Artificial Intelligence applied to last-mile logistics: a systematic review

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Abstract: Last-mile logistics is one of the biggest challenges in the modern supply chain, especially due to the rise in e-commerce and the high demand for fast and efficient deliveries. In this context, it is observed that Artificial Intelligence (AI) has stood out as a promising solution to optimize routing in this delivery process, improving the distribution of resources and dynamically adjusting routes. With the aim of analyzing and mapping AI techniques applied to last-mile logistics, this study developed a systematic review combined with a bibliometric and qualitative analysis. This methodology uses the strategy of searching and collecting works on a specific topic, evaluating their scientific relevance through the PRISM 2020 flowchart. Based on the results, it is concluded that AI applied to the last mile has the potential to reduce costs and increase operational efficiency and customer satisfaction.

Keywords: Artificial intelligence. Logistics 4.0. Last mile logistics. Innovation for logistics.

1.Introduction

Logistics, as a strategic field of management, has evolved significantly over the years. The process consists of managing the supply chain, planning, executing and controlling the flow and storage of goods, services and related information, from the point of origin to the point of consumption, to meet customer requirements [1]. The development of transport networks and the creation of sophisticated storage systems are milestones in this evolution, which has transformed logistics into a strategic function within companies and a central element in global trade. Especially with the growth of e-commerce, where the demand for fast and efficient deliveries has required a new look at the distribution process, in particular, for last-mile logistics. The last mile refers to the final phase of the logistics process, which involves transporting the product to the final consumer, whether for B2B (CNPJ), B2G (Government) or B2C (CPF) customers. Thus, this phase represents one of the biggest challenges of the modern supply chain, given that it involves operational complexity, high costs, and the need for satisfactory customer experience [2].

With technological advancement, Logistics 4.0 emerges, a new paradigm that integrates technologies such as automation, internet of things (IoT), big data, and, especially, Artificial Intelligence (AI). The concept of Logistics 4.0 can be summarized by the improvement of ancestral (traditional) logistics, which has as its basic proposal more need for technological investments [3]. In this way, it represents a revolution in the sector, allowing the digitalization of logistics operations and the optimization of processes through intelligent solutions.

Among these technologies, Artificial Intelligence (AI) stands out, considered one of the central pillars of Logistics 4.0 for its ability to analyze, learn, and make decisions in real time. AI encompasses a set of techniques applicable through computer systems that are related to the intelligent behaviors of human beings. And when applied to logistics, it has the potential to bring innovative solutions to optimize routing in the last mile [4]. Through intelligent algorithms, it is possible to predict demands, analyze traffic in real time, and adjust routes dynamically. In addition, AI contributes to a more efficient management of fleets and resources, with warehouse automation, the use of drones and autonomous vehicles such as RPAs and mobile robots, and the integration of automated systems.

These advancements offer a unique opportunity for companies not only to improve their processes, but also to adapt to new market demands, ensuring greater agility, sustainability, and competitiveness. But this requires planning for the incorporation of these emerging technologies.Given this scenario, this study explores the following guiding question: What is published in the state of the art about Artificial Intelligence solutions applied to last-mile logistics?

This article aims to present the impacts, analyze and map the AI tools strategically applied in *last mile logistics.* For this, a systematic review combined with a bibliometric and qualitative analysis will be presented through the PRISMA 2020 flowchart.

This study is relevant for the improvement of knowledge about Artificial Intelligence and Logistics, areas in constant evolution. In the social sphere, the improvement of routing in last-mile logistics brings direct benefits to society, making deliveries more accessible, efficient, and sustainable. The relevance of this research is also due to the academic and scientific contribution in gathering and analyzing the main studies on the application of AI in logistics routing and its impacts, to assist in studies to identify strategies and technological tools for optimizing transport and distribution and as a reference for academics and professionals.

