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# Autonomous Logistics in the Context of Sustainability and Digitalisation: A Systematic Review

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**ABSTRACT:** Increasing global competition has expanded the role of logistics within supply chains and heightened its importance. The awareness raised by the environmental, social and economic challenges faced has led to the widespread global acceptance of a sustainability approach that calls for the use of resources with due regard for the needs of future generations. This has highlighted the need to reorganise logistics activities – which, by their very nature, have a significant environmental impact – with sustainability in mind. As in all other sectors, the opportunities offered by advancing technology are driving digital transformation in logistics. In line with all these developments, autonomous logistics—one of the emerging trends in the sector—is finding an increasingly broad scope of application. This study aims to examine the concept of autonomous logistics within the context of sustainability and digitalisation. To this end, a systematic review was conducted using the PRISMA approach. As part of the research, a search was carried out in the Web of Science and Scopus databases, resulting in the analysis of 20 studies deemed suitable. Based on the qualitative analysis of the findings, it can be said that the literature reveals a strong relationship between autonomous logistics and digitalisation, and its supportive effect on sustainable logistics transformation.

**KEYWORDS:** Autonomous logistics, sustainable logistics, digitalisation in logistics, smart systems in logistics, SCM

## I. INTRODUCTION

In today's environment, logistics can be described as the most important component of the supply chain. Traditionally, logistics involves managing the forward and/or reverse movement of raw materials, components, semi-finished and finished products, and other related items along the supply chain, from their point of origin to where they are required. A wide range of activities, including—first and foremost—transport and storage, as well as order processing, packaging, handling, inventory control, forecasting, production planning, procurement, customer service, dispatch, distribution, delivery, returns management, document management and data processing, can be considered within the scope of logistics (Sun et al., 2021).

Logistics is a concept with deep historical roots. However, it can be said that its importance in terms of industrial production has steadily increased since the Industrial Revolution. The rising trend of globalisation in the 20th century, combined with developments in technology, transport and communications, has resulted in logistics evolving into a sector in its own right. Globalisation has made competition more challenging for businesses. In order to adapt to global competitive conditions, businesses have focused on their core competencies whilst turning to outsourcing for support activities; collaborative activities and inter-firm cooperation have gained importance (Sun et al., 2021). Alongside the strength of the supply chains in which businesses operate, the logistics strategies they implement have also become key elements for competitive advantage, and the importance and share of logistics service providers within these networks have increased.

In a globalising world, the impacts of industrial production and consumption have brought the concept of sustainability to the fore. The awareness raised by climate change, environmental disasters and global crises makes it imperative to bring under control, as of today, factors that could threaten the right to life of future generations—particularly in terms of environmental, social and economic impacts (Yontar, 2022). Sustainability, a broad concept on a global scale, has become a fundamental element that businesses must consider when organising their operations. Given its growing share and importance within the supply chain, as well as the critical role its activities play in sustainability, the logistics sector has become one of the sectors most affected by all these developments and changes (Chen et al., 2024). For logistics firms, the need to keep pace with rapid technological advancements whilst ensuring compliance with sustainability principles has become imperative as they expand their operations on a global scale (Parvasi et al., 2025). In this process, new approaches have emerged that will lead to a structural transformation of the sector.

Sustainability in logistics encompasses a broad range of areas, primarily environmental sustainability practices—referred to as 'green logistics'—aimed at reducing carbon emissions, waste and pollutants. Economic sustainability focuses on preventing waste and increasing efficiency, whilst social sustainability centres on employee health and safety and societal impacts (Al-Emran, 2022).

In line with technological advancements, the key technologies driving digital transformation in logistics include big data analytics, the Internet of Things, artificial intelligence, smart devices, robotics and automation. These technologies not only enhance speed and efficiency in logistics operations but also provide transparency and traceability, whilst helping to manage their environmental impacts (Sun et al., 2021).

The concept of autonomous logistics refers to smart systems that enable logistics activities—supported by artificial intelligence, sensors and unmanned vehicles—to manage themselves independently of human intervention and location. AGVs (Automated Guided Vehicles) and AMRs (Autonomous Mobile Robots), smart shelving and inventory systems, route optimisation and fleet tracking software, driverless vehicles, delivery robots and unmanned aerial vehicles (UAVs) – drones – are already being utilised in the sector (Bechtsis et al., 2018; Nitsche, 2021). These applications, which can be classified under autonomous logistics, not only enhance speed in warehousing, transport and last-mile delivery but also offer numerous benefits in terms of reducing errors and costs, as well as promoting sustainability (Gružauskas 2018, Sun 2022, Chen 2024).

In the following sections of this study, the concepts of sustainability and digitalisation in logistics will be explained, and the autonomous logistics approach—as a current trend—will be discussed. Studies in the literature that address autonomous logistics within the context of sustainability and digitalisation will be systematically reviewed, and the findings will be discussed and interpreted. The aim of this study is to provide a perspective that will shed light on future research in this field.

## II. THEORETICAL FRAMEWORK

### *A. Logistics sustainability*

Sustainability can be defined, in its broadest sense, as meeting the needs of the present whilst ensuring that future generations retain the right to meet their own needs. The three fundamental dimensions of sustainability have been identified as the environment, society and the economy (Al-Emran 2023, Lennon et al. 2018).

- Environmental sustainability encompasses the conservation of natural resources, water and air, the reduction of waste, and the preservation of climate balance.
- Social sustainability encompasses human rights, social justice, ensuring equality of access to education and other opportunities, and the fair distribution of prosperity.
- Economic sustainability aims for the efficient use of resources, profitability and cost reduction to achieve long-term, responsible and healthy growth.

