



Taxonomy for Integrated Passenger—Freight Transportation Models as an Alternative for Urban Logistics

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Abstract. The integration of passenger and freight transport through urban areas could be an effective way to reduce traffic in cities, and its negative externalities, making transport activities more efficient and respectful of the environment. This could be done by sharing infrastructure, such as roads and railways, or by sharing vehicles. This paper proposes a novel taxonomy based on seven classification criteria: Type of Study, Type of Analysis, Objective Focus, Solution Method, Geographic Location, Type of Transportation, and Type of Integration, to better understand the performance of integrated passenger and freight initiatives and identify trends in their development. The proposed taxonomy identifies important research gaps. They include the need for intelligent transportation system applications that enable data exchange between passenger and freight systems, theoretical and practical studies, incorporating stakeholder desires through a multi-objective approach, and the use of alternative fuel vehicles for the first and last mile of goods transportation in combination with passenger transportation. If we close these gaps, we can optimize the merger of passenger and cargo transport, leading to a more sustainable and efficient urban transportation system. In addition, the integration will promote a high efficiency of the passenger transport network and improve living conditions in metropolitan areas.

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1 Introduction

The rise of e-commerce and same-day delivery has led to a decline in the number of people commuting to crowded city centers and shopping malls. This is because people can now buy almost anything they need online and have it delivered to their door, often within hours. This trend has had a number of implications for cities, including reduced traffic congestion, lower air pollution, and increased energy efficiency. Meanwhile, cargo boxes have been taking up the seats that travelers and attendees of conferences in far-off destinations once occupied on passenger airplanes. Alternatively, the COVID-19 pandemic activated significant disruptions in the global supply chain, revealing inherent weaknesses within the system. As a result, delays and unstocked shelves became commonplace. Hospitals faced supply shortages of critical equipment and supplies, while grocery stores encountered unprecedented scarcity of food and other essential items [1, 2].

COVID-19 pandemic led to a significant decrease in demand for freight transportation in the post-crisis economic landscape, giving place to a considerable shift in the old balance between passenger and freight transportation. This situation presents an opportunity to transform the traditional mobility sector by creating a comprehensive transportation system that addresses both passenger and freight needs and tackle the ongoing climate crisis. It is critical to prioritize integrating passenger and freight transportation, thus increasing the resilience and sustainability of the whole mobility system. While various terms describe passenger and freight transportation, such as freight in transit, cargo hitching, and passenger-and-package sharing, exploring additional options can further enhance our transportation capabilities [3–6].

According to the WEF [7], the demand for last-mile deliveries in cities is projected to increase by 78% by 2030, leading to a 35.9% growth in delivery vehicles in the world's top 100 cities. City planners must, therefore, prioritize the planning of delivery and storage of goods to avoid potential damage to the transportation system, with congestion, secondary parking, and the use of sidewalks as makeshift distribution centers. While certain cities have already established specific plans for urban freight, more comprehensive planning is essential to ensure efficient and sustainable last-mile deliveries [2].

Many large as well as small businesses rely on a daily collection and transportation of goods in today economy. Consequently, several researchers have already studied different ways of taking advantage of existing public systems, such as inner-city subways or trams, for goods transportation in crowded urban areas.

Some authors, such as Jansen et al. [8], Ghilas et al. [9], and Li et al. [10] show how the freight transportation sector, including public transportation agencies, manufacturers, shippers, carriers, and receivers, can derive economic benefits from moving goods using their spare transportation capacity. Additionally, pub-

lic agencies can financially benefit from increased sustainability of transit operations, resulting in less burdensome transit operations; thus, paving the way for delivery and passenger services. These services are better located in shrinking areas and improve their attractiveness to current and future populations, providing sustainable transportation to and from crucial transit hubs or corridors.

Given the steady evolution of urban logistics systems worldwide, examining the similarities and differences in the elements that characterize the integration is interesting. However, to our knowledge, no integrated passenger and cargo transportation classification in the literature provides a systematic and complete understanding of this topic. As a result, it is difficult to identify important characterizing factors, filter out and understand success factors, and analyze trends worldwide.

This paper aims to introduce a novel taxonomy of passenger and freight transportation through an analysis of a wide range of works from around the world. This taxonomy is divided into seven classification criteria: Type of Study, Type of Analysis, Objective Focus, Solution Method, Geographic Location, Type of Transportation, and Type of Integration. We will discuss these criteria in detail in the following sections.