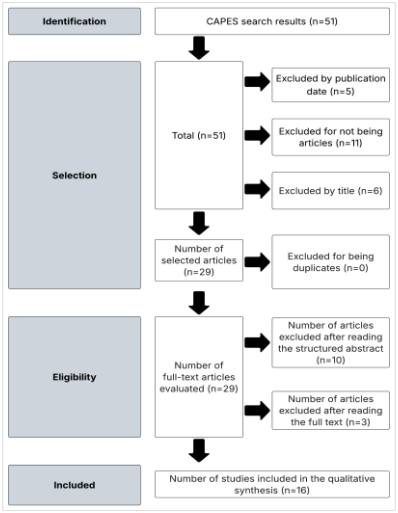
2.Methodology

The methodology of the present study is a systematic review of the literature combined with a bibliometric and qualitative analysis, using the PRISMA 2020 flowchart. Thus, it is characterized as a bibliographic survey that integrates qualitative and quantitative aspects.

PRISMA 2020 (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*) is a protocol used in conducting and reporting systematic reviews. It provides guidelines to ensure transparency, reproducibility, and methodological quality. The updated model includes a checklist with 27 items and a standardized flowchart, which organizes the selection of studies into four main steps: a)

identification, b) screening, c) eligibility, and d) inclusion. This structure allows us to clearly understand how the studies were filtered and to justify any exclusions based on objective criteria [5]. Remembering that PRISMA 2020 is a reporting tool, with the objective of assisting authors in the transparent reporting of the methods and results of systematic reviews and should not be used as a guideline for conducting systematic reviews, evaluating methodological quality or as a study protocol [6]. Thus, this study, despite having used the checklist to verify the methodology, was limited to a clear and succinct description of the methodological steps developed, in a structured way, presented in Figure 1 below.

Figure 1. Flowchart of the selection process based on the PRISMA 2020 method.



Source: own elaboration, adapted from PRISMA (2020), 2025

In the identification phase, the keywords addressed were delimited: *"last mile logistic" and "artificial intelligence",* using the results of the research carried out in several relevant sources such as Science Direct and IEEE, and through the CAPES journal portal, obtaining 51 articles. For selection and screening, the search was refined in peer-reviewed scientific articles (disregarding books, book chapters, *conference papers,* and others) in the last five years, comprising publications between 2020 and 2025, resulting in 35 articles (excluding 11 non-articles and 5 outside the publication period), no duplicates were detected. After analyzing the titles, 6 divergent articles on the topic were excluded, studies that addressed last-mile logistics without the use of Artificial Intelligence or AI applications in different sectors, as well as research on logistics or urban transport without a direct link to the last mile, leaving 29 articles.

In the next phase (eligibility), the abstracts were read and 10 articles were eliminated, studies that mentioned AI or logistics without direct application to the last mile, studies that dealt with AI in a conceptual way, without practical application, and research focused on different technologies (for example, IoT or Blockchain without integration with AI) were excluded. Posteriorly 19 articles were read in full, resulting in the exclusion of 3 more articles that did not present a description of AI methods, models, or tools applied to last-mile logistics, used AI in different stages of the logistics chain or had only theoretical discussions without results or practical cases. Finally, the 16 articles that addressed AI tools applicable to last mile logistics were validated and included in the

qualitative analysis of the present study. Although the selected studies present different approaches and scopes, all met the established eligibility criteria and demonstrate alignment with the objectives of the review.

3. Results and Discussion

Table 1 below lists the 16 articles selected through the funnel of criteria presented in item 2. Methodology, with the information of the authors, year of publication, as well as the sources, in which ScienceDirect stands out with 9 articles.

Table 1. List of selected articles.

