Systematic Review

The Integration of Urban Freight in Public Transportation: A Systematic Literature Review

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Abstract: Urban logistics face growing complexity as cities seek sustainable development pathways; one solution is integrating freight transportation with public transit. The purpose of this study is to evaluate current practices, identify gaps, and highlight opportunities for advancement in this field. Through a comprehensive literature review guided by four research questions, this study evaluates methodologies, vehicle choices, the application of intermodal containers, and the shared use of public transportation infrastructure for freight delivery. A meticulous search methodology was employed to select references, which were then analyzed and classified into two main tables. Findings reveal a progression from initial pilot projects and cost analyses to sophisticated planning and optimization challenges, with a focus on metro networks and buses. This study uncovers a predilection for certain research types, the utilization of varied transportation modes, underexplored intermodal container use, and an emerging emphasis on transshipment operations. The integration of freight and public transportation within urban settings is identified as a dynamic and diversifying field, with significant potential for contributing to sustainable urban development. We outline nine areas for future research, including the incorporation of external costs and congestion effects into optimization models, and the exploration of unmanned vehicles, thereby laying the groundwork for more inclusive and efficient urban logistics solutions.

Keywords: urban logistics; literature review; public transportation; intermodal containers; last-mile delivery

1. Introduction

Presently, urban environments from small towns to megacities accommodate the largest share of the global populace. In 2022, the degree of urbanization worldwide was at 57% [1]. While it continues to increase, urban transportation-related problems, such as traffic congestion, pollution, and accidents, have become more pronounced; in particular, freight transportation within urban areas has a substantial impact both on the economic growth and the environment, as well as the functioning of cities. The reliance on freight transportation was further needed during the COVID pandemic when retail e-commerce sales grew by 17.1% in 2021 and are expected to grow by 56% by 2026 [2].

The COVID-19 pandemic accelerated the growth of the e-commerce industry. In Poland, online sales increased by almost 26% in 2020, with parcel deliveries increasing by 20–100%, depending on the courier service, according to a study by [3]. This surge reported by the authors, as well as the inefficiencies and high energy consumption associated with current last-mile delivery systems (according to that study, current models can consume over 70% of the energy of the entire distribution), necessitates improved models. Furthermore, the study by [4] provides a comprehensive analysis of the factors influencing e-commerce and last-mile delivery during the pandemic. The study highlights
consumers shifting to online shopping due to lockdowns and social distancing measures as key factors in this surge, leading to a 25% increase in business-to-consumer parcel deliveries in 2020. This increase placed significant pressure on urban logistics and last-mile delivery systems, worsening issues such as traffic congestion, delivery route inefficiencies, and higher delivery costs. The pandemic also caused changes in consumer behavior, with a trend in purchasing essential goods online and an increased demand for contactless delivery.

Within the literature, multiple solutions are being actively researched to solve last-mile delivery, including the use of drones and cargo bikes. A recent case study conducted by [5] explores this through pilot implementations in five Greek cities. According to the authors, the integration of drones and cargo bikes in last-mile delivery offers numerous benefits, including reduced congestion, lower emissions, and cost-effective solutions for urban freight transport. The strength of drones lies in their speed and efficiency, particularly in delivering lightweight packages over long distances, while cargo bikes navigate urban areas, bypassing traffic. However, according to [6], these solutions face significant challenges, such as the need for supplementary infrastructure, regulatory hurdles, and safety concerns. Even with these challenges, several key areas are at the center of research on drones and cargo bikes to solve last-mile delivery. This includes the infrastructural requirements to support these emerging transportation modes, such as recharging stations for drones or cargo bikes and dedicated bike lanes, as well as urban consolidation centers. Another area of research being focused on is advancements in technology, particularly improvements in drone battery life, payload capacity, and autonomous navigation systems. For cargo bikes, the focus is on enhancing electric assist mechanisms as well as the design of the cargo area to increase cargo capacity. Another common area of research between these two models is route optimization to ensure the efficient use of both modes in last-mile delivery. In a paper by [7], the authors aimed to optimize the delivery routes of urban couriers that minimize the costs associated with the delivery, considering vehicles and walking as final transportation methods between delivery hubs and customers. The authors used a dynamic learning process, which was enhanced by emerging information and communication technologies (ICTs). The model was tested in a case study in Rome, and it led to significant reductions in driving time when real-time information was used to update delivery routes. Incorporating these ICTs and the learning model can benefit cargo bikes and drones. For example, the integration of delivery bay booking systems can ensure that they have access to designated unloading zones, reducing idle time. Another interesting modeling framework is the one used by [8]. The authors proposed a continuous approximation method to optimize a hybrid transport network while aiming to minimize costs for passengers and the operator. It is therefore a question of effectively optimizing the transport network by integrating complementary services. This framework can be used in urban logistics to further enhance urban logistics networks. This helps to create local delivery routes for cargo bikes and drones established in dense urban centers to serve high demand, ensuring timely and efficient delivery of goods.

One potential solution to optimize last-mile delivery is the use of public transportation systems for freight delivery where the spare capacities of public vehicles like buses, trams, metros, and trains are utilized. Shared transport systems are quite common in first-mile distribution systems and are beginning to gain popularity for last-mile operations. The use of public transportation for freight transportation has the potential to reduce congestion and emissions, as well as improve the efficiency of urban transportation systems [9]. However, it is important to consider the shared aspects of the use of public transportation for freight transportation, such as shared vehicles between passengers and freight, shared infrastructure when the freight shares the stations of public transportation with passengers and uses them as storage, or if the delivery vehicles use the rail or road infrastructure of public transportation to navigate within cities [10].

Many pilot projects have been launched, such as the Monoprix Freight-On-Transit (FOT) project in Paris between 2007 and 2017, which involved using the RER line D
(commuter rail and rapid transit system serving Paris and its suburbs) to transport goods from their distribution center to the boundary of the city [11]. Another pilot project worth mentioning includes the transport of goods by tram in Dresden, where Volkswagen used a 5.5 km stretch of tram line to transport automotive parts and modules from its warehouse near Dresden’s rail terminal to its factory in the city center [12].

In Great Britain, a case study reported by Momentum Transport Consultancy was conducted in London using the Orion train. The trial was called the Orion high-speed logistics, and it aimed to provide regular logistics services throughout the day from/to London and international rail freight terminals and different logistics hubs. Customers would enter their delivery origin and destination using an online platform that suggested a delivery plan, after which a space would be booked on the Orion train. Goods would be picked and delivered to the passenger station or freight hub either by autonomous vehicles or cargo bikes to later be taken into Central London. This experiment started in 2021, and its adaptation was permanent as the interior of the train was stripped of seats and filled with metal floors. Many opportunities were identified through this case study; an interesting one is that the containers adapted to both trains and cargo bikes are easily transferable from one mode of transport to the other, resulting in the efficient integration of the two modes. The main challenge faced by Orion is finding sufficient traffic or volume of goods to make both directions economically viable [13].

The integration and combination of multiple solutions are highlighted in the literature as a strategy to minimize the disadvantages associated with last-mile delivery. For instance, combining sustainable alternatives such as parcel lockers, cargo bikes, and drones or integrating these solutions into traditional networks can create a symbiotic environment where the strengths of one solution offset the weaknesses of another. Although some studies have explored combined solutions like cargo bikes and delivery points, some other innovative concepts, including the use of IoT, AI, and Industry 4.0 in logistics, are less examined. For example, blockchain technology could be used to trace and track last-mile operations, providing valuable insights for improving efficiency. However, most publications focus on single solutions, indicating a gap in research on the integration of multiple concepts. Furthermore, emerging technologies like drones and autonomous vehicles face regulatory and technical challenges, limiting their widespread adoption. Research in these areas is still in its infancy due to the dependency on technological advancements and legal frameworks. Collaborative approaches that involve a wider range of stakeholders and partnerships between industry, public administration, and academia are essential for developing comprehensive, sustainable last-mile solutions. Additionally, more attention should be given to the social dimension of last-mile logistics, including the role of consumers and the potential of crowdsourcing logistics to address social inequalities and enhance sustainability.

