispatch model with mobile satellites (2ECD-MS). Expand this model to enable trucks to dispatch directly (2ECD-MS-TDD) for further cost reduction. Utilise a cluster-based variable neighbourhood search (VNS) algorithm to optimise the routes based on customer demands, geographical locations and distribution types (Lan et al., 2022; Tsang et al., 2021);
14) To assess risk on last-mile delivery, develop a stochastic evolutionary game model to analyse vehicle routing optimisation for Less-than-Truckload (LTL) carriers and carrier selection for customers. This model minimises delivery costs and delays while considering customer decision-making dynamics. Utilise accurate trace data to evaluate the performance of the proposed models, ensuring their effectiveness in real-world scenarios (Kaewpuang et al., 2023).

This conceptual framework synthesises the findings of this SLR into a structured model that connects theoretical insights with practical applications. It offers stakeholders a clear understanding of how Web3 technologies can be utilised within trucking logistics to achieve specific operational goals while promoting the principles of Logistics 5.0.

5.2. Literature gaps

Despite the increasing interest in emerging technologies, several significant gaps remain in the literature regarding the application of Web3 technologies within the logistics sector. Metaverse applications, for example, are notably underexplored, with fewer than 5% (three out of 82) of the reviewed articles addressing this topic. Among the limited articles available, the focus primarily rests on human-machine interactions and technological integrations aimed at worker training rather than a thorough exploration of broader logistics applications. This is particularly important given that the human factor is a central theme in Logistics 5.0. Yet it remains one of the least researched areas, representing only 9% (seven out of 68) of the articles. In logistics operations, metaverse technologies have not been utilised in critical areas such as last-mile delivery or freight brokerage, which may contribute to the lack of investment and development in these fields.

Similarly, although Blockchain is the technology most commonly linked with Web3, it is paradoxically the second least utilised in the articles reviewed, appearing in just 9% (six out of 68) of cases. This underutilisation is surprising given the high reliability that Blockchain can provide through applications such as smart contracts and supply chain information security. While blockchain has been explored in areas such as freight brokerage, warehousing and distribution, and transportation management, no articles have investigated its potential in last-mile delivery, which is a critical segment of modern logistics. Additionally, within the framework of Logistics 5.0, blockchain has been moderately applied to areas focused on sustainability and resilience. Still, the human factor is largely neglected, with only a single article addressing this intersection.

Another significant gap concerns the integration of the IoT with AI. Current literature reflects limited synergy between these technologies despite their potential to enhance logistics operations. Articles utilising real data generated by IoT devices tend to produce better results compared to AI models trained solely on open and public databases. This discrepancy arises because LSP's vary in scale, ranging from small to medium-sized enterprises, which influences the objectives and operational nuances captured in the data. Real data from specific LSP terminals often yield more accurate insights tailored to particular logistics environments than generic AI models fed by IoT-generated data. Furthermore, while IoT is a prominent technology in logistics, the number of articles focusing on it is nearly half that of those centred on AI, highlighting an imbalance that calls for more research to optimise the complementary strengths of IoT and AI.

In direct response to SRQ3 - the present findings highlight critical deficiencies that impede seamless progression. Notably, there is a pronounced need for further research and practical deployment of Web3 technologies, particularly regarding the metaverse and Blockchain, alongside enhanced IoT-AI integration in underrepresented areas such as last-mile delivery and the human factor in Logistics 5.0. The human factor, in particular, represents a pivotal area for future development, as it embodies the mainly evolution from Logistics 4.0 to Logistics 5.0, warranting more focused attention concerning emerging technologies.

5.3. Challenges in Web3 adoption for logistics service providers

Analysing all the SLR articles, several barriers and difficulties were identified in the adoption of Web3 technologies, which make it challenging for LSP's to invest money and time in developing new solutions using these technologies. One significant barrier is the high initial investment cost for technologies such as IoT equipment and HD camera systems, which can be prohibitively expensive for many companies (Morsali & Kianfar, 2024); (Zhao et al., 2020). Additionally; the need for a robust network infrastructure to support these technologies is often a limiting factor; requiring significant investment and changes to the company's entire communications infrastructure (Morsali & Kianfar, 2024).