The components and elements of sustainability are shown in Figure 1. The figure illustrates that, for sustainability, the three fundamental dimensions must first meet the condition of being socio-economically equitable, from an environmental economics perspective, viable and ecologically bearable in their interrelationships.

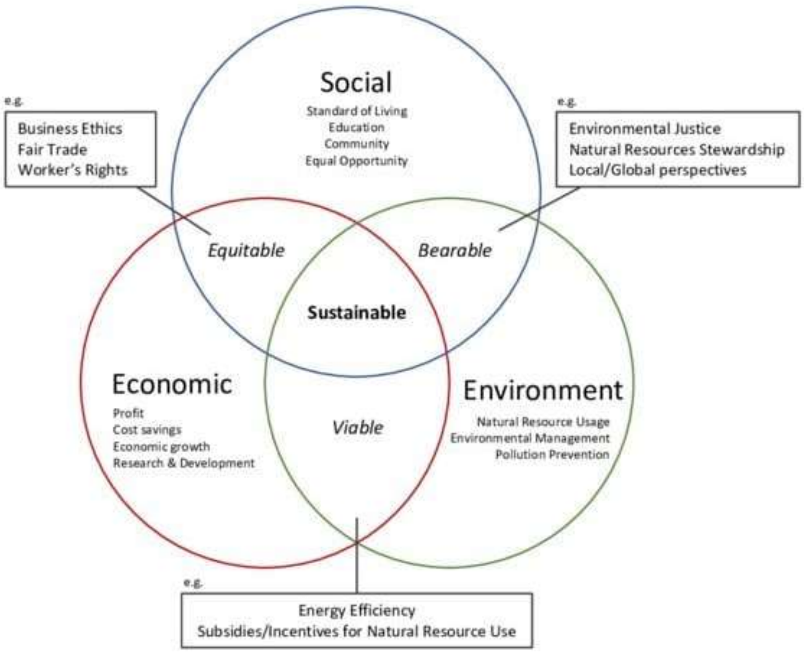


**Figure 1. The three spheres of sustainability (Lennon et al., 2018)**

When it comes to logistics—which is at the heart of modern supply chains—sustainability emerges as a key factor to be considered in the organisation of operations, particularly in terms of its environmental dimension. This is because, by their very nature, logistics operations have a high potential to generate adverse environmental impacts (Al-Emran 2022). A significant proportion of the energy required for logistics activities, particularly in transport, is derived from fossil fuels; this leads to carbon emissions and the release of greenhouse gases. Controlling these gases, which pollute the atmosphere, is of great importance in preventing climate change, which leads to global disasters (Parvasi et al., 2025). In terms of environmental sustainability in logistics, the increased use of renewable energy sources, route optimisation, consolidation, lean practices aimed at eliminating unnecessary activities, and 'green' approaches that reflect environmental awareness are coming to the fore. These practices can often be linked to economic sustainability, as they help reduce costs, and to social sustainability, as they serve to protect the shared environment.

The key areas of focus for sustainable logistics are illustrated by Yontar (2022) as shown in Figure 2. According to Yontar, alongside internal and external factors influencing sustainability in logistics, elements such as logistics performance factors, resource utilisation, environmental and social impacts, transport and warehouse management, and waste management play a decisive role.


**Figure 2. Sustainable logistics parameters (Yontar, 2022).**

### *B. Digitalisation in logistics*

In the simplest terms, digitalisation refers to the restructuring of information, processes and services through digital technologies. Many activities that were previously carried out using paper, analogue devices or physical environments are now conducted via digital systems, software and online platforms. This transformation is not merely a technological shift; it is also having a profound impact on the way we do business, our methods of communication and our social habits.

Whilst digitalisation involves transferring existing information and processes to a digital environment, digital transformation is a broader concept encompassing the use of these digital technologies in a way that transforms business models, corporate strategies and organisational culture. The internet is one of the key components of digitisation. The internet and internet-connected technologies enable many processes to be carried out remotely as physical elements are digitised. Alongside the internet, technologies such as cloud computing, artificial intelligence and the Internet of Things (IoT) can also be cited as key components of digitisation (Sun et al., 2021). Computers, tablets, mobile phones and similar devices that enable the use of these technologies constitute the physical components of digitalisation.

In businesses, digitalisation enhances competitiveness and enables sustainable growth by modernising traditional ways of working through technology. Proper integration not only accelerates processes but also significantly reduces costs. Digitalisation in logistics involves the management of transport, warehousing and supply chain processes using artificial intelligence, the Internet of Things (IoT), cloud computing and automation systems (Tran et al., 2026). This transformation increases operational speed by reducing manual tasks, lowers costs and ensures full transparency in processes (Kayıkçı, 2018).

Key technologies and their areas of application can be illustrated as follows (Chen et al., 2024; Sun et al., 2021; Kayıkçı, 2018):

- Artificial Intelligence (AI): Route optimisation and demand forecasting.
- IoT Sensors: Real-time vehicle and cargo tracking.
- Warehouse Automation: Smart shelving and barcode systems.
- Cloud Software: Supplier and customer integration

Whilst digitalisation offers advantages such as fast and error-free deliveries, low fuel and labour costs, uninterrupted data flow, access and reporting, and increased customer satisfaction, companies that fail to manage the transformation correctly may face serious strategic, financial and cultural challenges, as well as operational disruptions, in practice (Tsolakis et al. 2021).

Digital applications in logistics, along with the benefits and challenges of digitalisation, are illustrated by Tran et al. (2026) as shown in Figure 3.