2 Related Work

Urban logistics (UL) is a critical aspect of urban mobility, as it encompasses the delivery and collection of goods in urban areas. The customary undertakings of transferring, manipulating, and preserving commodities, supervising stock, waste, and remissions, along with home delivery conveniences, typically fall under logistics. The proliferation of literature on this topic reflects a growing preoccupation with this issue [11–14].

This paper uses two approaches: a theoretical view and an emphasis on practical implementations.

2.1 Theoretical Approach

Theoretically, the issue can be approached by extending existing transportation and allocation models, such as the well-known pickup and delivery problem with time windows and scheduled lines, as explained in Ghilas et al. [9]. Their work addresses the challenge of scheduling vehicles to comply with requests, considering the multimodality of modes of transportation that are designed for the movement of passengers, such as taxis, buses, trains, or trams. They present an arc-based mixed-integer programming formulation incorporating passenger and parcel pickup and delivery orders.

Several other researchers have made noteworthy contributions to this field. For instance, Massion et al. [20] and Li et al. [10] developed optimization algorithms and techniques to help decision-makers optimize urban logistics (UL) systems that involve both passengers and goods. While Strale et al. [21] explored the

potential use of light rail for freight transportation, using Brussels as an example. They propose an effective transportation system that combines passenger and freight rapid transit to improve the sustainability of urban logistics.

Li et al. [10] integrate passenger and parcel flows using taxis to support taxi routing. The authors propose MIP formulations for both static and dynamic planning situations. They conclude that computationally intensive algorithms are necessary for solving realistic scenarios. Subsequently, Li et al. [15] later developed a modified version of the algorithm described earlier. This version accounts for uncertainty related to transportation times and delivery locations. They present a two-stage mixed-integer stochastic programming model and an adaptive algorithm for exploring large neighborhoods.

In a case study in the La Rochelle-France, Masson et al. [20] proposed a solution to optimize the daily distribution of urban goods in a business to business context. They proposed integrating passenger and freight flows using a homogeneous fleet of buses and a homogeneous fleet of Environmentally friendly urban freight vehicles that can carry one mobile container to the final destination.

Fatnassi et al. [22] consider that although passenger and freight transportation have different destinations and constraints, mixing their trips on the same network aligns with the trend. They explore how passenger and freight rapid transit can share a network and use the available transportation capacity within a city more efficiently by linking them. Based on the common characteristics of these two modes of transportation, this paper proposes a new and efficient transportation solution to improve the sustainability of urban logistics.

Arvidsson and Browne [23] summarized the main issues related to the first and last mile in freight and passenger transport. They explored passenger and freight transportation synergies to enable resource sharing regarding time, space, and vehicles. They presented several examples of resource sharing in passenger and freight transportation. They found that combining passenger and freight traffic in cities could be an effective way to address the last-mile challenge.

Zhao et al. [24] proposed a method for constructing an integrated logistics system for the metro by locating distribution hubs. They first segmented the urban metro network into subnetworks. Then, they used complex network theory to select indicators or measures to rate the relevance of each metro station. The weight of each evaluation index was calculated using the analytical hierarchy process method. The relevance of each metro station was then assessed using the TOPSISO model, which is an acronym for Technique for Order Preference by Similarity to an Ideal Solution. This identified the metro distribution nodes eligible for the location model. Finally, a locational decision model was formulated to decide the final distribution hubs from the candidates. The Shanghai metro system was used as a case study. The mathematical formulation of the location model for metro distribution nodes is defined by the following objective function: Minimize the total distance between demand points and metro distribution nodes for all deliveries. The relative relevance of each metro station was assessed using the TOPSISO model, and the metro hubs nodes under consideration were determined using the P-median model.

Behiri et al. [25] studied urban freight transportation using the rail passenger network. First, they identify the relevant problems at strategic, tactical, and operational levels. Then, they looked at the Freight-Rail-Transport-Scheduling Problem, proposing many heuristics to solve it. They have also developed a framework for discrete-event simulation. The problem was first formulated as a MIP problem. The authors then prove that the problem is NP-hard and equivalent to the generalized assignment problem and proposed two heuristics to solve the problem: a dispatch rule-based heuristic and a simple train-based decomposition metaheuristic algorithm. The effectiveness of these heuristics is assessed using a discrete-event simulation approach. This provides a general way for decision-makers to simulate and analyze the performance of various solutions for a given system in multiple situations.