Data limitations pose another challenge, including the scarcity of high-quality, detailed data essential for effective risk management and accurate predictions (Tomasoni et al., 2024). This is compounded by challenges such as missing values; class imbalance in datasets; and the need for continuous learning and adaptation of machine learning models (Hussain et al., 2024). The complexity of integrating new modules and functionalities into existing platforms also presents significant technical challenges (Xiao et al., 2020).

The reliance on historical data, which may not fully capture evolving driving behaviours or other dynamic factors, is a further limitation (Abdulrashid et al., 2024). This is particularly relevant in the context of unexpected traffic congestion and other time-variant factors that can disrupt delivery schedules (Yu et al., 2021). The heterogeneity of trucking activities and the difficulty in obtaining accurate and detailed data on freight movements also pose substantial challenges (Taghavi et al., 2023).

Scalability and integration with existing logistics systems are additional barriers, as ensuring data privacy and security in a decentralised network can be complex (Dutta et al., 2023). The need for broader stakeholder engagement and potential resistance from traditional players further complicates the implementation of new technologies (Choudhury et al., 2023). Moreover; the focus on specific study areas or regions; such as the German transport market or truck populations in California; may limit the generalizability of findings to other contexts (Heinbach et al., 2022); (Li, Tok, et al., 2024).

Finally, some problems are so complex that they are classified as NP-Hard (Nondeterministic Polynomial-time Hard), meaning they are challenging to solve precisely within a reasonable time frame. This complexity necessitates the use of heuristic methods and algorithms, such as Reinforcement Learning combined with Simulated Annealing (RL-SA), to find solutions that are close to optimal for more significant problems (M. Lee et al., 2022); (Shahmardan & Sajadieh, 2020). Additionally; there is a clear need for further research to overcome these challenges and determine how well these solutions can be applied to various logistics networks; transportation systems; and supply chain operations across different geographical locations (Heinbach et al., 2022).

5.4. Implications for the academy

This paper highlights the innovative implementations in recent years within LSP's and provides fresh insights into the relationship between Web3 technologies, the Logistics 5.0 concept, and trucking logistics. Understanding these relationships enables academic researchers to initiate new empirical articles and create case analyses. The proposed framework provides insights into potential opportunities for enhancing technological solutions and improving logistics systems. Furthermore, this framework underscores the importance of multidisciplinary research areas (engineering, data science, IT, and management) collaborating to design the future generation of Logistics 5.0.

5.5. Implications for the industry

This paper highlights the advantages, initiatives, and effects of implementing Web3 technologies in transportation tasks and their contributions to Logistics 5.0, as well as the potential improvements in the performance of LSP's, which is a crucial area in the next generation of the industry. Furthermore, as companies invest in developing and integrating Web3 technologies, managers need to familiarise themselves with these concepts and remain updated on the evolution of disruptive technologies for the future of transportation globally. Additionally, the proposed framework is beneficial for assessing the potential effects on medium to large-scale companies and supporting strategic decision-making.

5.6. Synthesis of research questions

This SLR has comprehensively addressed the main research question: "What is the current state of applying Web3 technologies in trucking logistics for the transition to Logistics 5.0?", the findings reveal that whilst blockchain and artificial intelligence are increasingly adopted in trucking logistics, particularly for fleet management, risk assessment, and supply chain transparency, the application of other Web3 technologies such as the metaverse, digital twins, and decentralised governance models remains limited. Furthermore, current implementations exhibit critical gaps in scalability, cross-context validation, IoT-AI integration, and alignment with the human-centric and sustainability principles central to Logistics 5.0. The conceptual framework developed in this study (Fig. 9) synthesises these findings and provides a structured roadmap for stakeholders seeking to transition towards Logistics 5.0 by identifying priority areas for technological investment and operational improvement. The four sub-research questions (SRQs) have also been systematically addressed throughout the manuscript. SRQ1 ("What are the technologies more associated with Web3?") was answered through cluster analysis, identifying five core technologies: blockchain, artificial intelligence/machine learning, Internet of Things, Semantic Web, and metaverse (Section 2.3). SRQ2 ("Which Web3 technologies are currently being applied in trucking logistics?") is addressed by the analysis of usage frequencies (Fig. 7), which reveals the predominance of AI and blockchain, with limited concurrent adoption of other technologies (Section 4.2). SRQ3 ("What are the gaps between current Web3 applications and the transition to Logistics 5.0?") highlights deficiencies in metaverse and blockchain deployment, IoT-AI integration, and human-centric aspects such as last-mile delivery and workforce empowerment (Section 5.3). Finally, SRQ4 ("Which Web3 applications should stakeholders invest in for Logistics 5.0, and what are their impacts?") is directly addressed by the conceptual framework (Fig. 9), which maps logistics areas, operational goals, Web3 technologies, and Logistics 5.0 focus areas to guide strategic investment decisions (Section 5.1).