While the concept is promising, several technical and management challenges must be addressed to ensure its feasibility. Within the context of Brazil, the study by [14] aimed to classify the key factors by means of SWOT analysis. These key factors were classified into main four categories, namely strengths, challenges, benefits, and barriers. The challenges included the need for specialized loading and unloading equipment, ensuring the safety and security of both passengers and goods, and maintaining the punctuality and reliability of public transportation schedules while accommodating freight operations. On the management side, coordinating between freight operators and public transportation authorities is crucial. This involves developing clear guidelines and protocols for shared usage, managing potential conflicts of interest, and creating an efficient communication system for real-time updates on vehicle capacity and scheduling. Additionally, addressing regulatory issues and obtaining the necessary approvals for mixed-use transportation systems are essential steps.

In this paper, we aim to explore the potential of using public transportation systems for freight delivery, with a focus on the use of intermodal containers as consolidation containers that facilitate the efficient transshipment of goods across multiple modes of
As a secondary aim, this paper will analyze the different shared aspects of the use of public transportation for freight transportation. This aspect was analyzed by [10,15], and these studies provide valuable contributions. The authors conducted a systematic literature review, focusing on the integrated and organized transportation of passengers and goods within urban areas using public transportation. Their analysis resulted in five main fields for future research, but their studies were limited regarding their scope since they focused on logistics and management perspectives and did not consider other perspectives such as environmental or social perspectives. Another gap is that their studies did not investigate approaches from other research fields such as underground logistics systems and crowd shipping, the use of automated last-mile delivery vehicles such as unmanned aerial vehicles (UAVs) and unmanned ground vehicles (UGVs); however, readers should refer to those studies for a more detailed explanation of the findings.

Recognizing the rapid developments in this research area since the last literature review in 2022, and that the previous literature reviews excluded research fields that did not fully include the integration of freight delivery in public transportation, this paper aims to bridge the gap by providing a comprehensive analysis. It will review the literature on the integration of freight transportation with public transportation while including fields of research such as crowd-shipping and drone-assisted delivery. By highlighting the types of studies conducted, the delivery vehicles most frequently discussed, and the prevalence of intermodal containers and multimodality approaches in recent research, we aim to provide a thorough systematic literature review. To systematically address these areas, we formulated the following research questions:

RQ1: What are the common study types in the literature for last-mile freight on public transportation?

The research methodology employed in various studies holds significant importance, as they can describe the state of the art for the use of public transportation for freight transport in city limits. These methods can range from case studies to modeling studies as well as hybrid ones, i.e., modeling and case studies. The second research question is as follows:

RQ2: What are the delivery vehicles utilized in the first entry to the city and last-mile delivery in the literature?

Understanding the choice of delivery vehicles utilized in the literature will allow researchers and practitioners to draw valuable insights, such as the applicability of the different last-mile delivery concepts in each of the cities, and it can highlight any challenge or benefit that can be gained by using a specific set of transportation modes. The third research question is as follows:

RQ3: What are the potential benefits and challenges of using intermodal containers?

Exploring this research question can yield valuable insight into the cost-effectiveness of adopting this packing methodology into urban freight transportation, how it can enhance the transportation efficiency between what transportation mode, and if it can lead to faster and more streamlined cargo movements.

RQ4: What are the aspects of integration of freight transportation in public transportation?

The final research question is aimed at providing insights into which shared aspects are most considered in the literature, and how they affect passenger transport in terms of cost and infrastructure requirements.

The remainder of the paper is structured as follows: Section 2 will provide the methodological approach used for conducting the systematic literature review, as well as the different criteria used in the classification table. In Section 3, a descriptive overview of the references chosen for the literature review is offered, as well as the results of content-based analysis of the literature. We also answer the research questions proposed in the Introduction. In Section 4, a well-rounded conclusion for the review is formulated, including the key findings and perspectives drawn from the entire research endeavor.
2. Methodology

To conduct the systematic literature review, the methodology recommended by Denyer and Tranfield [16] was followed. This methodology involves the following five steps:

Formulate the research questions: The research questions were clearly defined and extracted from the topic of interest of this paper. The research questions are detailed in the previous section; the keywords chosen to conduct this study are cited in Table 1.

<table>
<thead>
<tr>
<th>Urban Freight/Logistics</th>
<th>Public Transportation</th>
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<td>“Urban freight”</td>
<td>“Public transportation”</td>
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<tr>
<td>“Urban logistics”</td>
<td>“Transit systems”</td>
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<td>“City logistics”</td>
<td>“Public transportation network”</td>
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<tr>
<td>“Freight”</td>
<td>“Passenger parcel integration”</td>
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<td>“Cargo”</td>
<td>Metro</td>
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<tr>
<td>“Last mile delivery”</td>
<td>Tramway</td>
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<tr>
<td>“Last-mile delivery”</td>
<td>Bus</td>
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Identify studies: The studies were identified using a comprehensive search strategy. In this case, the Scopus database was used to search for papers related to the topic of interest, and the selection guidelines are presented in Table 2. The original search by keywords yielded 965 papers.

<table>
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<th>Item</th>
<th>Description</th>
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<tbody>
<tr>
<td>Database</td>
<td>Scopus</td>
</tr>
<tr>
<td>Language</td>
<td>English</td>
</tr>
<tr>
<td>Publication time range</td>
<td>2015–2023</td>
</tr>
<tr>
<td>Keywords</td>
<td>Table 1</td>
</tr>
<tr>
<td>Document</td>
<td>Indexed journals and conference papers</td>
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</table>

Select and assess these studies: The studies were selected based on the specified inclusion and exclusion criteria. In this case, the inclusion criteria for this study were that the selected paper needed to focus on the use of public transportation to move freight in cities. The exclusion criteria were papers not in English or studies published before 2015 or after May 2023. Following these criteria, the number of papers was reduced to 518. After removing all the research areas that were unrelated to the scope of the study, such as the subject areas of environmental science, materials science, earth and planetary sciences, economics, physics and astronomy, medicine, multidisciplinary studies, chemistry, chemical engineering, biochemistry, genetics and molecular biology, neuroscience, arts and humanities, agricultural and biological sciences, as well as pharmacology, 248 papers were left. After the screening of the 248 papers, 54 papers were selected as the corpus to be reviewed. Figure 1 illustrates the framework of the systematic literature review methodology, considering the abovementioned criteria.
Figure 1. Review process (data source: authors' elaboration).

Analyze and synthesize: In this step, the selected papers were systematically analyzed and organized using a classification table that captured relevant information such as the authors, type of study, and planning level. In quantitative studies, additional insights were extracted, such as the nature of the mathematical model and solution methods. Another classification criterion was the first mode of transportation and then the last mode of transportation used for the delivery of the goods to the clients. These criteria were used to gauge the existence of multimodality and the use of intermodal containers in the chosen corpus. For papers that were qualitative in nature, a different table was used to classify them. While this table shares similar features with the table for quantitative papers, the main difference is that there is no classification based on the mathematical model or solution method; only the objective of the paper and type of study, the modes of transportation utilized, and the complexity of the network are presented.

Report and use the results: The results obtained in the form of a classification table were then analyzed, and conclusions were drawn based on it.

3. Systematic Literature Review and Discussion

This literature review aims to assess the state of the art regarding the use of either public transportation infrastructure or vehicles in freight transportation in urban cities. From the corpus chosen, it is clear that there is a variety of research papers that have pursued different questions and used different methodologies. Table 3 displays the composition of the examined corpus. The references can be categorized into qualitative and quantitative publications.
Table 3. Number of publications per paper type.