Cieplinska et al. [26] developed a workable model for a company organizing the movement of people and goods in urban areas. The proposed model could be an effective tool for local authorities to improve passenger and freight transportation in urban areas. The study analyzed practical solutions in the field in European metropolitan areas. The paper presents a framework for organizing urban agglomerations with conceptual modeling. The theoretical part of the paper is based on the existing materials from public sources and the authors' research experience.

Cargo hitching was studied by Romano-Alho et al. [27] to consider the use of spare capacity in passenger transportation. This contribution to the cargo hitching studies the following dimensions: a) Application of an agent-based simulation framework to understand the impact of cargo hitching from different perspectives: transportation companies, travel customers and regulators. The simulation framework is used for modeling of mobility-on demand services on the supply as well as the demand side, explicitly capturing the interactions between supply and demand; b) Comprehensive simulations to understand different freight demand allocation strategies using a 2030 model of Singapore to gain insights into the potential impacts of cargo hitching. The platform SimMobility was used to get a high-resolution agent-and activity-based simulation for flows of passenger and freight.

Barán et al. [28] examined a collaborative passenger and freight transportation system in a multi-objective context, as a sustainable option for urban logistics (UL). They proposed a model for parcel delivery services, considering the metro of Quito-Ecuador as a typical case study with metro stations used for parcel pickup and delivery. This study suggested a mixed-integer linear multi-objective programming model to represent this problem of joint transportation of passengers and parcels, including some criteria and constraints that represent real operational and business rules. Finally, a well-known evolutionary multi-objective algorithm called NSGA-II (Non-dominated Sorting Genetic Algorithm, version 2) was implemented to solve the proposed model.

2.2 Practical Approach

Real-world examples of successful integration between passenger and freight transportation are needed to demonstrate the potential of this approach. This is particularly important given the close link between UL, the urban mobility system, and the main actors of urban management and economies including public administrations, commercial actors, manufacturers, carriers, and residents. In their study, Ghilas et al. [9] analyzed the UL system in detail, considering door-to-door passenger transport, parcel transport, and fixed public services. They developed different scenarios with different levels of integration. Establishing profitable cooperation is necessary for the success of an integration process, but it requires time and great political effort. For example, Fatnassi et al. [22] showed that sharing goods and passengers across a network could lead to significant sustainability gains, such as improved service times and reduced energy waste.

Traditionally, urban transportation planning has treated the movement of people and goods as separate entities, even though they utilize the same road infrastructure and exert mutual influence. By integrating both types of traffic flow, we can optimize the utilization of available capacity, reduce the number of vehicles and drivers required to meet transportation needs, and create new business opportunities [32]. In their work, Boudoin et al. [33] discuss the advantages of such integration. However, recent studies in urban logistics emphasize the importance of integrated management of freight movements in urban areas, which combines various actors and services and encourages the emergence of new business models that promote agile distribution using smaller, less-polluting vehicles, such as bicycles [34].

The concept of integrating passenger and freight transportation has been explored not only theoretically, but also through initial pilot studies. These studies have focused on shared-use approaches and have yielded some valuable insights, which we briefly present below.

- *India*: In India, the Dabbawala organization is a lunchbox delivery and return system that achieves high service performance with low cost and a simple operating system based on color-coded and numbered lunchboxes [35]. Every morning, a dabbawala collects lunchboxes from homes and offices in their area on foot or by bicycle, goes to the local train station, and sorts the lunchboxes by destination. The lunchboxes are then placed on the trains and delivered to the appropriate dabbawalas at their destination. The dabbawalas then deliver the lunchboxes to the owners by bicycle. The empty lunchboxes are then collected by the dabbawalas and returned to the homes and offices.
- *Sweden*: In Sweden, Bussgods is a nationwide transportation system that provides transportation for both businesses and individuals using existing bus routes. This makes Bussgods one of the most environmentally friendly and punctual transportation options as they carry both passengers and packages at the same time [36]. Bussgods has a few agencies and service points in the main cities in Sweden. Customers can find the nearest agents and track their packages through the website.