6. Conclusion

6.1. Key findings

This PRISMA-guided SLR synthesised peer-reviewed evidence on how Web3 technologies are being applied in trucking logistics and how these applications support the transition from Logistics 4.0 towards Logistics 5.0. The review demonstrate that the current research landscape is strongly implementation-oriented, with a high share of empirical and practical contributions, but with uneven coverage across Logistics 5.0 pillars and logistics areas.

Three consolidated findings emerge:

1) Technology dominance is unbalanced and primarily optimisation driven. Across the reviewed studies, AI-driven approaches (often combined with telematics/GPS and other operational data) are the most prevalent, focusing on predictive performance, risk assessment, operational efficiency, and waste minimisation. IoT appears as a critical enabler for real-time data collection and visibility but is not leveraged as consistently as its operational relevance would suggest.
2) The Logistics 5.0 "human factor" remains structurally underrepresented. While Logistics 5.0 is positioned as a human-centric evolution of Logistics 4.0, the literature emphasises resilience and sustainability far more than human-centric outcomes such as worker well-being, training, empowerment, and technology acceptance. This imbalance limits the field's ability to claim genuine alignment with Logistics 5.0, particularly in trucking contexts where safety, workforce retention, and operational stressors are central.
3) Web3 is rarely treated as an integrated stack in trucking logistics. Despite "Web3" commonly being associated with blockchain, blockchain-based solutions appear comparatively infrequently in the reviewed body of work, and metaverse applications are mostly confined to training and human–machine interaction rather than core operational domains. In addition, the literature indicates limited synergy between IoT-generated real-time streams and AI modelling, even though evidence suggests real operational data improves relevance and performance.

6.2. Contributions and implications

This study contributes to the Industry 4.0 discourse in two ways. Theoretical contribution. We move beyond a technology inventory and provide a trucking-focused synthesis that links (i) logistics areas, (ii) operational goals, (iii) Web3 technology choices, and (iv) Logistics 5.0 pillars (resilience, sustainability, human factor). The resulting conceptual framework consolidates fragmented evidence into a decision-oriented structure that can be tested and extended in future work.

Practical/managerial contribution. For LSPs and solution developers, the evidence suggests a pragmatic sequencing strategy:

- Short term: prioritise AI plus operational data pipelines for measurable gains (risk reduction, routing, performance, waste minimisation) while strengthening data governance and interoperability foundations.
- Medium term: scale IoT deployments to improve data quality and real-time decisioning, reducing the gap between academic prototypes and operational adoption.
- Strategic term: expand investments into blockchain-enabled trust, security, and automated contracting where multi-stakeholder coordination is essential (e.g., brokerage interfaces, compliance evidence, auditable exchanges) and explore metaverse/digital-twin approaches where training, safety, and human-centric performance can be demonstrated with rigorous evaluation.

Overall, the review indicates that the trucking sector's transition towards Logistics 5.0 will depend less on adopting a single "breakthrough" technology and more on integrated architectures that combine data, automation, trust mechanisms, and workforce-centred design.

6.3. Limitations

This review is subject to four principal limitations. The evidence base was intentionally restricted to peer-reviewed journal articles published in English and indexed in four major databases (Scopus, WoSCC, IEEE Xplore, ACM DL) within the specified temporal window. Consequently, relevant insights from grey literature, industry white papers, and technical reports may have been excluded from the analysis.

Whilst the review explicitly targets trucking logistics, a proportion of the included studies address logistics and supply chain management at broader organisational levels. The transferability of findings to trucking-specific contexts may therefore vary depending on operational configurations, regulatory frameworks, and fleet characteristics across different jurisdictions and business models.

A further limitation concerns the transparency of primary studies. Several reviewed papers provide insufficient detail regarding data provenance, deployment constraints, validation protocols, or evaluation comparators. This lack of methodological specificity constrains reproducibility and hinders systematic benchmarking of solution maturity across different implementations.