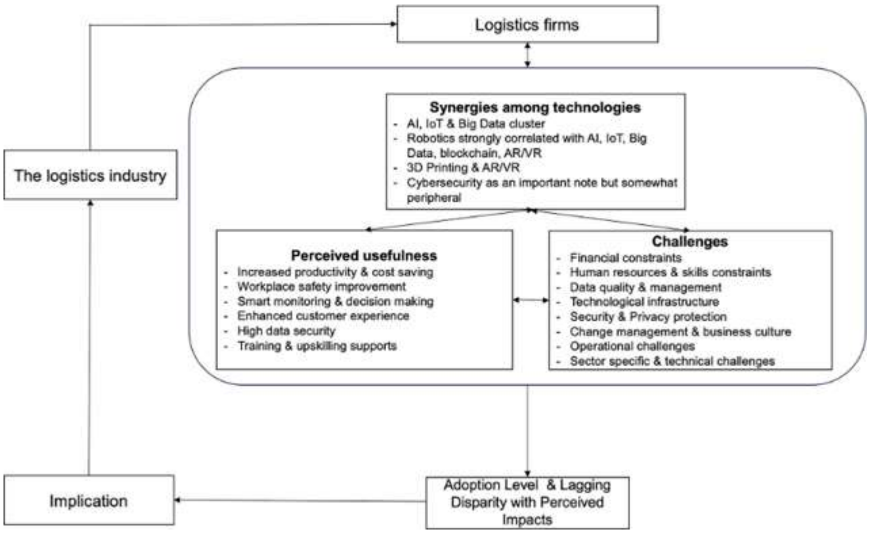


**Figure 3. A conceptual framework of logistics sustainability (Tran vd., 2026)**

Some conclusions that can be drawn from examining the figure are as follows:

- The key technologies in logistics digitalisation are AI, IoT, Big Data, Robotics, AR/VR, 3D printing and, whilst important, cybersecurity, which remains somewhat in the background. The synergy arising from the combined use of these technologies supports digital transformation.
- The main benefits provided by digitalisation in logistics include increased efficiency, reduced costs, improvements in workplace safety, smart monitoring and decision-making, improved customer service, enhanced data security, increased staff satisfaction, agility and flexibility, and easier adaptation to global competition.
- The challenges that need to be overcome in digital transformation include: high investment costs, a shortage of skilled labour, inadequate technological infrastructure, difficulties with data quality and management, challenges relating to ensuring security and privacy, difficulties arising from traditional management and business culture, and sector-specific operational and technical barriers.

### *C. Autonomous logistics*

The term 'autonomous logistics', which has its origins in the concepts of industrial automation and military procurement, has been in official use in both academic and industrial circles since the 2010s (Windl et al., 2010; Van Meldert & De Boeck, 2016)

Autonomous logistics is an innovative approach that is transforming traditional methods in the logistics sector. Through the integration of advanced technologies such as automation, artificial intelligence, smart sensor technology and autonomous vehicles, it aims to optimise logistics operations—including transport, storage, inventory management and distribution—whilst minimising human intervention (Kayıkçı, 20218). In this approach, which refers to the execution of one or more stages of logistics processes using autonomous systems, supply chain processes and the movement of vehicles, cargo, equipment, people, information or resources are carried out using advanced technology and directly, without human control. Autonomous systems utilise unmanned vehicles and automated storage systems in areas such as warehouse management, material handling and supply chain optimisation to increase operational efficiency, speed and workplace safety whilst reducing costs. These advanced applications minimise human error in logistics, thereby enhancing supply chain reliability and providing companies with a competitive advantage.

#### *1) Key technologies in autonomous logistics:*

The key technologies used in autonomous logistics; their areas of application and the benefits they provide are summarised below;

<u>*Autonomous Vehicles:*</u> Autonomous transport vehicles are vehicles capable of moving without driver intervention. These vehicles include various types such as lorries, drones, unmanned aerial vehicles (UAVs), and land and sea vessels. Autonomous vehicles can enable the transport of goods more quickly, safely and efficiently, and in this context, can bring a new perspective to the supply chain. Autonomous vehicles can be used to automate transport processes within distribution systems. For example, driverless land vehicles can travel automatically on motorways and urban roads (Gružauskas et al. 2018), monitoring their surroundings and making decisions using sensors such as cameras, radar and lidar (Sun et al. 2022, Wu et al. 2026). Drones can be

used to deliver parcels to recipients quickly and efficiently (Chen et al., 2024). Drone deliveries can offer a significant advantage, particularly in rural or hard-to-reach areas.

Sensor Technology: Autonomous logistics systems use various smart sensors to perceive their surroundings. Devices such as LIDAR, radar, ultrasonic sensors and cameras help vehicles continuously monitor their surroundings. This data is used for route planning and situational awareness. The use of advanced sensors for product tracking and monitoring enhances accuracy in inventory management (Wu et al., 2026).

Artificial Intelligence and Data Analytics: Artificial intelligence is one of the core technologies underpinning autonomous logistics. Data collected by sensors is analysed by artificial intelligence algorithms and used for route optimisation and the detection of abnormal situations. The use of artificial intelligence in logistics planning, forecasting and optimisation helps to improve decision-making and transport processes, increase on-time deliveries and reduce logistics costs (Sun et al., 2022; Kayıkçı, 2018).

Internet of Things (IoT): Internet of Things (IoT) technology enables devices to connect with one another and facilitates real-time data transmission. This technology contributes to the optimisation of transport processes and the reduction of logistics costs. For example, the location of goods and transport vehicles within the supply chain can be tracked, or temperature, humidity and other environmental variables can be monitored during the logistics process. IoT technologies can particularly enhance operational efficiency in inventory management and product quality control (Sun et al., 2022; Gružauskas et al., 2018).