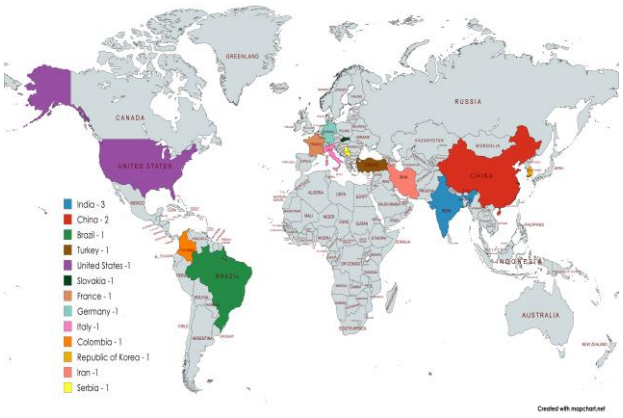
TITLE	AUTHORS	YEARS	SOURCES
Use of artificial intelligence in last mile delivery	Peter Jucha.	2021	Management Sciences
Sustainable last mile parcel delivery and return service using drones	Nawin Yanpirat, Daniel F. Silva, Alice E. Smith.	2023	SHS Web of Conferences
Delivery network design of a locker-drone delivery system	Bipan Zou, Siqing Wu, Yeming Gong, Zhe Yuan, Yuqian Shi.	2023	ScienceDirect
Artificial intelligence for last-mile logistics - Procedures and architecture	André Rosendorff, Alexander Hodes, Benjamin Fabian.	2021	ScienceDirect
Smart home devices and B2C e-commerce: a way to reduce failed deliveries	Arianna Seghezzi, Riccardo Mangiaracina.	2023	ScienceDirect
Learning for multiple purposes: A Q-learning enhanced hybrid metaheuristic for parallel drone scheduling traveling salesman problem	Ping Chen, Qianlong Wang.	2023	ScienceDirect
A novel Aczel-Alsina triangular norm-based group decision-making approach under dual hesitant q-rung orthopair fuzzy context for parcel lockers' location selection	Souvik Gayen, Animesh Biswas, Arun Sarkar, Tapan Senapati, Sarbast Moslem.	2023	International Journal for Research in Applied Science and Engineering Technology
Prioritization of crowdsourcing models for last-mile delivery using fuzzy Sugeno–Weber framework	Dragan Pamucar, Dragan Lazarević, Momčilo Đobrodolac, Vladimir Šimić, Ömer Faruk Görçün.	2023	IEEE Transactions on Evolutionary Computation
Optimal models for autonomous trucks and drones resupply for last-mile delivery in urban areas	Zhe Yuan, Simon HERVE.	2022	ScienceDirect
A two-stage data-driven metaheuristic to predict last-mile delivery route sequences	Juan Pablo Mesa, Alejandro Montoya, Raúl Ramos-Pollán, Mauricio Toro.	2023	Industrial Management & Data Systems
Multiple attribute decision-making model for artificially intelligent last-mile delivery robots selection in neutrosophic square root environment	M. Palanikumar, Chiranjibe Jana, Ibrahim M. Hezam, Abdelaziz Foul, Vladimir Šimić, Dragan Pamučar.	2024	ScienceDirect
Vehicle routing software selection for last mile delivery companies using Fermatean fuzzy-based model	Karahan Kara, Galip Cihan Yalçın, Vladimir Šimić, Pınar Gürol, Dragan Pamučar.	2024	International Journal of Production Research
Dynamic dispatch algorithm proposal for last-mile delivery vehicle	Daniel de Oliveira Mota.	2021	ScienceDirect
A novel mathematical model and a hybrid grouping evolution strategy algorithm for an automated last mile delivery system considering wind effect	M.T. Ahmadi, Seyed Hessameddin Zegordi.	2023	ScienceDirect
Review Paper on Anti-Theft Autonomous Delivery Robot for Food and E-Commerce	Shivansh Choudhary, Mansi Tiwari.	2023	IEEE Latin America Transactions
Enhancing Genetic Algorithm with Explainable Artificial Intelligence for Last-Mile Routing	Yonggab Kim, Reem Khir, Seokcheon Lee.	2025	ScienceDirect

Source: own elaboration, 2025

Regarding publication by authors, three participated in more than one publication within the ranking obtained, namely: Zhe Yuan (China and France), Dragan Pamučar (Serbia, India and Turkey) and Vladimir Šimić (India and Turkey).