Finally, although the proposed framework synthesises substantial empirical evidence, it remains conceptual in nature. Empirical validation through real-world implementation studies is necessary to confirm causal relationships, establish boundary conditions, and quantify measurable impacts across the three Logistics 5.0 dimensions (human-

Table 6
Synthesis of Web3 applications in logistics: operational characteristics, research priorities, and Logistics 5.0 alignment.

Logistics area	Operational scope	Dominant goals in literature	Dominant Web3 technologies reported	Logistics 5.0 focus most often addressed
Transportation management / fleet operations	Routing, dispatching, scheduling, fuel/energy efficiency, predictive maintenance, safety and risk analytics	Risk assessment; performance improvement; waste minimisation (fuel/emissions); accident prevention	AI/ML, IoT (telematics/GPS/sensors); occasional blockchain-enabled data integrity	Resilience and Sustainability dominate; human-factor less frequent
Warehousing & distribution (road freight interfaces)	Yard/terminal operations, dwell time, layout/inventory optimisation, coordination between trucks and facilities	Waste minimisation; performance improvement; management optimisation	AI/ML, IoT; limited blockchain/digital twin mentions	Mainly Resilience and Sustainability
Freight brokerage / trucking marketplaces	Shipper–carrier matching, rate prediction, transaction workflows, coordination and trust	Management improvement; performance improvement; risk mitigation (market/operational)	AI/ML for prediction; IoT for shared visibility; Blockchain for smart contracts, signatures, secure marketplaces	Primarily Resilience; blockchain contributes to trust/transparency; limited human factor
Last-mile delivery (truck-enabled distribution)	Urban delivery routing, two-echelon dispatching, LTL/LMD risk and cost optimisation	Waste minimisation; cost reduction; risk assessment	Predominantly AI/ML; limited IoT; blockchain and metaverse largely absent	Mostly Sustainability and Resilience; clear research gap for human factor and trust mechanisms
Cross-cutting (multi-area / architectural enablers)	Integrated platforms, interoperability, data governance, decentralised data sharing, digital twins	Scalability; security/privacy; integration with legacy systems; cross-stakeholder coordination	IoT + AI integration (often proposed more than implemented); early-stage blockchain/digital twin integration	Supports all pillars, but human factor is least operationalised

centricity, sustainability, and resilience).

6.4. Future research directions

To increase maturity and real-world relevance, future research should move from isolated prototypes towards integrated, empirically evaluated Web3 stacks in trucking logistics.

1. Empirical validation of the framework across contexts. Conduct multi-case studies with LSPs (small, medium, large fleets) and comparative evaluations across regions to test which technology-goal-pillar mappings hold under different constraints (infrastructure, regulation, market structure).
2. IoT-AI synergy as a first-order research priority. Design end-to-end pipelines that incorporate real-time IoT/telematics streams, model updating, drift monitoring, and operational decision integration. Research should explicitly report data quality constraints (missingness, imbalance), system integration, and deployment costs to close the adoption gap.
3. Blockchain beyond pilots: governance, security, and contracting outcomes. Advance blockchain research in trucking from feasibility discussions to measurable outcomes, including secure data sharing, auditable compliance evidence, and smart contract mediated transactions in brokerage and inter-organisational workflows.
4. Human-centric Logistics 5.0: safety, acceptance, and workforce outcomes. Develop and evaluate interventions where technology explicitly targets worker well-being, training efficacy, fatigue/safety, and adoption behaviours.
5. Metaverse/digital twins for operational innovation. Extend beyond training scenarios and test immersive collaboration and simulation in domains identified as underexplored (e.g., last-mile orchestration and brokerage interactions).

Table 6 synthesises the key characteristics of Web3 applications across different logistics areas, highlighting the operational scope, dominant research objectives, prevailing technologies, and alignment with Logistics 5.0 dimensions identified in the reviewed literature.

CRediT authorship contribution statement

Daniel Čale: Writing – original draft, Visualization, Validation, Methodology, Investigation, Data curation, Conceptualization. **João C. Ferreira:** Writing – review & editing, Validation, Supervision, Project administration, Funding acquisition. **Ana Madureira:** Writing – review & editing, Validation. **Carlos Coutinho:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.digbus.2026.100170.

Data availability

Data will be made available on request.

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