Robotics: In automation-based warehouse management, the use of in-warehouse robots integrated with equipment such as pallets, racking systems and conveyor belts speeds up in-warehouse operations and improves efficiency (Sun et al., 2021).

***2) The benefits of autonomous logistics systems:***

Faster and more reliable deliveries: AI-powered planning and management processes enable decision-making based on data and data analysis, leading to more accurate demand forecasting and improved inventory management. As a result, companies can optimise stock levels, reduce waste and respond more quickly to customer demands. Furthermore, thanks to sensor technology—the cornerstone of autonomous logistics—vehicles continuously monitor their surroundings. Lidar, radar, ultrasonic sensors and cameras enhance safety whilst facilitating real-time decision-making through a constant flow of data. They also help maintain product quality by monitoring the condition of goods and transport conditions. In an autonomous system, delivery reliability increases as human-related issues are eliminated (Acosta-Vargas, 2026). Autonomous vehicles and drones can make fast and reliable deliveries without being affected by traffic congestion. This leads to increased customer satisfaction and a competitive advantage (Engesser et al., 2023).

Lower operational costs: By eliminating labour costs and human error, autonomous systems reduce operational costs for businesses whilst improving fuel efficiency. Autonomous vehicles can be managed more effectively within traffic flow, and route optimisation—which prevents time loss in traffic—can shorten delivery times (Gružauskas et al., 2018; Sun et al., 2021; Wang & Lin, 2025).

Reduced environmental impact: Autonomous transport systems minimise environmental impact by enabling more efficient route planning and energy efficiency, thereby helping businesses achieve their environmental sustainability targets more quickly. The contribution of autonomous logistics processes to reducing the ecological footprint can create a significant environmental impact within the supply chain (Gružauskas et al., 2018; Sun et al., 2021; Chen et al., 2024; Wang & Lin, 2025).

Improved warehouse management: Smart warehouse systems enable more effective management of stock. Stockholding costs are reduced, and warehouse space is utilised more efficiently. Autonomous warehouse systems make warehouse operations smarter and more effective. Systems such as autonomous forklifts, automated warehouse racking and warehouse robots are solutions that enable stored goods to be stacked more systematically and optimise the use of warehouse space (El-Moussaouı et al., 2026).

***3) Barriers to autonomous logistics:***

The main challenges that may be encountered in the transition to autonomous systems in logistics include high initial costs (Nitsche, 2021) and technical integration challenges (Gružauskas et al., 2018), as well as the need for staff to adapt to new systems and the resulting requirements for training and skills development (Sun et al., 2021), data security (Chen et al., 2024), the security of artificial intelligence and machine learning algorithms, and safety challenges that may arise from the interaction of autonomous vehicles with their environment (Andrei et al., 2024).

## III.METHODOLOGY

This study was conducted in accordance with the PRISMA guidelines for systematic literature reviews. The PRISMA methodology is a recommended approach for enhancing the quality of systematic reviews. (Salvador et al., 2022; Tedja et al., 2024; Acosta-Vargas et al., 2026). The aim of the study is to comprehensively analyse the existing literature addressing autonomous logistics in relation to sustainability and digitalisation. Following a search using the Web of Science and Scopus databases, 20 articles deemed relevant to the study’s objective were examined in full and analysed qualitatively.

### *A. Search strategy and definition*

Web of Science and Scopus were selected as they are among the largest online academic databases providing access to peer-reviewed scientific studies.

The selection of studies to be included in the research was carried out in three stages:

1. Entering search keywords appropriate to the research objective

Keywords aimed at explaining the relationship between autonomous logistics and sustainability and digitalisation were identified as search criteria. A search was conducted in the databases using the following search keywords, based on titles, abstracts and keywords:

(autonomous AND logistics) AND (sustainability OR digitalisation) AND (SCM OR supply chain OR business OR management)

2. Titles, abstracts and keywords were examined and selected according to the eligibility criteria.

3. The full texts of all articles deemed suitable for inclusion in the study following the screening in the previous step were read, reviewed and subjected to a final screening based on the eligibility criteria. At the end of this stage, the final number of articles to be included in the study was determined.

### *B. Selection and eligibility process*

During the data collection process, data relating to the articles to be included in the study were recorded manually. Data were compiled that would facilitate content analysis aimed at evaluating the relationship between autonomous logistics and sustainability and digitalisation in logistics, such as article type, journal title, year of publication, subject, title, research methodology, relationships between variables, and indicators.

The inclusion criteria guiding the preparation of this systematic literature review are outlined as follows:

1. All publications are open-access, written in English, published in peer-reviewed journals, and are original studies.
2. The study aims to investigate the relationship between autonomous logistics and sustainability and/or digitalisation.
3. In line with the research objective, studies approaching the subject from the perspectives of business administration, supply chain management, logistics, etc., were included, whilst studies in fields such as engineering, computer science, communications, transport, urban studies and natural sciences were excluded.

The data elements extracted from each article have been summarised under the following categories: year of publication, type of research, research method, and research findings regarding the relationship between autonomous logistics and logistics sustainability, as well as digitalisation in logistics. The systematic literature review process flowchart, conducted in accordance with the PRISMA approach, is presented in Figure 4.

In the first stage, 254 scientific publications were identified based on keywords determined in line with the aim of the study. Of these, 35 duplicate articles were excluded; the remaining 219 publications were screened against inclusion criterion 1, reducing the number to 31. In the second stage, the articles were objectively reviewed based on their titles, abstracts and keywords, taking into account Inclusion Criteria 2 and 3; 10 studies were excluded as they were deemed irrelevant or did not meet the inclusion criteria, leaving 21 records. The full texts of 21 articles were obtained and their entire content reviewed; at this stage, one article was excluded in accordance with the inclusion criteria, leaving a final total of 20 articles.