<table>
<thead>
<tr>
<th>Type of Paper</th>
<th>Number of Published Papers</th>
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<tbody>
<tr>
<td>Conference Paper</td>
<td>13</td>
</tr>
<tr>
<td>Journal Article</td>
<td>41</td>
</tr>
<tr>
<td>Total</td>
<td>54</td>
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3.1. Descriptive Analysis

In this section, the results of a descriptive analysis of the chosen corpus are provided. Rather than citing various conferences where the papers were presented, a generalized term was employed to facilitate and quantify the number of conferences in the corpus. This approach also enabled us to assess their prevalence in relation to the quantity of journal papers.

Figure 2 presents the number of published papers and shows fluctuations in publications on the use of public transportation for freight within cities from 2015 to 2023. From 2015 to 2016, the number of publications remained relatively stable. In 2017, there was a noticeable decline in research output, possibly due to the emergence of drones and robots as a solution to last-mile delivery. Starting in 2018, there was a recognition of the potential benefits of using public transportation for urban freight. This trend continued till 2020 when a significant surge occurred, likely driven by the COVID-19 pandemic.

![Figure 2: Number of published papers by year (source: Excel; data source: authors’ elaboration).](image)

In 2021, the number of publications dropped again, but less than in 2017, which reflects a possible stabilization. However, the years 2022 and 2023 show a renewed growth in publications. This upward trend underscores an increasing interest and investment in integrating freight delivery into public transportation. Accompanying this increase is a maturation of the field with a substantial formal and in-depth analysis of the various challenges encountered. Notably, 41 of the 54 papers analyzed are journal articles, indicating...
a significant contribution of peer-reviewed research to this area. Consequently, this trend indicates a promising direction for future research and practice to optimize last-mile delivery.

The graph in Figure 3, generated using the Bibliometrix tool on R studio, highlights a clear trend in research publications from various countries. China is outpacing other countries, with a remarkable increase in research output, while France, Germany, and the United Kingdom maintain steady growth, indicating a sustained investment in research, albeit at a slower pace compared to China. Portugal shows a slight increase, demonstrating an emerging interest in this field.

![Figure 3. Country publications over time (Bibliometrix library; data source: authors’ elaboration).](image)

A bibliometric analysis was conducted on the chosen corpus using the software VOSviewer to gain a better understanding of how keywords and topics evolved. A minimum keyword co-occurrence of $n = 2$ was selected for the software. This setting resulted in the retention of 132 keywords and the creation of Figure 4.

The VOSviewer-generated visualization of keyword co-occurrence highlights the evolution of research topics in transportation from 2018 to 2022. Central themes in the corpus include “urban transportation” and “freight transportation”, indicating their critical importance in recent studies. There is a noticeable trend toward emerging topics, such as “multi-objective optimization,” “network design,” and “underground logistics systems,” reflecting the latest research interests. The network also reveals a significant interdisciplinary approach with connections to sustainability (“sustainable development,” “energy utilization,” etc.) and technological advancements (“intelligent systems,” “decision support systems,” etc.). Methodologically, the frequent appearance of terms like “integer programming”, “heuristics,” and “stochastic systems” underscores the reliance on mathematical and algorithmic techniques to address transportation challenges. Overall, the visualization illustrates a dynamic and evolving field, with a clear shift toward integrating sustainability, efficiency, and advanced technologies into transportation research.
3.2. Insights from Quantitative Papers

In this section, we conduct a review of current quantitative studies relevant to the scope of our research. The review is based on the characteristics highlighted in the Methodology section, along with key points that can help address the research questions proposed in the first section of this study. The findings of this review are organized and classified, and the summary is presented in Table 4.

3.2.1. Study Type

The analysis of Table 3 reveals that there is a clear dominance of modeling techniques in 17 out of 34 studies. Additionally, 15 out of 34 studies involve modeling and case studies. This indicates a comprehensive and balanced approach to this topic. For example, in
a recent study [17], the authors proposed an equilibrium chance-constrained programming approach for the metro-based underground logistics system network planning problem (MULNP) while considering uncertain demand and costs. The study aims to design the layout formation and facility components in a two-tier metro-based underground logistics system (M-ULS) network. To solve it, the authors introduced an improved multiobjective cooperative co-evolutionary algorithm resulting in high-quality solutions. The proposed method applied to a case study of the Beijing metro provided computational advantages over other methods used in the literature; however, it is important to acknowledge the limitations of the study in terms of applicability to other cities, which requires further investigation. The authors investigated conjoint objectives, namely minimal operating and penalty costs. Some other important objectives need to be studied. Maximizing the throughput of the system or minimizing the travel time are two examples. The study of [18] proposed a novel modular multipurpose pickup and delivery problem to investigate the potential of modular vehicle concepts and consolidation in freight and passenger urban transportation. The authors proposed an adaptive large neighborhood search (ALNS) algorithm to solve the proposed problem; however, the real-world implementation of the proposed modular transport systems is needed to validate these findings. Another limitation that needs to be further researched is the impact of the proposed system on traffic congestion and environmental sustainability.

3.2.2. Planning Level

The quantitative studies are diverse, but when it comes to planning level from the classification table, it can be calculated that only 5.8% of the papers worked on a tactical level, and 23.5% worked on a strategic level, while the operational level is the main focus of the quantitative studies, with 70% of the analyzed corpus of this literature review. At the operational level, routing problems are very relevant. The authors of [19] worked on the bus routing problem and bus trip scheduling with the objective of minimizing cost for the transit user and operator; they proposed a meta-heuristic model. At the strategic level, the authors of [20] proposed a reliable scheduling method to optimize the electric bus schedules and worked on minimizing the operational costs while avoiding transportation interruptions due to energy shortages. While their paper focused on the energy aspect, further study is needed to assess the effects of this method on congestion as well as evaluate the effect on pricing transportation where conflicts arise between on-demand passenger and cargo transportation. In [21], the authors expanded the model by including stochastic demands and renamed the problem to the pickup and delivery problem with time windows, scheduled lines, and stochastic demands (PDPTW-SLD). It was solved using the sample average approximation (SAA) method, which includes an adaptive large neighborhood search heuristic; authors considered transfers only at the end of line stations. This assumption does not fully reflect the complexities of a relaxation of this constraint. Although this increases the complexity of the problem, it will better reflect the real transportation system.

3.2.3. Problem Statements

Based on the classification table, the problems in the quantitative papers can be categorized into four categories:

- Vehicle Routing and Scheduling Problems: These problems aim to determine the optimal routes and schedules for a single vehicle or a fleet to visit a set of locations, often with constraints like time windows and vehicle capacity. This category includes problems such as the capacitated vehicle routing problem proposed in the paper by [22] where they used a K-means clustering algorithm to determine optimal locations for urban consolidation centers (UCCs). However, the primary analysis appears to be through simulation using the “simulation of urban mobility” (SUMO). While this approach helps to shed some light on the optimal location for UCCs, simulations
often rely on a controlled environment, resulting in the lack of interactions with ac-
tual systems and thus creating a gap between the theoretical findings and practical
findings.

- Transportation Network Planning Problems: This class includes problems related to
designing or optimizing the layout of transportation networks or their operations. In
the paper of [23], the authors proposed a new combinatorial optimization problem
with the objective of maximizing the demand routed. Nevertheless, the effectiveness
of the proposed model is limited to the data regarding the chosen public transport
system and the freight demand.

- Scheduling Problems: This class includes problems that focus on the optimal alloca-
tion of resources over time, often with the goal of maximizing efficiency or minimizing
costs, with resources being vehicles or crews. In the work by [24], the authors
focused on integrating passenger and freight transportation through a bus-pooling
service, using a two-stage model. Some hypotheses, such as the behavior of package
recipients walking to collect their packages, cannot be easily adapted or tested for
other areas, but they should be explored in more detail in future research.