- *Netherlands*: In 2007, CityCargo Amsterdam launched the CargoTram project to reduce the number of trucks circulating in the urban core by 50 (%) and decrease pollution by 20 (%). A successful trial run was conducted during which two empty CargoTrams were tested on the network for a month. However, CityCargo Amsterdam filed for bankruptcy in 2009 [23].
- *Germany*: Meanwhile, DVB Dresden’s CarGoTram transported car parts to Volkswagen’s “Transparent Factory” in downtown Dresden between 2001 and 2020. Up to eight daily trips resulted in 25 avoided truck journeys [37]. Additionally, Hermes and the Frankfurt University of Applied Sciences carried out a pilot “LastMileTram” project in Frankfurt in 2019. Specialized transport containers were conveyed by tram from a depot outside the city to the urban core. Subsequently, they were transported to their ultimate delivery destination by special e-bikes. Although the pilot study demonstrated the feasibility of transporting goods by tram, the costs were somewhat higher than those for delivery by road [38, 39].
- *Switzerland*: The Cargo Tram has facilitated the disposal of electronic waste and bulky items in Zurich since 2003. Eleven designated stops are made according to a fixed schedule, where citizens can drop off their e-waste or bulky waste free of charge. This approach has resulted in several hundred tons of unmanageable waste being disposed of annually, corresponding to reduced road traffic [40].

3 Taxonomy Dimensions

This section introduces our novel taxonomy and explains the main features we considered in its construction. It is based on a comprehensive review of 36 papers published between 2014 and 2023, representing very different approaches and addressing various issues related to passenger and freight transportation integration. The seven classification criteria ensure coherence and parsimony without compromising comprehensiveness. Each classification criterion has a specific component, as follows.

1. *Type of Study*: The literature on integrated passenger and freight transport models can be broadly divided into three focal points: theoretical investigations, practical applications, and survey-based studies. Theoretical studies develop new models and methodologies to facilitate integration and explore underlying principles and mechanisms. Practical applications demonstrate the feasibility of implementing these models in urban logistics systems. Finally, survey-based studies provide a comprehensive overview of the current state of research and practice in the field, identifying key trends, challenges, and opportunities. These three focal points offer a comprehensive framework for understanding the diverse range of studies related to integrated transport, providing valuable insights for researchers, practitioners, and policymakers alike.

2. *Type of Analysis:* When examining the literature on integrated passenger and freight transportation models, the type of analysis employed can be broadly categorized into two main approaches: qualitative and quantitative perspectives.

Qualitative analyses typically rely on non-numerical data, such as observations, interviews, and case studies, to develop insights into the complex social, economic, and environmental factors that influence the integration of passenger and freight transport. These studies often emphasize the importance of context and seek to understand the subjective experiences and perceptions of individuals and communities affected by transport systems. In contrast, quantitative analyses focus on numerical data and employ statistical and mathematical models to measure integrated transport systems' effectiveness, efficiency, and sustainability. In addition, these studies often prioritize objective measures and seek to quantify the impact of transport policies and interventions on key outcomes such as travel time, cost, and emissions.

3. *Objective Focus:* The literature on integrated passenger and freight transport models can also be analyzed based on the number of objectives considered, broadly categorized into two perspectives: single and multi-objective.

Single-objective perspectives focus on optimizing a single objective, such as reducing travel time or minimizing emissions, while holding other factors constant. These research often employ mathematical optimization techniques to identify the best solution for a given objective. In contrast, multi-objective perspectives consider multiple goals simultaneously, recognizing that optimizing one purpose may come at the cost of another. These studies often employ decision-making frameworks that allow for trade-offs between objectives, such as multi-criteria decision analysis or Pareto optimization.

4. *Solution Method:* We identified five primary perspectives: exact methods, heuristics and metaheuristics, hybrid methods, simulation, and scenario analysis.

Exact methods utilize mathematical optimization techniques to find the optimal solution to a given problem, often focusing on minimizing travel time, cost or emissions. Heuristics and metaheuristics offer alternative approaches to optimization that are often faster and more efficient than exact methods but may not guarantee the optimal solution. Hybrid methods combine elements of both exact and heuristic methods to balance efficiency and accuracy. Simulation methods use computer models to simulate the behavior of integrated transport systems and predict their performance under different scenarios. Finally, scenario analysis involves developing and analyzing various scenarios representing potential futures for integrated transport systems, allowing for exploring different policy interventions and their possible outcomes.