Consequently, 20 of the initial 254 records were included in the study. Qualitative analyses were conducted using the datasets obtained from the studies identified through a systematic review involving a stepwise reduction process, resulting in a transparent, structured and reproducible procedure.

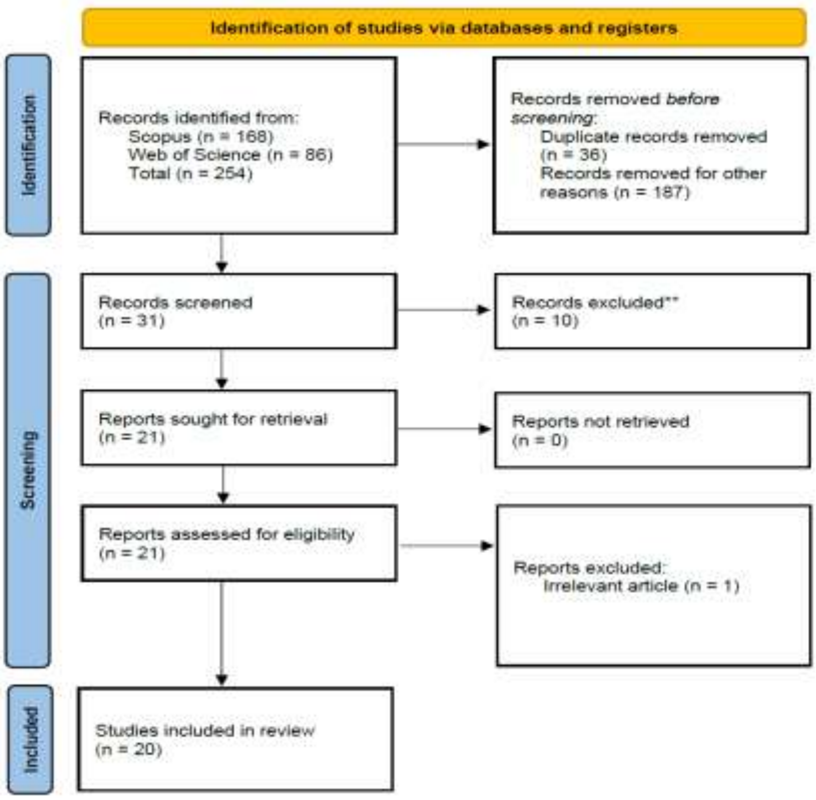


**Figure 4. PRISMA systematic literature review process flowchart (PRISMA 2020)**

## IV. RESULTS

This section will present the findings of the systematic literature review carried out as part of this study.

### *A. Distribution of the studies included in the research by year of publication, article type and journals in which they were published*

75 per cent of the studies included in the research were published in 2025 and 2026. A total of 15 studies from these years were included in the research, whilst 3 were from 2024 and one each from 2023 and 2017.

Of the articles included in the research, 14 were research articles and 6 were review articles. Expressed as a proportion, this distribution results in 70 per cent research articles and 30 per cent review articles in the sample.

Whilst the distribution of the 20 articles included in the study across the journals in which they were published shows high diversity, 'Logistics' stands out with 5 articles and 'Sustainability' with 2; the remaining 13 articles were each published in different academic journals. These journals demonstrate a wide range of academic diversity, covering topics such as autonomous and smart logistics in engineering and operations research (Operations Research Forum, Vehicles), production economics (International Journal of Production Economics), general scientific research (Scientific Reports), cyber security, marketing and the humanities and social sciences (Humanities and Social Sciences Communications). The distribution of the studies by year of publication, article type and journal in which they were published is summarised in the graphs in Figure 5.

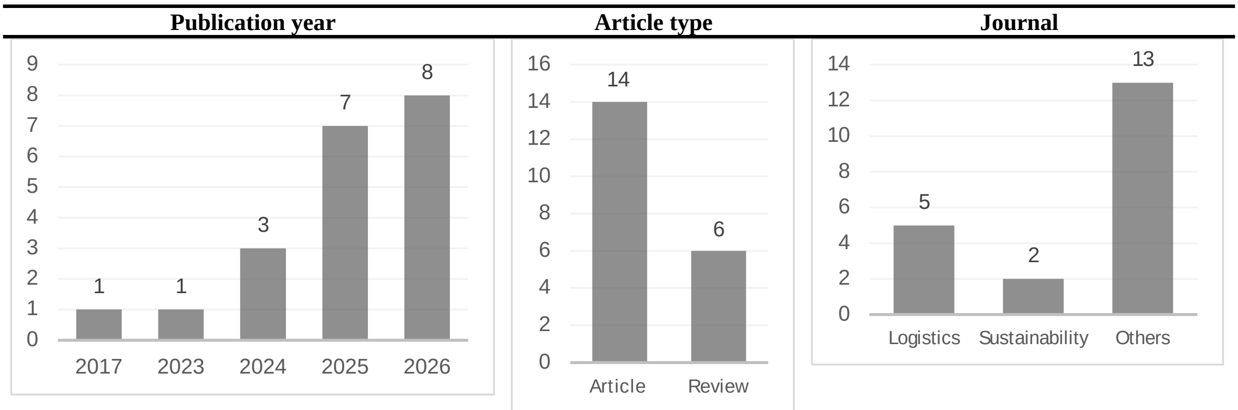


**Figure 5. Distribution of studies included in the research by publication year, article type and journal**

### *B. Focus areas and themes of the studies included in the review*

The topics and main themes addressed by the studies included in the research are summarised in Table 1. An examination of the table reveals that last-mile logistics and autonomous technologies are the most frequently addressed topics. Within the context of these main themes, other prominent topics include the transformation of logistics business models—particularly maritime logistics—as well as warehouse automation and cyber security.