- Mixed-Modal and Mode-Mixing Problems: This class includes problems that involve
scenarios where transportation modes such as light rail, road, and air are combined.
These problems often involve a complex coordination scheduling challenge. In the
paper by [25], the authors aimed to integrate the underground logistics systems with
the existing metro system. An evaluation model was then introduced by the authors,
and a “mixed-integer programming” model was used as a key tool to solve the opti-
mization problem. The system was applied in a case study to the Nanjing metro sys-
tem. However, the research could be further extended by considering the overall sys-
tem efficiency between the metro-based underground logistics system (M-ULS) and
the existing metro system. Another consideration is the applicability of the system to
loop network layouts instead of the cross-shaped layouts that the proposed model
was applied to.

The review of the quantitative papers presents a diverse landscape. While there is a
clear emphasis on “vehicle routing and scheduling problems” (Figure 5), these problems
involve optimizing the routes and schedules for either the first or last mode of transpor-
tation used to deliver the freight, which is crucial for efficient transportation operations.
Researchers are exploring various aspects within this category, such as capacitated rout-
ing, time windows, and stochastic demands. Another area of research that is attracting
attention from researchers is transportation planning problems. This category reflects the
importance of designing and planning transportation networks effectively. The network
resilience problem in the paper of [26] is also a welcome addition to the problems studied;
the authors developed a trackable assessment framework for the resilience of urban trans-
portation systems. The focus of their study was on the road system and metro systems, by
examining the impact of different types of failures on the functionality and structure of
transportation networks, but the paper does not provide any insights into the generaliza-
bility of the proposed framework and whether it can be applied to other urban transpor-
tation systems beyond the specific case studies considered.
3.2.4. Objectives

The objectives of the quantitative papers are diverse, but the different objectives can be grouped into the following three categories:

- **Cost Minimization** (22 of 34 papers): This category includes papers whose objective was mainly minimizing costs, which is a prominent and widely studied objective in this field. There are different forms of objective functions. In the case of [27], the authors’ objective was to consider both fixed and operating costs, but they did not address the potential trade-offs or conflicts between the costs considered and the sustainability aspect.

- **Transport and Logistics Optimization** (6 of 34 papers): This category is a significant area of interest, especially since it encompasses various strategies to improve the efficiency of transportation systems and logistics networks. Unlike cost minimization, this category of objectives aims to maximize the net profit [28]. To achieve this goal, the authors conducted a game theoretical analysis of the metro-integrated logistics system (MILS). This analysis provided insights into the optimal strategies and decision-making processes that can maximize net profit in the MILS system. Furthermore, the paper mainly focused on the strategic interactions and decision-making processes between the metro company and the logistics company, but it did not explore other stakeholders or external factors that may influence the system. The analysis assumed certain market conditions and did not consider the potential impact of regulatory interventions. In the paper by [29], the authors worked on the development of a collaborative transport model combining passengers and goods in a subway system. The objective was to alleviate traffic congestion and maximize the use of surplus capacity in subways. In this research, the authors concluded that combining passengers and goods in the subway can effectively alleviate traffic congestion and improve the efficiency of logistic distribution in urban areas.
• Service Quality and Efficiency: While having fewer papers (6 of 34 papers), this category presents a noteworthy research area since it underscores the importance of not only cost but also customer service. A significant example is [30], which proposed an innovative energy-consumption logistics drone using buses to increase the delivery range due to the limited battery charging capacity of UAVs (unmanned aerial vehicles). The approach incorporated an energy-neutral flight principle and a delivery scheduling algorithm to minimize the total time delivering all parcels and focused on improving the efficiency of the delivery process. The second part of the objective was to maximize the total number of parcels delivered.

3.2.5. Mathematical Modeling

Regarding mathematical modeling, the presence of deterministic optimization remains a crucial tool for solving transportation and logistics problems, which concerned 20 of the 34 papers. This popularity is because deterministic modeling allows authors to consider the problem and, under certain conditions and assumptions, their research can provide a baseline understanding of the problem and potential solutions. Another mathematical model that can be found in some of the papers is stochastic modeling, in which uncertainty is incorporated into the analysis by considering stochastic parameters such as demand, delivery time windows, destination addresses of the requests, and traffic congestion. Unlike deterministic models, this helps capture real-world variability and randomness associated with the problem, but it increases the complexity of the problem. In this framework, only 8 of the 34 papers used this modeling technique. An emerging hybrid modeling method is the deterministic and stochastic studies (“D, S”). This modeling technique was used in 6 of the 34 papers. In [31], the authors provided insights into the strategic planning of bus networks for integrated passenger and freight flows. A bus network planning problem (BNPP) was formulated as the generalization of the classic bin-packing problem (BPP); the paper described an exact method based on integer linear programming (ILP), which is a deterministic approach and considers a few uncertainties in freight demand and delivery time windows. These constraints are handled by a scenario optimization-based heuristic algorithm.

3.2.6. Solution Methods

Solution methods were categorized in the classification into two groups through statistical analysis: “optimization” and “simulation”. It is clear that heuristic (metaheuristic/heuristic) methods are the dominant ones for solving mathematical models (Figure 6). Among the most found metaheuristics, we have the ALNS (adaptive large neighborhood search). There were also other metaheuristics used, such as the multiobjective cooperative co-evolutionary algorithm (MoCC). In the paper by [17], this algorithm was used to solve the proposed metro-based underground logistics system network planning problem; the authors proposed an equilibrium chance-constrained programming approach solved with a metaheuristic method. There are limitations to this work, especially when it comes to applying it to other cities. There was also no discussion of the planning approach in terms of infrastructure requirements, stakeholder engagement, or regulatory considerations.
3.2.7. First and Final Mode of Transportation

An examination of the final mode of transportation compared to the first mode highlights that most research papers do not consider a consistent mode of transportation (Figures 7 and 8), but there are instances where the final mode is the same as the initial mode. This suggests a certain level of fluidity and adaptability within the transportation system, where cargo may change modes during its journey. The classification table also reflects some interesting trends in the way authors design their models, with buses and metros being prominent choices, while trains are less frequent but often associated with transshipment scenarios. Trains are one of the few transportation systems with well-established stops and a dedicated travel network. In addition, the fact that they can access dry ports makes them very useful for the transport of large quantities of cargo. The inclusion of robots as a mode of transportation in some instances also hints that researchers are becoming more aware of emerging technologies that play a role in urban freight transportation.

Contrast analysis of transportation modes across different data sources reveals significant variations. China shows a diverse use of transportation modes, including buses, LMO (last-mile operators), metro, and even drones, while Germany and France show reliance on metros and buses, respectively. Additionally, the use of scheduled lines (SLs) can be seen as the third most used transportation mode in quantitative studies. The term “scheduled lines” is an umbrella term used to describe public transportation. A correlation between the papers that used generated data and the use of scheduled lines can be distinguished, with a few papers specifically considering buses. This emphasis on lightweight and already established public transportation modes reflects a focus on flexible and potentially lower-cost transportation in modeling scenarios.
3.2.8. Trans-Shipment and Intermodal Container

From the classification table, it is clear that there are very few papers that include intermodal containers in their work. We found only 5 of the 34 papers that used this concept (Figure 9). In the paper [29], the collaborative transport model that combined passengers and goods in the metro system could meet 98.95% of the freight demand, alleviating 98.86% of the traffic congestion as well as shortening the delivery time by 9 min.

Another trend observed from the classification table is that considerable attention is being given to the trans-shipment process, making this an emerging study field. This recognition suggests that researchers appear increasingly interested in optimizing trans-shipment operations—not only routing and scheduling operations—to reduce costs and improve logistics performance.

3.2.9. Shared Aspects

The transportation of passengers and freight is a vital component of freight delivery systems. To categorize the references, three primary aspects have been identified. The first aspect, the “vehicle” category, encompasses not only the physical vehicle but also any wagon used in conjunction with the vehicle. The second category, “infrastructure,” applies when freight shares the physical route and stations with passengers. Finally, the “vehicle–infrastructure” category merges both the vehicle and infrastructure aspects. The statistics in Figure 10 highlight that the predominant research focus is on vehicle utilization and suggest that further exploration of infrastructure and combined approaches is needed.
Figure 9. Trans-shipment and intermodal containers (data source: authors’ elaboration).

