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# Multi-Criteria Analysis for the Evaluation of Urban Freight Logistics Solutions: A Systematic Literature Review

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**Abstract:** The tension between city logistics and its impact on sustainable urban development is evident. Often, local environmental decisions overlook the effects on urban freight logistics, lacking consideration for stakeholders. To address this, utilizing multi-criteria analysis becomes relevant for informed urban planning and management decision making. In this context, this paper conducts a systematic literature review from 2012 to 2022, focused on implementing the multi-criteria analysis methodology to evaluate alternatives for solutions in urban freight logistics. The PRISMA tool was used in the review to select publications and categorize the information obtained to address the research questions. Results display the most prominent authors and publications, authors' country affiliations, annual publication frequency, research objectives, used frameworks, involved actors, defined evaluation criteria, types of alternatives for solutions considered, and MCDM methods applied. The main finding is that the most commonly used MCDM methods were AHP hybrid followed by MAMCA. In addition, no clear correlation between the pursued objectives and the MCDM methods employed by the researchers is identified. It is important to note that all publications with the highest number of citations use fuzzy methods in their analyses.

**Keywords:** MCDM; multi-criteria decision analysis; multiple-criteria decision making; multi-criteria; decision making; urban freight logistics; urban logistics; literature review

**MSC:** 90B50; 90B06

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**Citation:** Alvarez Gallo, S.; Maheut, J. Multi-Criteria Analysis for the Evaluation of Urban Freight Logistics Solutions: A Systematic Literature Review. *Mathematics* **2023**, *11*, 4089. https://doi.org/10.3390/math11194089

Academic Editors: Shiv Raj Singh, Dharmendra Yadav, Himani Dem and João Paulo Costa

Received: 21 July 2023
Revised: 1 September 2023
Accepted: 5 September 2023
Published: 27 September 2023

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## 1. Introduction

Urban logistics has become a crucial factor in the economic momentum of cities [1]. This relevance is closely linked to population growth, subsequent increase in consumption through various channels in urban areas, and the increased flow of goods to and from different consumption points. This has created the need to improve logistics activities to optimize resources and reduce the associated environmental impacts [2,3].

It is also important to consider the transformation that urban areas have experienced in recent years, and the decisions made by governments to improve the quality of life in these areas. These factors directly affect the urban and last-mile logistics that organizations must coordinate to deliver to their customers effectively [2,4,5].

Urban freight logistics aim to plan and manage the flow of goods, information, and related activities in urban areas, mainly seeking effective services, operations profitability, and sustainability [6]. Traffic and environmental pollution are among the main issues that must be addressed in this field [7]. In order to achieve these objectives, decision making is involved because urban freight logistics have particular connotations given the typology of cities, circulation restrictions, social and topographical aspects, and development focus, among other factors. These conditions require the design and definition of policies that will govern logistics to be made more strictly and thoroughly [8,9]. In addition, these decisions

involve different parties or stakeholders (merchandise shippers, receivers, transport operators or carriers, citizens, public administrators, service logistics providers, information technology and infrastructure, and industry associations, among others) with diverse objectives, which makes the process much more complex. In this context, urban freight logistics emerges as an issue of indisputable relevance due to the lack of sufficient consideration in the decisions taken by local authorities to preserve the environment, improve the welfare of citizens, and enhance mobility in urban environments [10]. On many occasions, the measures taken to reduce pollution and promote sustainable practices often focus on the mobility of people and public transport [11], neglecting the significant impact that freight logistics has on urban structure and daily life [12].

The lack of a thorough and detailed analysis of local policies can result in inefficient and unsustainable urban freight logistics [13] which affects the smooth operation of the supply chain and can also generate negative externalities such as congestion, pollution, and high operating costs [10,14]. Therefore, urban freight logistics has the potential to affect both the citizens' quality of life and the businesses' economic viability.

Thus, urban freight logistics appears as a fundamental discipline to address current city challenges and guide planning and management decisions, resulting in optimized solutions amid increasingly complex urban challenges. The lack of comprehensive consideration in local policies and the growing need to create sustainable cities highlight the importance of exploring, understanding, and optimizing freight logistics in urban environments to achieve more livable and competitive cities.