**Table I. Focus areas and themes of the studies included in the review**

| *N* | *Author(s) & Year* | *Title* | *Research Area and Focus* | *Theme* |
|---|---|---|---|---|
| ***1*** | Andrei (2026) | Simulation-Based Evaluation of AI-Orchestrated Port–City Logistics | A simulation-based evaluation of port-city logistics orchestrated by artificial intelligence. | Maritime Logistics |
| ***2*** | Dupljanin et al. (2026) | Is last-mile delivery by autonomous robots a reality? A multi-criteria decision-making approach for prioritization of autonomous vehicle modes | Evaluating last-mile delivery with autonomous robots and prioritizing vehicle modes using multi-criteria decision-making (MCDM). | Last Mile LMD |
| ***3*** | El Moussaoui et al. (2026) | Smart Industrial Robots, AI-Driven Autonomous Vehicles, and Drones in Warehouse Logistics | Integration of smart industrial robots, AI-controlled autonomous vehicles, and drones in warehouse logistics. | Warehouse Automation |
| ***4*** | Gyenge et al. (2026) | A Refined Kano Model Approach to Sustainable Last-Mile Convenience Services and Customer Satisfaction | Analysis of the impact of sustainable last-mile convenience services on customer satisfaction using an improved Kano Model. | Last Mile LMD |
| ***5*** | Hussain et al. (2026) | Smart Last-mile Delivery Systems: Technological Advances, Operational Strategies, and Future Directions | Technological advancements, operational strategies, and future trends in smart last-mile delivery systems. | Last Mile Logistics |
| ***6*** | Sakita (2026) | Technological–inter-organizational–organizational–environmental (TIOE) framework for digital transformation of a maritime port in a developing country | Implementation of the TIOE framework for the digital transformation of seaports in developing countries. | Maritime Logistics |
| ***7*** | Xie et al. (2026) | Digital supply chain configurations and rural entrepreneurial vitality: evidence from ethnic minority regions in China | The impact of digital supply chain configurations on the vitality of rural entrepreneurship. | Business Model Transformatio n |
| ***8*** | Bhuvaneshwar i & Kaythry (2025) | Secure IoV communications for smart fleet systems empowered with ASCON | Secure Internet of Vehicles (IoV) communications in intelligent fleet systems, enhanced with ASCON cryptography. | Cybersecurity |
| ***9*** | Alavi-Borazjani et al. (2025) | An Overview of Critical Success Factors for Digital Shipping Corridors: A Roadmap for Maritime Logistics Modernization | The critical success factors and roadmap for digital shipping corridors in the modernization of maritime logistics. | Maritime Logistics |
| ***10*** | Jun et al. (2025) | Technological Convergence and Innovation Pathways in Sustainable Logistics Systems: An Integrated Graph Neural Network and Main Path Analysis | Technological convergences in sustainable logistics systems using Graphical Neural Networks (GNN) and main path analysis. | Methodology / Patent |
| ***11*** | Liu et al. (2025) | Federated digital twins platform for smart city logistics: A knowledge-driven approach | Design of an information-driven federal digital twin platform for smart city logistics. | Digital Twins |
| ***12*** | Moradi et al. (2025) | A Systematic Review of Sustainable Ground-Based Last-Mile Delivery of Parcels: Insights from Operations | A systematic examination of sustainable terrestrial last-mile delivery processes from an operations research (OR) | Last Mile LMD |

| | | | | |
|---|---|---|---|---|
| | | Research | perspective. | |
| ***13*** | Sharma et al. (2025) | Strategic insights into last-mile delivery: modelling the industry 4.0 enabler for e-commerce industry | Modelling Industry 4.0 enablers for the e-commerce sector and strategic insights for last-mile delivery. | Last Mile Logistics |
| ***14*** | Silalahi et al. (2025) | Agent-Based Simulation of Digital Interoperability Thresholds in Fragmented Air Cargo Systems: Evidence from a Developing Country | Agent-based simulation of digital interoperability thresholds in fragmented air cargo systems in developing countries. | Platform Integration |
| ***15*** | Wang & Lin (2025) | Concurrent optimization of routing and platooning decisions for autonomous truck fleets | Simultaneous optimization of routing and platooning decisions in autonomous truck fleets. | Autonomous Transportation |
| ***16*** | Andrei et al. (2024) | Transforming E-Commerce Logistics: Sustainable Practices through Autonomous Maritime and Last-Mile Transportation Solutions | Sustainable practices in e-commerce logistics with autonomous maritime and last-mile transportation solutions. | Green Logistics |
| ***17*** | Kotlars & Skribans (2024) | Literature review: Efficiency, environment and robotization in first and last mile logistics | Literature review on efficiency, environmental impacts, and robotization in first and last mile logistics. | Last Mile Logistics |
| ***18*** | Turienzo et al. (2024) | Logistics business model evolution: digital platforms and connected and autonomous vehicles as disruptors | The disruptive effects of digital platforms and connected and autonomous vehicles (CAVs) on the evolution of the logistics business model. | Business Model Transformation |
| ***19*** | Stamadianos et al. (2023) | Routing Problems with Electric and Autonomous Vehicles: Review and Potential for Future Research | Literature review and future research areas on routing problems with electric and autonomous vehicles. | Autonomous Transportation |
| ***20*** | Hofmann & Osterwalder (2017) | Third-Party Logistics Providers in the Digital Age: Towards a New Competitive Arena? | The transformation of third-party logistics (3PL) providers and new areas of competition in the digital age. | Business Model Transformation |

### *C. Methodological grouping of studies included in the research*

The studies included in the review exhibit a high degree of methodological diversity. For this reason, it was deemed preferable to summarise the methodologies by grouping them. Table II presents the studies included in the review, grouped according to their methodologies.