Figure 10. Frequency of the shared form of freight on public transportation (data source: authors’ elaboration).
Table 4. Classification table for quantitative paper. Study type: M: modeling, M/CS: modeling–case study; planning level O: operational level, S: strategic level, T: tactical level; mathematical model: D: deterministic, S: stochastic (data source: authors’ elaboration).

<table>
<thead>
<tr>
<th>Reference</th>
<th>Study Type</th>
<th>Planning Level</th>
<th>Problem Description</th>
<th>Mathematical Model</th>
<th>First Transport Mode</th>
<th>Shared Transportation</th>
<th>Objective</th>
<th>Optimization</th>
<th>Simulation</th>
<th>Data Source</th>
<th>Transport Network</th>
<th>Final Intermodal Transport</th>
<th>Final Container Mode</th>
</tr>
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<tbody>
<tr>
<td>[31]</td>
<td>M</td>
<td>S</td>
<td>Bus network planning problem</td>
<td>D, S</td>
<td>Bus</td>
<td>Vehicle</td>
<td>Minimizing the number of buses</td>
<td>Exact, heuristic</td>
<td>No</td>
<td>Generated</td>
<td>Direct</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>[32]</td>
<td>M</td>
<td>O</td>
<td>Train schedules and container allocation</td>
<td>D, S</td>
<td>Tram</td>
<td>Infrastructure</td>
<td>Selecting the optimal train schedule and allocation of containers</td>
<td>Exact, heuristic</td>
<td>No</td>
<td>Generated</td>
<td>Direct</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>[19]</td>
<td>M/CS</td>
<td>O</td>
<td>Bus routing and bus trip scheduling</td>
<td>D, S</td>
<td>Bus</td>
<td>Infrastructure</td>
<td>Minimizing costs</td>
<td>Heuristic</td>
<td>Yes</td>
<td>China</td>
<td>Network</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>[23]</td>
<td>M</td>
<td>S</td>
<td>Strategic freight-on transit problem</td>
<td>D</td>
<td>SL</td>
<td>Vehicle–infrastructure</td>
<td>Maximizing the demand covered by the public transport system</td>
<td>Heuristic</td>
<td>No</td>
<td>Generated</td>
<td>Direct</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>[29]</td>
<td>M/CS</td>
<td>O</td>
<td>Collaborative transport mode mixing passengers and goods</td>
<td>D</td>
<td>Metro</td>
<td>Vehicle–infrastructure</td>
<td>Alleviating congestion and maximizing the use of surplus capacity in a subway</td>
<td>ML</td>
<td>Yes</td>
<td>China</td>
<td>Network</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>[33]</td>
<td>M/CS</td>
<td>S</td>
<td>Capacitated location allocation problem and multi-depot vehicle routing problem</td>
<td>D</td>
<td>Metro</td>
<td>Vehicle</td>
<td>Minimizing costs</td>
<td>Heuristic</td>
<td>Yes</td>
<td>China</td>
<td>Network</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>[34]</td>
<td>M</td>
<td>T</td>
<td>Train carriage arrangement and flow control problem</td>
<td>D</td>
<td>Metro</td>
<td>Vehicle</td>
<td>Minimizing delay penalty and costs</td>
<td>Exact</td>
<td>No</td>
<td>China</td>
<td>Direct</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>[35]</td>
<td>M/CS</td>
<td>S</td>
<td>Network design problem</td>
<td>S</td>
<td>Metro</td>
<td>Infrastructure</td>
<td>Minimizing total costs</td>
<td>Exact</td>
<td>No</td>
<td>Germany</td>
<td>Network</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>[28]</td>
<td>M</td>
<td>S</td>
<td>Pricing and modal split problem</td>
<td>D</td>
<td>Metro</td>
<td>Vehicle–infrastructure</td>
<td>Maximizing the net profit</td>
<td>Analytical</td>
<td>No</td>
<td>Generated</td>
<td>Direct</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>[36]</td>
<td>M</td>
<td>O</td>
<td>Last-mile delivery problem with satellite facilities</td>
<td>D</td>
<td>SL</td>
<td>Vehicle</td>
<td>Minimizing the number of city freighters, routing costs, and number of trips</td>
<td>Exact, Heuristic</td>
<td>No</td>
<td>Generated</td>
<td>Network</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>[37] M/CS O</td>
<td>Simultaneous delivery and pickup wagon scheme on hybrid siding network</td>
<td>D, S</td>
<td>Train Infrastructure</td>
<td>Minimizing total cost</td>
<td>Heuristic</td>
<td>No</td>
<td>China</td>
<td>Network</td>
<td>No</td>
<td>No</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[38] M O</td>
<td>Route planning problem</td>
<td>D</td>
<td>Bus Infrastructure</td>
<td>Minimizing total costs</td>
<td>Heuristic</td>
<td>No</td>
<td>Generated Network</td>
<td>Yes</td>
<td>No</td>
<td>LMO</td>
<td></td>
<td></td>
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<tr>
<td>[22] M O</td>
<td>Capacitated vehicle routing problem</td>
<td>D</td>
<td>Bus Vehicle-infrastructure</td>
<td>Optimal location for urban consolidation centers</td>
<td>ML</td>
<td>Yes</td>
<td>Generated Network</td>
<td>No</td>
<td>No</td>
<td>LMO</td>
<td></td>
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<tr>
<td>[39] M O</td>
<td>Weighted vehicle routing problem</td>
<td>D</td>
<td>Bus Vehicle</td>
<td>Minimizing the total delivery cost</td>
<td>Heuristic</td>
<td>No</td>
<td>China</td>
<td>Network</td>
<td>No</td>
<td>No</td>
<td>Bus</td>
<td></td>
<td></td>
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<tr>
<td>[30] M O</td>
<td>Optimal delivery schedule problem</td>
<td>S</td>
<td>Bus Vehicle</td>
<td>Minimizing the total time of delivering all parcels and maximizing the total number of parcels that are delivered</td>
<td>Heuristic</td>
<td>Yes</td>
<td>China</td>
<td>Network</td>
<td>No</td>
<td>No</td>
<td>Drone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[40] M O</td>
<td>Pickup and delivery problem with time windows and scheduled lines</td>
<td>S</td>
<td>Train Vehicle</td>
<td>Minimizing the total cost of the delivery system</td>
<td>Exact, Heuristic</td>
<td>No</td>
<td>Generated Network</td>
<td>No</td>
<td>No</td>
<td>Robot</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[41] M T</td>
<td>Route planning problem</td>
<td>D</td>
<td>Bus Infrastructure</td>
<td>Minimizing the total cost of the delivery system</td>
<td>Exact</td>
<td>No</td>
<td>Generated Network</td>
<td>No</td>
<td>No</td>
<td>Bus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[42] M/CS O</td>
<td>Two-echelon vehicle routing problem with fixed scheduled lines</td>
<td>D</td>
<td>Bus Vehicle-infrastructure</td>
<td>Minimizing total cost</td>
<td>Heuristic</td>
<td>No</td>
<td>China</td>
<td>Network</td>
<td>Yes</td>
<td>Yes</td>
<td>LMO</td>
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<tr>
<td>[43] M O</td>
<td>Pickup and delivery problem with time windows and scheduled lines</td>
<td>D</td>
<td>SL Vehicle</td>
<td>Minimizing costs</td>
<td>Exact, Heuristic</td>
<td>No</td>
<td>Generated Network</td>
<td>Yes</td>
<td>No</td>
<td>LMO</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>[44] M O</td>
<td>Train schedule problem</td>
<td>D</td>
<td>Train Infrastructure</td>
<td>Minimizing tardiness and inventory levels</td>
<td>Exact, Heuristic</td>
<td>No</td>
<td>Generated Direct</td>
<td>Yes</td>
<td>No</td>
<td>Train</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[45] M O</td>
<td>Assignment and synchronization problem</td>
<td>D</td>
<td>Bus Vehicle-infrastructure</td>
<td>Minimizing the total customer’s service time</td>
<td>Exact</td>
<td>No</td>
<td>Generated Network</td>
<td>Yes</td>
<td>Yes</td>
<td>LMO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[25] M/CS T</td>
<td>Capacitated metro-based underground logistics system location-allocation problem</td>
<td>D</td>
<td>Metro Infrastructure</td>
<td>Minimizing costs</td>
<td>Exact, Heuristic</td>
<td>Yes</td>
<td>China</td>
<td>Network</td>
<td>No</td>
<td>LMO</td>
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<td></td>
<td></td>
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<tr>
<td>[46] M/CS S</td>
<td>Mixed urban transportation problem</td>
<td>D</td>
<td>Bus Vehicle-infrastructure</td>
<td>Minimizing the number of LMOs and minimizing costs</td>
<td>Exact, Heuristic</td>
<td>No</td>
<td>France</td>
<td>Network</td>
<td>Yes</td>
<td>Yes</td>
<td>LMO</td>
<td></td>
<td></td>
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<tr>
<td>[21] M/CS O</td>
<td>Pickup and delivery problem with time windows and scheduled Lines, stochastic demands</td>
<td>S</td>
<td>SL Vehicle</td>
<td>Minimizing costs</td>
<td>Heuristic</td>
<td>No</td>
<td>Netherlands</td>
<td>Network</td>
<td>Yes</td>
<td>No</td>
<td>LMO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[47] M O</td>
<td>Pickup and delivery problem with time windows and scheduled lines</td>
<td>D</td>
<td>SL Vehicle</td>
<td>Minimizing costs</td>
<td>Heuristic</td>
<td>Yes</td>
<td>Generated Network</td>
<td>No</td>
<td>No</td>
<td>LMO</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>[48] M/CS O</td>
<td>TPP problem with time window</td>
<td>D</td>
<td>Bus, Tram Vehicle</td>
<td>Minimizing the total distance traveled by the delivery agents</td>
<td>x</td>
<td>Yes</td>
<td>Germany</td>
<td>Network</td>
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<td>No</td>
<td>LMO</td>
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<td>Problem</td>
<td>Domain</td>
<td>Model</td>
<td>Infrastructure</td>
<td>Objective</td>
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<td>Network</td>
<td>Algorithm</td>
<td>Network</td>
<td>Country</td>
<td>Route</td>
<td>Algorithm</td>
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</tr>
<tr>
<td>[26] M/CS S</td>
<td>Network resilience problem</td>
<td>D Internet, LMO</td>
<td>Vehicle</td>
<td>Network resilience assessment framework</td>
<td>x</td>
<td>Yes</td>
<td>China</td>
<td>Network</td>
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<td>No</td>
<td>LMO</td>
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</tr>
<tr>
<td>[49] M O</td>
<td>Pickup and delivery problem with Time Windows and Scheduled Lines</td>
<td>D SL</td>
<td>Vehicle</td>
<td>Minimizing costs</td>
<td>Exact</td>
<td>No</td>
<td>Generated Network</td>
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<tr>
<td>[50] M O</td>
<td>Dynamic one-to-one pickup and delivery problem</td>
<td>S Robot</td>
<td>Infrastructure</td>
<td>Minimizing the movement of empty vehicles and the waiting time of passengers and goods</td>
<td>Exact</td>
<td>Yes</td>
<td>United Kingdom</td>
<td>Network</td>
<td>Yes</td>
<td>Yes</td>
<td>Robot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[27] M O</td>
<td>Service network design and vehicle routing with time windows problem</td>
<td>D SL</td>
<td>Infrastructure</td>
<td>Minimizing the sum of fixed and variable costs</td>
<td>Exact, Heuristic</td>
<td>No</td>
<td>Generated Network</td>
<td>Yes</td>
<td>No</td>
<td>LMO</td>
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</tbody>
</table>
3.3. Insight from Qualitative Papers