In order to plan and optimize the associated processes of urban logistics, multiple methodologies have been integrated. These methodologies include heuristic methods, stakeholder consultation and participation, simulation models, multi-criteria analysis methodologies, cost models [15], life cycle assessment, and risk analysis. These methodologies are supported by a quantitative analysis that allows the process to be improved, considering the restrictions and particularities of each urban area.

In this setting, the role of the Multi-Criteria Decision-Making (MCDM) approach is highlighted, as it contributes to decision making in situations where multiple alternatives must be evaluated. This approach belongs to the operations research branch, which considers multiple quantitative and qualitative criteria [16]. It is important to note that each urban logistics problem is unique, with specific internal conditions and external determining elements, such as physical aspects and public and political factors. Although common goals may exist and similar techniques are used, there are no identical problems.

This paper will explore various applications of multi-criteria or multi-attribute methods in urban logistics, demonstrating how these methodologies adapt to the particular conditions and needs of each case. Addressing urban logistics challenges clearly requires considering the diversity of factors and finding customized solutions that fit the specific conditions of each zone.

This paper aims to present a systematic literature review on the use of multi-criteria techniques applied in the evaluation of alternatives for urban freight logistics based on the public policy and business performance approach, through which the following research questions will be addressed:

1. What are the objectives pursued for redefining public policies for urban freight logistics?
2. What are the stakeholders or interested parties directly or indirectly involved in any proposed transformation?
3. What are the factors and criteria for evaluating alternatives for urban freight logistics?
4. What are the categories of the alternatives for solutions being proposed?
5. What are the multi-criteria decision-making methods used to transform urban freight logistics?
6. What are the frameworks developed in research to support decisions related to shaping urban freight logistics?

The abovementioned questions are of great importance, as they address essential aspects in the multi-criteria analysis for selecting strategies in urban freight logistics. These

questions guide the actors involved in the transformation of cities, allowing them to understand the objectives and challenges shared in previous studies (question 1). On the other hand, these processes involve multiple stakeholders who may or may not participate in the decisions and be affected directly or indirectly in several ways. Thus, identifying who has been integrated into the process (question 2), understanding the criteria considered (question 3), and knowing the grouping or categorization of possible solution alternatives (question 4) will allow readers to assess whether similar contexts have been addressed in the literature.

Finally, analyzing the techniques used in the literature and existing conceptual frameworks will help analysts recognize the multi-criteria methodologies and techniques used, their usefulness, and their relevance (questions 5 and 6). These approaches will jointly provide valuable guidance for addressing similar challenges in urban logistics.

This paper is structured as follows: Section 2 addresses previous literature reviews, while Section 3 describes in detail the applied methodology, referring to the implemented search protocol and information analysis. Section 4 conducts a descriptive analysis of the results, including relevant information such as annual publications, relevant authors, authors' institutional affiliation countries, and most-cited papers. Section 5 addresses the research questions raised, including publication objectives, applied frameworks, stakeholders or actors involved in decision making, defined analysis criteria, evaluated alternatives for solutions, and MCDM methods used in selected publications. Finally, Section 6 presents the conclusions derived from the work carried out.

## 2. Previous Reviews

Table 1 displays previously conducted literature reviews whose research focuses on applying MCDM techniques in logistical matters. Among these publications, those centered on studying transportation include the work by Mardani et al. [17], who research MCDM implementation on transportation systems, identifying service quality as the main study field. Moslem et al. [18] mainly examine the AHP method in transportation problems and highlight public transport as the most notable application area. Likewise, Kenger et al. [19] focus on the use of the AHP method in public transport decisions, finding that the most notable application lines are the improvement of service quality, bus and vehicle choice, optimization of facility location, passenger satisfaction, and route planning for buses and bicycles. Keshavarz-Ghorabaee et al. [20] evaluate urban and public transport systems, identifying a significant use of hybrid MCDM methods and a growing interest in addressing uncertain data for public transport problems. Kügemann and Polatidis [21] evaluate fuel types suitable for each type of road vehicle and, in their review, they determine the use frequency of evaluation criteria and the methodology used for the criteria and alternatives' selection. In turn, Macharis and Bernardini [22] focus on the evaluation of transport projects and find that the decision types are divided into passenger, freight, and technology domains, in addition to a general field that encompasses projects of wide application. Their literature review investigates the participation of stakeholders in the evaluation steps, concluding that they participate mainly in the criteria and alternatives' choice and in criteria weighting. Yannis et al. [16] explore the application of multi-criteria analysis in the transportation sector, both in discrete and continuous choice options. They identify the evaluation of transportation alternatives—and not transport policies—as the most frequent field of application, since in the transport policies field, only 2 of the 50 selected papers are related to urban logistics. Tian et al. [23] focus on low-emission transport together with green logistics. In their review, they recommend conducting studies on the development of sustainable urban logistics, as only two related publications were found.