**Table II. Methodological grouping of studies included in the research**

| ***N*** | ***Methodological Group*** | ***Author(s)*** |
|---|---|---|
| 1 | Mathematical Modelling, Optimization and Operations Research (OR) | Wang & Lin (2025), Andrei et al. (2024), Stamadianos et al. (2023) |
| 2 | Simulation and Modelling (Agent Based and Digital Twin) | Silalahi et al. (2025), Liu et al. (2025), Andrei (2026), Bhuvaneshwari & Kaythry (2025) |
| 3 | Quantitative Survey, Statistics and Structural Modelling (SEM) | Moussaoui et al. (2026), Gyenge et al. (2026) |
| 4 | Multi-Criteria Decision Making (MCDM) and Configuration Analyses | Dupljanin et al. (2026), Xie et al. (2026), Sharma et al. (2025) |
| 5 | Qualitative Case Analysis, Grounded Theory and Theoretical Frameworks | Sakita (2026), Turienzo et al. (2024), Hofmann ve Osterwalder (2017), Alavi-Borazjani et al. (2025) |
| 6 | Systematic Literature Reviews (SLR) and Bibliometrics/Patent Analyses | Hussain et al. (2026), Kotlars & Skribans (2024), Jun et al. (2025), Moradi et al. (2025) |

## V. DISCUSSION

The importance of autonomous technologies in logistics is steadily increasing. The fact that the majority of the 20 academic articles examined were published in recent years demonstrates that this technological transformation in logistics is an extremely topical area of research. Although a highly rigorous and focused systematic review was conducted, the diversity of the journals in which the articles were published, the topics they addressed, and their methodologies highlights the multidisciplinary nature of the subject and the fact that it is being discussed across a very broad academic spectrum. Furthermore, the prominent emergence of last-mile logistics and autonomous technologies as the main themes can be interpreted as a reflection of developments in e-commerce and technology within the logistics sector. The concepts of sustainability and digitalisation are given balanced coverage in the articles, and it is evident that these two elements are at the heart of the transformation in logistics.

A systematic review of the 20 selected articles reveals that autonomous applications in the logistics sector are closely linked to sustainability and digitalisation.

Firstly, autonomous technologies used in logistics will be examined in the context of environmental, social and economic sustainability: The reduction of the carbon footprint and greenhouse gas emissions—key objectives of environmental sustainability—and applications supporting the Net Zero framework in this regard (Alavi-Borazjani et al., 2025; Sakita, 2026), the use of alternative fuels such as LNG, wind and solar energy, and the significant reduction of fuel consumption and emissions through AI-based fuel optimisation and the integration of smart navigation (Andrei et al., 2024; Alavi-Borazjani et al., 2025) have been highlighted. The substantial growth in e-commerce has brought to the fore not only the importance of last-mile deliveries but also their environmental impact. In their study, Moradi et al. (2025) emphasised the expected increase in emissions arising from last-mile deliveries and urban freight transport. It has been suggested that using micro-hubs, electric cargo bicycles and autonomous delivery robots (Liu et al., 2025), as well as redirecting home deliveries to automated parcel lockers (APLs) (Moradi et al., 2025), could be effective in reducing carbon emissions. Similarly, it has been noted that the use of autonomous lorry fleets, combined with appropriate routing and optimisation, could lead to significant fuel savings and emission reductions in the transport sector (Wang & Lin, 2025).

As a dimension of social sustainability, the use of light autonomous delivery robots and mobile parcel lockers to reduce impacts such as traffic congestion and noise pollution (Dupljanin et al., 2026; Stamadianos et al., 2023), by alleviating traffic congestion, noise pollution and parking problems, the quality of urban life can be improved (Dupljanin et al., 2026; Gyenge et al., 2026). Port-city-hinterland logistics can be organised through AI-supported system coordination, thereby reducing exhaust emissions associated with idling (Andrei, 2026). The standardisation of responsible practices—such as green packaging, paperless invoicing and low-emission logistics—which currently create value in the eyes of customers and provide a competitive advantage for businesses, contributes to sustainability by embedding a cultural shift towards responsible and low-impact consumption, alongside corporate responsibility (Gyenge et al., 2026).

From the perspective of economic sustainability, the integration of digital twin technology into smart city systems enables logistics service providers to utilise 'dormant assets'—such as unused transit capacity in freight transport or underutilised infrastructure outside working hours—thereby reducing the distance travelled by vehicles, emissions and transport costs, and achieving resource efficiency and waste reduction (Liu et al., 2025; Moradi et al., 2025). In rural areas, digital logistics applications can minimise damage to agricultural produce during transport and reduce packaging waste, thereby creating a positive impact on local trade and entrepreneurship (Xie et al., 2026). Digitally coordinated networks make supply chains more resilient to external shocks by supporting transparent data and trust-based information sharing (Xie et al., 2026; Alavi-Borazjani et al., 2025)