In this section, we delve into the qualitative papers within the corpus, which comprises a total of 20 papers. The classification table for these papers is detailed in Table 5.

3.3.1. Study Type

In qualitative studies, there is a large number of papers (8 of 20 papers) that focus on case studies; these case studies are mainly considered by examining real-life projects, as can be seen in the classification table. Note that all the case study papers are related to a country in the data source column. The second most found study type is conceptual ones (9 of 20 papers) dealing with different objectives. Review papers are underrepresented in this corpus, with only 3 out of 20 papers being review papers. For instance, the authors of [51] performed a traditional review based on the data collected from the Web of Science database, aiming to introduce different innovative solutions in last-mile delivery. On the other hand, the authors of [52] sought to introduce an autonomous shuttle-as-a-service system, utilizing the data collected from the Scopus database. In another study [53], the authors explored the major trends in the theory and practice of shared transport systems and suggested a conceptual framework within the physical internet (PI) for integrating shared freight and passengers. While this is an interesting concept, the paper does not provide any empirical evidence or quantitative analysis to support the feasibility or effectiveness of the proposal. Although the concept papers and case studies are comparable, there appear to be gaps in the literature review papers on the use of public transport for freight transport.

3.3.2. Objectives

The objectives in qualitative studies focus on evaluating, designing, or proposing a new system, and these objectives can be categorized into one of the following three classes:

- Evaluating: This class includes 12 of the 20 objectives, such as evaluating the overall performance of the metro-based underground logistics system, assessing the suitability of the metro for urban freight transportation, exploring the potential of the ring rail and metro rail system, and identifying the conditions so that metro would become a mass shipping mode [54].
- Introducing or proposing: This class, including 3 of the 20 objectives, is highlighted in [55]. The authors aimed to present a preliminary design for a public transportation-based logistics transport system and its service procedure. An evaluation of the system’s potential benefits was conducted, but the proposed system requires further empirical testing to validate its feasibility and scalability beyond the considered mid-size Chinese city.
- Designing: This class includes objectives like the development of a framework for shared freight and passengers’ integration on a metro. In this framework, the authors of [56] designed a concept involving adding mechanical structures to the existing metro systems in order to separate freight from passenger transport, utilizing “RFID” technology for control. While this approach is innovative, a feasibility analysis and an investigation of the potential benefits of this integrated transport mode are needed to offer a broader perspective on its relative pros and cons when compared to systems like dedicated freight corridors.

These objectives collectively represent a comprehensive approach to the challenges of last-mile delivery and the integration of freight transportation in public transportation networks. These papers demonstrate a commitment to evaluating existing systems, introducing new sub-concepts, and designing efficient solutions for transportation in urban landscapes, taking into consideration diverse methodologies used to deal with specific classes of studies and categories of objectives.
3.3.3. First and Final Transport Mode

The transportation modes for freight delivery in qualitative data are dominated by the metro, followed by the bus (Figure 11), unlike quantitative papers that focused on the bus, followed by the metro. This is consistent with the practice as most of the projects are rail-based. Interestingly, there are similarities in the final mode transportation between the two research methodologies as in qualitative papers (Figure 12), the primary mode of final transportation is LMO (Last Mile Operators), with limited use of other transportation modes. However, there are a few deviations. In [52], the authors conducted a literature review on the use of autonomous shuttles and an empirical study with experts in the field of smart mobility. The paper provided insights into the state of the art on autonomous shuttles and their potential to improve mobility and minimize noise and pollution, but it did not provide any discussion on the technical challenges associated with implementing autonomous shuttles and the economic and social implications associated with them, which will require further research. The authors of [57] also worked on freight delivery using an automated public transportation system (APTS) by introducing an illustrative example of an APTS called dynamic autonomous road transit (DART). Their paper, however, did not provide a feasibility analysis of integrating different transportation modes and the impact it can have on employment in the transportation sector, for example.