5. *Geographic Location:* According to the geography classification criteria, integrated passenger and freight transport models can also be analyzed based on

geographic location, which can provide insights into the regional differences and similarities in research and practice. The literature can be broadly classified into six continents: Europe, North America, Asia, Latin America, Oceania and Africa. Studies from Europe and North America are relatively more numerous and established, given these regions' more comprehensive research and development history. In contrast, studies from Asia, Latin America, and Africa tend to focus on specific local contexts and often address the unique challenges and opportunities of developing economies. Oceania is relatively underrepresented in the literature, but a few notable studies are from Australia and New Zealand.

6. *Type of Transportation:* Another way to categorize the literature on integrated passenger and freight transport models is based on the kind of transportation systems considered. The combination of passenger and freight transport can be realized in various types of transport, including buses, metros and trains, trams, and private vehicles (such as small cars).

Integrating passenger and freight transport in bus systems is relatively common, as buses are versatile and can accommodate passenger and freight needs. Metro and train systems also offer opportunities for integration but are often constrained by the need for specialized infrastructure and the potential for safety concerns. Tram systems provide a more localized form of transport that can be tailored to specific urban contexts and effectively reduce congestion and improve air quality. Finally, integrating passenger and freight transport in private vehicles, such as small cars, is an emerging area of research, with potential applications in last-mile delivery and other localized transport needs.

7. *Type of Integration:* In general, there are three types of integration: shared track, shared vehicle, and shared wagon.

- *Shared track:* The shared track model involves transporting freight in a separate vehicle that only shares infrastructure with public transport vehicles. This approach is often used in metro and train systems, where dedicated freight cars can be attached to passenger trains or transported separately on the same tracks.
- *Shared vehicle:* The shared vehicle model involves transporting freight in a separate carriage on light railways or a trailer affixed to vehicles, such as buses. This approach is often used in bus rapid transit systems, where freight can be transported in dedicated trailers attached to passenger buses.
- *Shared wagon:* in the shared wagon model, freight is transported with passengers in a shared wagon or compartment. This approach is often used in trams and light rail systems, where cargo can be transported in dedicated compartments integrated with passenger cars.

Table 1 presents a complete summary of the proposed taxonomy, where the taxonomy and its content are sketched.

Table 1. Summary of the classifications.

1. Type of Study	
1.1 Theory	[6, 9, 10, 15, 18–20, 42–44]
1.2 Practical	[2, 4, 8, 22, 24, 25, 27–30], [31, 45, 46], [47–51]
1.3 Survey, review	[3, 5, 17, 23, 35, 52]
2. Type of Analysis	
2.1 Qualitative	[2, 3, 5, 17, 23, 28, 35, 44]
2.2 Quantitative	[4, 6, 8–10, 15], [18–20, 22], [24, 25, 27, 29–31, 42, 43, 45], [46, 47, 51]
3. Objective Focus	
3.1 Single Objective	[4, 6, 9, 10, 15, 18, 20, 22, 24, 25], [29, 42, 43, 50]
3.2 Multi-Objective	[28, 31, 48],
4. Solution Method	
4.1. Exact methods	[6, 9, 15, 20, 22, 24, 25, 42, 43]
4.2. Heuristics and Metaheuristics	[15, 20, 25, 28, 29, 31, 48, 50]
4.3. Hybrid methods	[27, 31, 49, 50]
4.4. Simulation	[8, 18, 19, 22, 25, 27, 30, 47, 49, 51]
4.5. Scenarios Analysis	[9, 18, 19, 30, 44–46, 49]
5. Geographic Location	
5.1. Europa	[2, 3, 5, 8, 17, 20, 22, 23, 25, 30, 42], [43–47, 51, 52]
5.2. Asia	[4, 18, 19, 24, 27, 29, 31, 35, 48, 49], [50]
5.3. Latin American	[28]
5.4. North America	[3, 17]
5.5. Africa	Not found
5.6. Oceania	Not found
6. Type of Transportation	
6.1. Bus	[3–6, 8, 9, 17, 20, 22, 42, 52]
6.2. Metro and Train	[3, 5, 9, 17–19, 24, 25, 27, 28], [29–31, 35, 43, 45–49], [50–52]
6.3. Tram	[2, 3, 5, 17, 22, 23, 44, 46, 52]
6.4. Particular	[4, 8–10, 15, 27]
7. Type of Integration	
7.1. Shared track	[2, 17, 22, 23, 45, 46, 52]
7.2. Shared vehicle	[4–6, 10, 15, 17, 20, 24, 27, 29], [30, 31, 42, 43, 47–50, 52]
7.3. Shared Wagon	[3, 5, 18, 19, 25, 28, 35, 44, 51, 52]