Secondly, the studies included in the research will be assessed in the context of the effects of digitalisation on logistics: Digitalisation enhances operational efficiency through digital platforms and automated workflows, which simplify documentation (Sakita, 2026; Alavi-Borazjani et al., 2025; Silalahi et al., 2025; Turienzo et al., 2024). When IoT tracking and big data analysis are used for route and fleet optimisation, container capacity and delivery success rates increase (Alavi-Borazjani et al., 2025; Moradi et al., 2025; Sharma et al., 2025; Hussain et al., 2026). The use of autonomous truck fleets significantly reduces fuel consumption and operating costs (Wang & Lin, 2025). Operational costs and emissions can be reduced by mobilising 'dormant assets' such as off-peak urban infrastructure and unused public transport capacity (Liu et al., 2025) Optimised delivery networks directly reduce fuel wastage, urban greenhouse gas emissions, noise and traffic congestion (Gyenge et al., 2026; Moradi et al., 2025). Conducting processes in a way that allows them to be tracked and monitored digitally ensures transparency and accountability (Sakita, 2026). The ability of different stakeholders within the supply chain to carry out transactions collaboratively via digital platforms accelerates the resolution of bottlenecks and strengthens the network (Silalahi et al., 2025). Digitalisation activates local resources and fosters regional entrepreneurship by improving market linkages in rural areas and expanding non-agricultural employment (Xie et al., 2026).

Alongside all these benefits, digitalisation also presents certain challenges that require addressing;

There are some organisational adaptation issues in the implementation of smart technologies (El Moussaoui et al., 2026). Resistance from employees to traditional ways of working and concerns about a lack of digital skills can increase anxiety whilst leading to operational disruptions (Sakita, 2026). A lack of trust between employees, management and partners leads stakeholders to maintain unnecessary parallel control processes, despite investment in advanced technology (Sakita, 2026). Differing levels of digital maturity among supply chain stakeholders make information sharing and joint decision-making more difficult (Silalahi et al., 2025). It is difficult to establish standardised cross-border protocols and data-sharing platforms (Alavi-Borazjani et al., 2025). Connected digital infrastructures, real-time data exchange and Vehicle-to-Vehicle (V2V) communication increase cyber security vulnerabilities, giving rise to cyber security and data privacy risks such as the exposure of sensitive information (Alavi-Borazjani et al., 2025; El Moussaoui et al., 2026; Silalahi et al., 2025; Andrei et al., 2024; Turienzo et al., 2024). Significant start-up capital is required for smart port systems and automated warehouse technologies (Alavi-Borazjani et al., 2025; El Moussaoui et al., 2026). Financial inequalities deepen the digital divide between businesses, increasing the likelihood of dominant firms monopolising markets and the risk of survival for SMEs (Turienzo et al., 2024). Outdated infrastructure and regulations, as well as rigid technical and legal frameworks, can act as barriers to the implementation of digital strategies (Andrei et al., 2024; Sakita, 2026). As the simple and static variables used in theoretical approaches do not align with the dynamic and stochastic nature of real life, many studies fall short in terms of practical applicability (Moradi et al., 2025; Stamadianos et al., 2023).

Finally, the research gaps identified in the articles included in the review have been categorised as follows, in order to provide guidance for future studies: shortcomings regarding the adaptation of mathematical models to real-world conditions and applications (Moradi et al., 2025; Stamadianos et al., 2023; Alavi-Borazjani et al., 2025; Dupljanin et al., 2026; Hussain et al., 2026; Wang & Lin, 2025; Bhuvaneshwari & Kaythry, 2025), deficiencies in system integration and infrastructure, and difficulties in accessing accurate and reliable data on all process elements (Andrei, 2026, Sakita, 2026, Alavi-Borazjani et al., 2025, Andrei et al., 2024, Kotlars & Skribans, 2024; Liu et al., 2025; Stamadianos et al., 2023; Turienzo et al., 2024; Sharma et al., 2025), and the fact that the literature, being generally focused on developed economies, does not adequately represent applications in less developed regions and rural areas (El Moussaoui et al., 2026; Hussain et al., 2026; Sakita, 2026; Xie et al., 2026; Silalahi et al., 2025), shortcomings arising from data collection methods and methodology (Gyenge et al., 2026, Jun et al., 2025, Xie et al., 2026, Hofmann & Osterwalder, 2017), and the neglect of human-related dimensions such as workforce adaptation and safety as a result of a focus on technology (El Moussaoui et al., 2026)

## VI. CONCLUSION

Considering the articles included in the study, it is evident that digitalisation should be regarded not merely as a simple reflection of technological progress, but as an ecosystem that redefines value, reshapes production and distribution, and requires social and technical integration. Thanks to digitalisation, autonomous applications can make logistics more efficient, transparent and organised, whilst reducing their environmental impact. However, these positive effects are only possible if the right conditions are met across a range of factors, including workforce adaptation, technological integration, infrastructure, costs, collaboration, cyber security and governance.

Technology holds the potential to create a more sustainable, fair and prosperous world, going beyond merely being a tool for progress. Studies have shown that, when linked to sustainability objectives, the digital transformation in the logistics sector has significant positive effects on environmental, social and economic sustainability; however, reported negative effects also exist. Consequently, advanced technologies have significantly influenced autonomous logistics and distribution systems, enabling them to become more efficient, flexible and intelligent, subject to certain conditions being met.

Due to the rapid growth in e-commerce, last-mile logistics has emerged as a key area in autonomous logistics. Application areas such as unmanned vehicles, route planning and optimisation are becoming increasingly widespread. The data-driven nature of digital systems has greatly increased the importance of data security. The fact that human-technology harmony has become one of the key issues of our time has given rise to approaches such as Industry 5.0 and Logistics 5.0, which reflect the social integration of emerging technologies. New research focusing specifically on these topics will contribute to the literature. By its very nature, the subject is also highly suitable for interdisciplinary research. Researchers can build upon the approach adopted in this study by refining the search and inclusion criteria.

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