![Figure 11. First mode of transportation. SLs: scheduled lines; LMOs: last-mile operators (data source: authors’ elaboration).](image1)

![Figure 12. Final mode of transportation. SLs: scheduled lines; LMOs: last-mile operators (data source: authors’ elaboration).](image2)

3.3.4. Shared Aspects

The integration of freight with public transportation is an important aspect that needs to be considered before attempting to realize any real-life project. From the classification table, it is clear that sharing the vehicle between freight and the passengers is the most
studied aspect and also the most difficult, while sharing the infrastructure is almost non-existent, with only one study working on the infrastructure in the qualitative papers analyzed in this review (Figure 13). The authors of [58] employed a comprehensive methodology that included traffic zoning, surveying multimodal infrastructure, and shaping spatial structures. By integrating rail for the first and last mile of freight delivery, the authors aimed to reduce congestion. However, the implementation of this strategy faces challenges, such as operational constraints and market acceptance. Another limitation of the study is data constraints, as it relies on existing data, and that may not capture the challenges currently faced in infrastructure and logistics. This coincides with the results of quantitative studies where only a few papers researched the utilization of infrastructure as a shared element in integrating freight with public transportation.

Figure 13. Distribution of shared aspects (data source: authors’ elaboration).

3.3.5. Intermodal Containers

The utilization of intermodal containers has the potential to enhance the speed of goods transfer between different modes of transportation, resulting in cost savings. However, in the qualitative studies reviewed, most did not incorporate this approach (13 out of 20 papers), while a minority incorporated it. For example, in a study conducted by [59], the researchers aimed to mitigate the adverse effects of urban logistics, including issues like congestion, pollution, and noise. It is worth noting that the paper did not explicitly mention the limitations of this proposed conceptual model, nor did it delve into the potential challenges and complexities that may affect stakeholder cooperation, coordination, and acceptance of the proposed solution.
<table>
<thead>
<tr>
<th>Reference</th>
<th>Study Type</th>
<th>First Transport Mode</th>
<th>Final Transport Mode</th>
<th>Data Source</th>
<th>Share Aspect</th>
<th>Transport Network</th>
<th>Inter Modal Container</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>[51]</td>
<td>Review</td>
<td>x</td>
<td>x</td>
<td>web of science</td>
<td>x</td>
<td>x</td>
<td>No</td>
<td>Reviewing innovative solutions in last-mile delivery</td>
</tr>
<tr>
<td>[54]</td>
<td>Case study</td>
<td>Metro</td>
<td>LMO</td>
<td>China</td>
<td>Vehicle</td>
<td>Network</td>
<td>No</td>
<td>Evaluating the overall performance of metro-based underground logistics system</td>
</tr>
<tr>
<td>[53]</td>
<td>Review</td>
<td>SL</td>
<td>LMO</td>
<td>x</td>
<td>Vehicle–infrastructure</td>
<td>x</td>
<td>Yes</td>
<td>Reviewing the major trends in shared transport systems</td>
</tr>
<tr>
<td>[52]</td>
<td>Review</td>
<td>Robot</td>
<td>Robot</td>
<td>Scopus</td>
<td>Vehicle</td>
<td>x</td>
<td>No</td>
<td>Introduction of an autonomous shuttle-as-a-service</td>
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<tr>
<td>[60]</td>
<td>Concept</td>
<td>Metro</td>
<td>LMO</td>
<td>x</td>
<td>Vehicle–infrastructure</td>
<td>Direct</td>
<td>Yes</td>
<td>Proposing a preliminary prototyping approach for metro-based underground logistics systems</td>
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<tr>
<td>[59]</td>
<td>Concept</td>
<td>Bus</td>
<td>LMO</td>
<td>x</td>
<td>Vehicle–infrastructure</td>
<td>Direct</td>
<td>Yes</td>
<td>Proposing an integrated urban logistics and passenger flow concept</td>
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<tr>
<td>[57]</td>
<td>Concept</td>
<td>Robot</td>
<td>Robot</td>
<td>Robot</td>
<td>Vehicle</td>
<td>Direct</td>
<td>No</td>
<td>Designing an automated public transportation system</td>
</tr>
<tr>
<td>[61]</td>
<td>Case study</td>
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<td>Metro</td>
<td>United Kingdom</td>
<td>Vehicle</td>
<td>Direct</td>
<td>No</td>
<td>Evaluating the suitability of the metro for urban freight transportation</td>
</tr>
<tr>
<td>[62]</td>
<td>Case study</td>
<td>Metro</td>
<td>LMO</td>
<td>India</td>
<td>Vehicle</td>
<td>Network</td>
<td>No</td>
<td>Exploring the potential of ring rail and metro rail system</td>
</tr>
<tr>
<td>[63]</td>
<td>Case study</td>
<td>Metro</td>
<td>LMO</td>
<td>Italy</td>
<td>Vehicle</td>
<td>Network</td>
<td>No</td>
<td>Identifying the conditions so that metro users can become crowd-shippers</td>
</tr>
<tr>
<td>[56]</td>
<td>Concept</td>
<td>Metro</td>
<td>LMO</td>
<td>China</td>
<td>Vehicle</td>
<td>Direct</td>
<td>Yes</td>
<td>Development of a framework for shared freight and passengers’ integration on a metro</td>
</tr>
<tr>
<td>[64]</td>
<td>Case study</td>
<td>Bus</td>
<td>LMO</td>
<td>United Kingdom</td>
<td>Vehicle</td>
<td>Network</td>
<td>No</td>
<td>Calculating costs for installing recharge stations for freight vehicles</td>
</tr>
<tr>
<td>[65]</td>
<td>Case study</td>
<td>SL</td>
<td>LMO</td>
<td>Slovakia</td>
<td>Vehicle</td>
<td>Network</td>
<td>Yes</td>
<td>Evaluating the potential of using urban public transport for freight deliveries</td>
</tr>
<tr>
<td>[66]</td>
<td>Case study</td>
<td>Metro</td>
<td>LMO</td>
<td>Italy</td>
<td>Vehicle</td>
<td>Network</td>
<td>No</td>
<td>Evaluating the feasibility of using the metro to deploy crowd-shipping services</td>
</tr>
<tr>
<td>[67]</td>
<td>Concept</td>
<td>Metro</td>
<td>Robot</td>
<td>United Kingdom</td>
<td>Vehicle</td>
<td>Direct</td>
<td>No</td>
<td>Evaluating various innovative designs for the interior of the metro carriage</td>
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<tr>
<td>[68]</td>
<td>Concept</td>
<td>Train</td>
<td>LMO</td>
<td>France</td>
<td>Vehicle</td>
<td>x</td>
<td>No</td>
<td>Designing a social cost-benefit analysis framework</td>
</tr>
<tr>
<td>Case study</td>
<td>Concept</td>
<td>Vehicle–infrastructure</td>
<td>China</td>
<td>Direct</td>
<td>Yes</td>
<td>Evaluating the performance of the proposed baggage transfer system</td>
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<tr>
<td>Concept Metro LMO United Kingdom</td>
<td>Metro</td>
<td>Infrastructure</td>
<td>Austria</td>
<td>Direct</td>
<td>No</td>
<td>Evaluating current metro infrastructure</td>
<td></td>
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<tr>
<td>Concept Metro LMO United Kingdom</td>
<td>Direct</td>
<td>Vehicle–infrastructure</td>
<td>China</td>
<td>Yes</td>
<td>No</td>
<td>Evaluating the feasibility and potential of metro-based delivery network</td>
<td></td>
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</table>

Designing of public transport-based urban logistics transport system
4. Conclusions

The purpose of this paper was to conduct a systematic review of the scientific literature on the integration of freight delivery in public transportation in urban areas. The scientific literature on the subject has expanded and become highly diverse in recent years due to the interdisciplinary nature of the research field. By employing a strict searching methodology and a classification table, the papers were divided into quantitative and qualitative, and an in-depth analysis was conducted. The main findings of this review can be summarized based on the research questions (RQs).