3.1 Type of Study

There are a variety of approaches taken in the literature regarding integrated passenger and freight transportation models, with differing levels of theoretical and practical emphasis (Fig. 1). The literature surveyed includes ten theoretical contributions that provide a conceptual framework for understanding integrated transport, and 18 applied contributions that demonstrate the implementation of these concepts in practical scenarios. In addition, six contributions that explore the topic based on a survey and a literature review, without proposing a clear taxonomy.

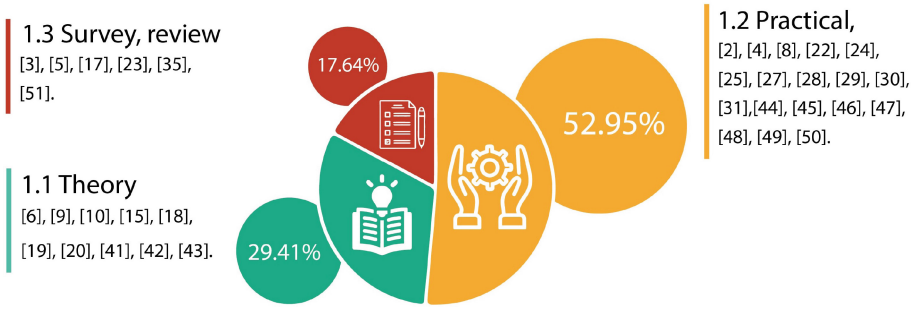


Fig. 1. Type of Study

3.2 Type of Analysis

We found eight papers with a qualitative analysis of passenger and freight integration. At the same time, we found 22 articles with quantitative analysis (Fig. 2).



Fig. 2. Type of analysis

3.3 Objective Focus

In 14 papers, only a single objective function is considered, generally minimizing total cost or distance. Only three papers consider a multi-objective perspective, such as transportation cost, level of service, used capacity, travel time, and reduction of carbon emissions (Fig. 3).

3.4 Solution Method

First, nine papers, mainly with a single objective function, exact methods or comparisons with heuristics were used as solution methods. Second, heuristics and metaheuristics were presented in eight papers, mainly Greedy randomized

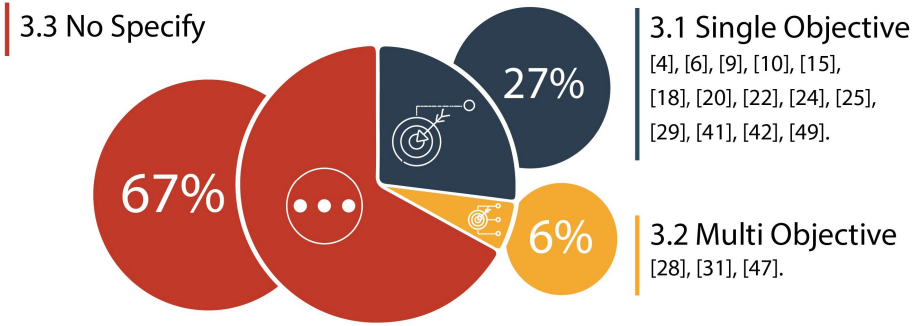


Fig. 3. Objective focus

adaptive search procedure (GRASP), population-based algorithms such as genetics methods, Tabu Search, ant colony, and particle swarm algorithms. Third, for multi-objective models, most of the time, the non-dominated classification genetic algorithm version 2 (NSGA-II) was used. Third, a hybrid scheme combining different solution methods or optimization with simulation approaches was used in four papers. Fourth, ten papers used simulation as an analysis method to evaluate different models for combining passenger and freight transportation. Finally, the scenario analysis was used in eight papers to address the issue from a statistical point of view (Fig. 4).