The surveys were carried out in several countries around the world, as illustrated in figure 2. On the Asian continent, seven institutions are included, making this the continent with the largest number of institutions that produced the research. In second place, with six institutions, is Europe and, finally, America, containing three intuitions, two from South America and one from North America. Among the countries, India stands out as the leader in the number of publications, with three educational institutions.

Figure 2. Map of searches by country.



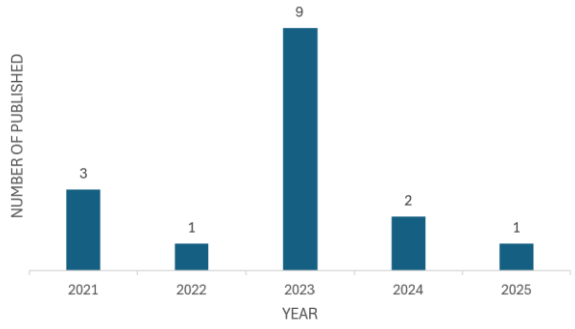
Source: own elaboration, 2025

It is also observed that a large part of the studies focuses on technologically advanced regions, such as Asia, Europe and North America, where investments in autonomous vehicles and AI are already more consolidated.

3.1. Temporal Distribution of Publications

The temporal analysis of the selected publications shows a growing trend in academic interest in the theme of AI applied to last-mile logistics. A significant peak was observed in 2023, which concentrated most of the studies included in the review. This increase may reflect the maturation of research in the area, as well as the intensification of debates and recent technological advances. Although the number of publications was lower in years such as 2021, 2024 and 2025, the fact that there are studies published already in the current year (2025) reinforces the timeliness and continuity of discussions in literature (see figure 3). This distribution confirms that the theme remains relevant and evolving, justifying the relevance of its investigation.

Figure 3. Temporal distribution of the selected publications.



Source: own elaboration, 2025

3.2. Keyword Analysis

57 keywords were identified in the publications. Figure 4 highlights the most recurrent ones, including: Last mile delivery (10 times), Fuzzy sets (7 times), Logistics (6 times), Drone (5 times), Artificial intelligence (4 times), Decision-making (4 times), Machine learning (3 times) and Traveling salesman problem (3 times). They also appeared with two occurrences: Vehicle routing problem and Genetic algorithm. The other words occurred only once each.

Figure 4. Keyword frequency.

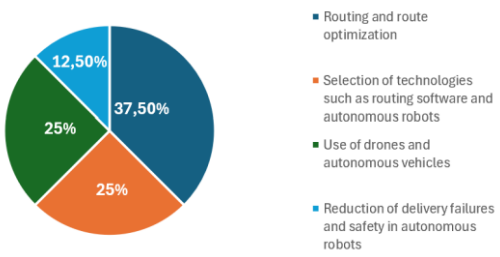
Source: own elaboration, 2025

3.3. Critical Analysis of Articles

In the analysis of the 16 selected publications, different lines of investigation are identified on how AI was applied: five studies present mathematical and metaheuristic models for routing and dispatching vehicles [7, 8, 9, 10, 11], two articles deal with the use of drones and autonomous vehicles for sustainable deliveries [12, 13], three studies apply multicriteria decision models with fuzzy logic for robot selection, software and locker locations [14, 15, 16], and others address autonomous robots, anti-theft security, and smart home devices to reduce delivery failures.

The analysis showed that the research focuses mostly on routing and route optimization, followed by the selection of technologies such as routing software and autonomous robots, the use of drones and autonomous vehicles and, to a lesser extent, solutions aimed at reducing delivery failures and safety in autonomous robots, as shown in the graph below, figure 5.

Figure 5. Distribution of research topics.