Regarding RQ 1 (main study types), freight in public transportation is an active area of research that has attracted the interest of researchers around the world, as papers are continuously being published on the matter. Initially, the focus in qualitative papers was on the analysis of pilot projects and cost–benefit analyses for planned projects, which can be seen in the equal number of case studies and concept papers. For quantitative papers, the focus shifted from simple modeling study types to modeling studies with case studies of the models included. This progressive move toward validating theoretical models with practical applications can be further enhanced by simulations.

Regarding RQ 2 (main modes of transportation), the dominant modes in quantitative papers are buses and the metro network. However, authors tend to use scheduled lines to introduce more flexibility into their models as multiple modes of transport can be categorized as such. For the final mode of transportation, last-mile operators dominate. Similar patterns were found in transportation modes in both qualitative and quantitative papers. This consistency in the choice of transportation modes across different studies highlights a consensus in the field about the importance of these modes for urban freight transport.

Regarding RQ 3, there are very few papers that considered the use of intermodal containers in their study. This will require further research. However, the papers that used these containers reported a cost reduction as well as shorter delivery times.

In response to RQ 4, from the review conducted, it is clear that the most researched aspect of the integration of freight in public transportation is vehicle utilization. This is followed by the use of a combined method of vehicle and infrastructure utilization. In terms of future research needs, nine perspectives were identified.

Every literature review has its inherent limitations, including this one. Many constraints were imposed in the analysis and on the corpus; for instance, each considered paper needed to include the use of public transportation in infrastructure or vehicles, and it was required to research freight transportation. This enabled us to delve deeply into the literature that closely aligned with our topic. Consequently, this approach might have led to the exclusion of other pertinent contributions during the review process. The interpretation of a paper’s focus might also have led to the inclusion or exclusion of certain studies.

4.1. Perspectives for Future Research

After presenting the classification tables and the conclusion, in this subsection, nine perspectives for future research opportunities are identified and presented as follows:

- Packing and design of intermodal containers: While there is a positive correlation between trans-shipment and the use of intermodal containers, an analysis of how the packing and design of the containers are conducted is missing in research. This suggests a gap in the literature that can be filled by pursuing simulation models to assess the impact of different packing and design strategies on efficiency and cost, as well as the effects of this integration on passenger transportation service quality. An interesting study was carried out by [71], where the authors aimed to teach an autonomous tug master to manage rolling cargo and perform loading and unloading operations. This training was performed through a deep reinforcement learning algorithm. These loading and unloading operation strategies are of immense importance for the optimized implementation of this integration and can help improve space utilization and handling efficiency.
• Network failure assessment and Resilience research: According to the literature review, there is only one paper that worked on the resilience assessment of an urban delivery network, namely [26]. Further developments are needed to identify critical links or nodes in a delivery system, especially when it includes a public transportation network. Research on this aspect must be carried out through simulations or qualitative studies regarding stakeholders’ involvement and policy implications. A relevant study by [72] introduced a deep anomaly detection framework for connected autonomous vehicles (CAVs), which can be adapted for urban logistics networks to enhance the resilience of urban delivery systems, as it ensures continuous monitoring and immediate response to disruptions.

• Unmanned vehicles and their integration with public transportation: Unmanned aerial vehicles (UAVs) or unmanned ground vehicles (UGVs), such as modular vehicles, are evolving at a fast pace, and many of these projects are active in some cities in the world, providing very good results. Only two papers were found in this literature review integrating unmanned vehicles with public transportation [30,40]. Further research should be conducted to assess how these vehicles can work combined with the public transportation network or vehicles to deliver freight. The viability of using public transportation stations as hubs for recharging either drones or cargo bikes needs to be simulated and modeled before attempting to make any permanent changes to the urban network.

• Incorporating external effects into mathematical models: Reducing external costs is a significant driver for promoting the use of public transportation for freight. However, the integration of environmental factors into transportation models has been limited. While some models include external cost indicators, none incorporate these costs directly into their objectives. Future research should aim to internalize these policy measures, such as CO₂, into existing models and evaluate the benefits gained from the integration of freight into public transportation.

• Optimizing service quality and efficiency problems: Current research on the use of public transportation to deliver freight in cities primarily focuses on cost reduction while meeting transportation demands. While cost reduction is an important aspect of optimizing urban logistics, there are other objectives that are not handled enough, such as maximizing load efficiency. Advanced load planning algorithms need to be developed, and their effects on empty miles in public transportation and last-mile operators need to be assessed.

• Further incorporation of stochastic and real-time information: Quantitative analyses form a significant portion of the reviewed literature with reliable conclusions depending on accurate estimation of real-world data. Future research should prioritize acquiring high-quality data, as few studies have included stochastic or real-time information to date. Incorporating stochastic data, such as freight demand, capacity, travel time, and traffic variations, can enhance the robustness of solutions by accommodating varying and uncertain parameters. This approach is particularly beneficial for addressing vehicle routing and scheduling challenges. Additionally, integrating real-time data, such as incoming orders or live traffic updates, can reduce service times and improve coordination in multi-tier models. To advance this research, it is crucial to collect high-quality stochastic and real-time data, develop models that incorporate this information, create dynamic optimization algorithms, and test and validate these models in real-world settings.

• Incorporating AI methods: AI methods are scarce in the literature on urban logistics; only two papers utilized machine learning algorithms, namely the K-means algorithm [22,29]. Further applications of these methods can contribute to the more sustainable utilization of public transportation for freight transportation. An example of an interesting study is the one conducted by the authors of a case study on Casablanca [73]. The aim of this paper was to understand and evaluate the patterns of traffic congestion by calculating the TTI (travel time index). Similar studies can be
performed to classify different urban areas, based on logistics activity and congestion.

- Increasing the number of simulation studies: Another notable gap in methodological research concerns the absence of simulation studies, in particular, the potential synergy achievable by combining simulation and optimization methods, which remains promising. Using high-level aggregated models to represent overall network flows and performance is a promising research avenue, as well as microscopic simulations to simulate interactions between last-mile operators and public transportation vehicles.

- Development of exact methods: In the case of larger problem instances and models that incorporate stochastic or real-time data, it becomes imperative to employ more streamlined solution methodologies. When assessing solution methods for quantitative references, a prevalent trend emerges in favor of heuristic approaches. Conversely, there is a scarcity in terms of developing accurate solution techniques. Only [34,41,43,49,50] deal with this topic. In particular, the authors of [34] worked on the development of Benders decomposition, which provides a valuable benchmark for evaluating the effectiveness of heuristics.

**Author Contributions:** Conceptualization, A.M.E.A. and M.F. and N.R.; methodology, A.M.E.A., M.F. and N.R.; validation, A.M.E.A., M.F. and O.B.; formal analysis, A.M.E.A.; writing—original draft preparation, A.M.E.A.; writing—review and editing, A.M.E.A. and M.F.; visualization, A.M.E.A.; supervision, O.B., M.F. and N.R.; funding acquisition, O.B. All authors have read and agreed to the published version of the manuscript.

**Funding:** This work received funding under the Al Khawarizmi program in artificial intelligence and its application, under the subsidy of the Digital Development Agency (ADD), the Ministry of Higher Education Scientific Research and Innovation, and the National Center for Scientific and Technical Research (CNRST).

**Data Availability Statement:** All data are publicly available.

**Acknowledgments:** The authors are grateful to the Euro-Mediterranean University of Fez for providing access to the Scopus database and to the reviewers for their valuable suggestions and comments, which have significantly enhanced the quality of this review paper.

**Conflicts of Interest:** Authors declare no conflicts of interest.

**References**


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