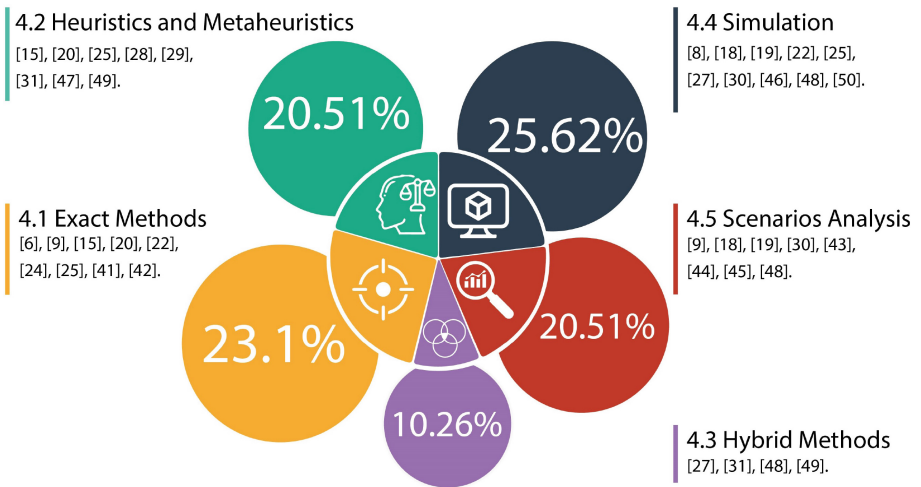


Fig. 4. Solution method

3.5 Geographic Location

Most theoretical and practical applications were in Europe, with 18 papers, followed by Asia with 11 articles. Only two of the applications were in North America. There is only one publication studying implementation in Latin America. We found no publication from Africa or Oceania implementations (Fig. 5).

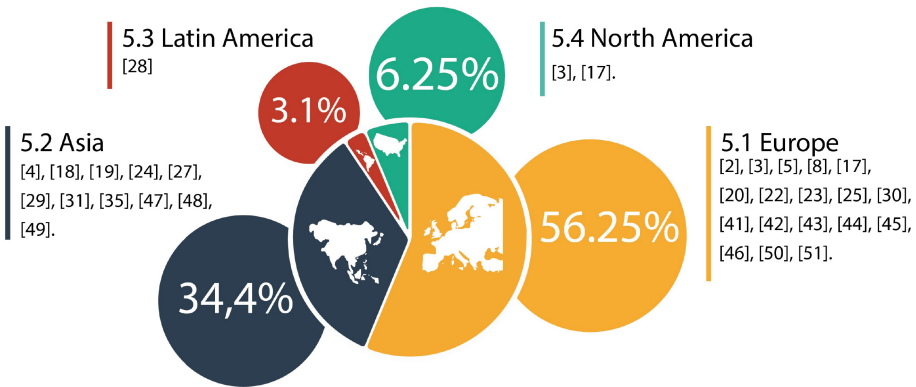


Fig. 5. Geographic location

3.6 Type of Transportation

First, in 11 applications, freight was combined with public transportation such as buses. Second, long-distance trains and metros were the most used, with 22 contributions. Third, nine contributions used trams or light rail as a new business model for urban logistics. Finally, in six contributions, a special means of transportation such as a small car, is used to deliver goods, e.g., a system called Uber Freight or similar schemes [41] (Fig. 6).

3.7 Type of Integration

The literature on urban freight transportation reveals three main approaches concerning to the integration type. The first approach, identified in seven studies, involves using of common rail infrastructure where goods are conveyed in a distinct/separate vehicle that shares the tracks with public transport vehicles. The second approach, found in 19 papers, pertains to shared vehicles in which freight is carried in a separate wagon attached to light rail or buses. Finally, ten contributions focus on shared wagons, where passengers and cargo are transported together in the same compartment or wagon, sharing not only the travel