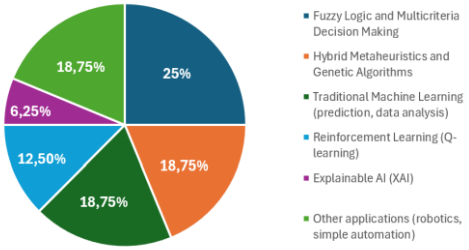
Source: own elaboration, 2025

These percentages show that the application of AI is more strongly directed to operational efficiency and intelligent resource management, indicating a global concern to reduce costs and delivery times.

The adherence classification of the studies revealed that 56.25% (9 articles) have high adherence, that is, they apply AI in a robust and central way in the development of new logistics solutions. Among these approaches, advanced techniques such as machine learning, intelligent metaheuristics, Q-learning, and fuzzy logic stand out, which are key elements for complex decision and routing problems in the last mile. Another 31.25% (5 articles) were classified as medium adherence, as they partially apply AI or use automated technologies without fully exploring intelligent methods. Finally, 12.5% (2 articles) have low adherence, treating AI only as a theoretical mention or applying traditional methods without intelligent integration.

Regarding the AI techniques used, it was observed that 25% of the articles employ fuzzy logic and multicriteria methods, mainly for the selection of software, robots, and definition of locations for smart lockers. Hybrid metaheuristics and genetic algorithms were applied in 18.75% of the studies, while traditional machine learning (for prediction and analysis of historical data) also accounted for 18.75%. More advanced methods, such as Q-learning, appeared in 12.5% of the surveys, and only 6.25% explored explainable AI (XAI) through techniques for assigning importance to variables such as SHAP (SHAP) [22]. Simple robotics and automation technologies, without extensive use of AI, appeared in 18.75% of the articles, aimed at anti-theft security and reduction of delivery failures. This implies that last-mile AI is applied primarily for operational efficiency, while explainability (XAI) is still underexplored, indicating a gap for future research. These data are shown in the graph in figure 6.

Figure 6. Distribution of AI techniques used.



Source: own elaboration, 2025

Another relevant fact is that 75% of the articles are based on computer simulations, while only 25% have validation in real cases or empirical data collected in logistics operations. This predominance of theoretical studies and modeling demonstrates that, although AI has great potential and is advanced in scientific and academic research, its practical implementation in large-scale global solutions is still limited. The reasons include the difficulty of integrating with existing logistics systems, high costs of adopting emerging technologies (such as drones and robots), and the lack of standardization in metrics to evaluate the gains obtained with AI [12, 13, 14].

4. Conclusion

In this study, emerging trends in the area were identified: a) hybrid solutions that combine AI with traditional optimization methods to deal with complex scenarios; b) intelligent automation of deliveries, including the use of drones, autonomous trucks and robots for urban operations; c) sustainability, as an additional factor [12], although little explored, aiming at reducing emissions and energy efficiency; and d) explainable systems (XAI), which are beginning to emerge to provide greater transparency in automated decisions. Techniques such as *fuzzy logic*, intelligent metaheuristics, and *machine learning* are already consolidated, while more advanced approaches (XAI, *deep reinforcement learning*) are still incipient. Despite the advances, important limitations were identified in the studies that form real barriers to implementation, such as: lack of integration between operational efficiency [7,8], social and environmental aspects [12,19], little attention to the scalability of solutions in complex urban environments [13,18,17], and the lack of research on the impact of AI on the consumer experience and social acceptance of autonomous technologies [19,21]. As one of the limitations of the research (gap between theory and practice), it is noteworthy that the absence of standardized benchmarks makes it difficult to compare studies.

It is concluded that, although AI represents an inevitable path for the evolution of last-mile logistics, its full and sustainable use still depends on significant advances. Future research should prioritize robust, interpretable, empirically validated, replicable, and aligned solutions with the principles of sustainability and social responsibility, ensuring that technology not only optimizes processes but also contributes to more resilient, ethical, and environmentally responsible supply chains.

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