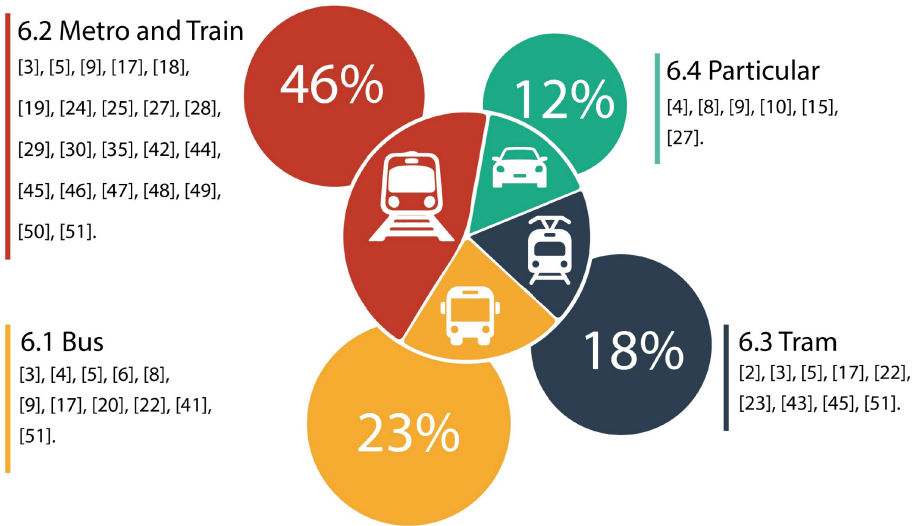


Fig. 6. Type of transportation

route, time, and distance but also the physical space (Fig. 7). It is essential to carefully evaluate the advantages and disadvantages of each approach in the context of the specific urban environment and transportation system to ensure efficient, safe, and sustainable urban freight transportation.

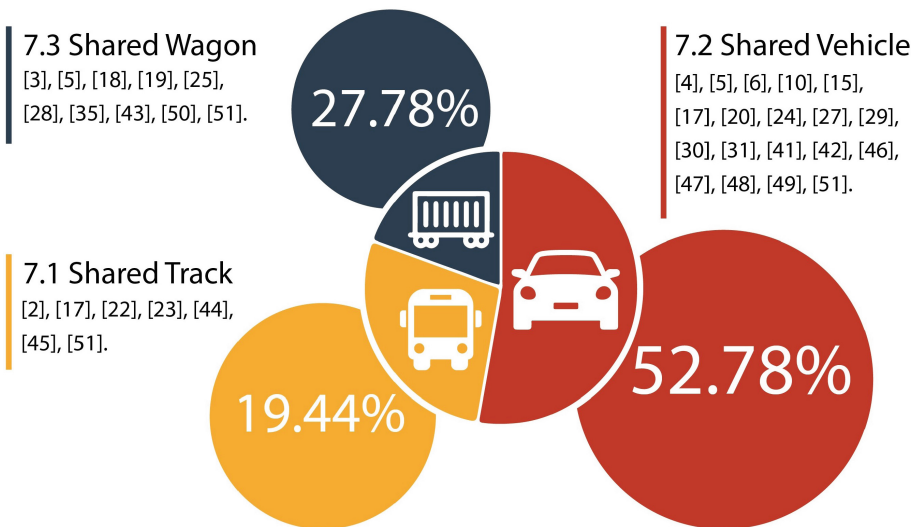


Fig. 7. Type of integration

4 Conclusions

A passenger and freight integration taxonomy can be used to evaluate, analyze, and compare different configurations in different contexts. It can also be used to analyze the impact of these configurations and to study common aspects of passenger and freight transportation integration. This taxonomy can be helpful for decision-makers who want to promote the economic, social, logistical, or environmental development of cities through new urban logistics systems. The taxonomy provides a comprehensive analysis and can be used to develop solutions that meet the logistical requirements of each context while maintaining a global view.

At this point, the main research gaps identified should be mentioned: Intelligent Transport Systems applications for sharing and exchanging data between passenger and freight transportation systems; both theoretical and practical applications in Latin American cities with high levels of urbanization, which require innovative systems to reduce the externalities of urban logistics; further applications using a multi-objective approach that takes into account the different perspectives of stakeholders. Electric vehicles can also be used for freight transportation, especially for the first and last mile, which can be combined with the passenger transportation system. However, further research is needed to identify potential gaps and opportunities in this area.

For all of these reasons, there is a general opportunity for studies in a variety of practical and academic areas when it comes to integrating passenger and freight transportation models.

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