These publications reflect the progress and interest in the transport research field. However, it is important to note that these literature reviews have not specialized in the topic of urban freight logistics, which is the focus of this review.

Moreover, Table 1 also includes the publication by Mardani et al. [24], where publications from 2000 to 2014 are analyzed and 15 fields of application of MCDM are identified.

One of these fields corresponds to supply chain management on matters related to quality, performance, supplier selection, supply chain process, and sustainable supply chain management. However, their research does not focus on urban logistics analysis.

Furthermore, in the review conducted by Kramar and Topolšek [25], which focused on applying the Fuzzy Analytic Hierarchy Process (F-AHP) method in the urban mobility field, there is only one reference linked to freight logistics. This same paper has also been identified in the current literature review.

**Table 1.** Previous literature reviews with implementation of the MCDM methodology in the context of logistics and transportation.

| Paper | Year | Focus | Coverage | Methodology | Selected Publications | Research Focus and Main Findings |
|---|---|---|---|---|---|---|
| [24] | 2015 | Supply chain | 2000–2014 | Literature review | 23 | It identifies 15 MCDM application fields and applied techniques, which include the supply chain. One of the most widely applied fields is energy, sustainability, and environment. The most widely used MCDM methods are AHP, hybrid methods, and TOPSIS. |
| [22] | 2015 | Transportation | 1985–2012 | Review | 276 | It focuses on evaluating passenger transport projects, freight transport, and transportation technology using MCDM methods. It is stated that the applicability success of a method may be related to the possibility of involving actors in decision making. |
| [26] | 2019 | Logistics centers | 1999–2016 | Literature survey | 32 | It focuses on the selection of distribution centers, identifying applied MCDM models and criteria defined in the evaluation of alternatives. The most commonly used methods are AHP, TOPSIS, and ÉLECTRE. Cost and natural resources are among the most commonly applied decision criteria. |
| [17] | 2016 | Transportation | 1993–2015 | Systematic reviews | 89 | It reviews MCDM application for solving transportation system problems which, upon identifying the main application areas, are service quality and transportation performance evaluation. |
| [18] | 2023 | Transportation | 2003–2019 | Systematic reviews | 58 | It seeks to identify the contribution of AHP to transportation problems. Public transportation is identified as the main application area in the selected publications. |
| [23] | 2023 | Green logistics and environmentally friendly transportation | 2010–2022 | Literature review | 190 | It focuses on MCDM, low-carbon transportation, and green logistics. It identifies the growing use of fuzzy language. |
| [15] | 2019 | Urban logistics | 2000–2017 | Literature review | 5 | It reviews applied criteria and MCDM techniques for selecting sustainable city logistics alternatives and collaborative partners. This work highlights the use of multi-criteria AHP and TOPSIS methods as the most used ones. |
| [16] | 2020 | Transportation | 1982–2019 | State-of-the-art review | 50 | Its focus is MCDM in the transportation sector, identifying that they are mainly displayed in the transportation options' evaluation instead of transportation projects or policies. It is also identified that problem-solving methods with a continuous set of options are not commonly used for this type of problem. |

**Table 1.** *Cont.*

| Paper | Year | Focus | Coverage | Methodology | Selected Publications | Research Focus and Main Findings |
|---|---|---|---|---|---|---|
| [20] | 2022 | Urban and public transportation systems | 2017–2022 | Bibliographic review | 72 | It investigates the use of MCDM in assessing urban and public transport systems, identifying that AHP and TOPSIS were the most popular methods. It also highlights the increase in the application of decision-making approaches in situations of uncertainty in public transport. |
| [19] | 2023 | Urban transportation | 1987–2022 | Bibliometric and social network analysis | 222 | Its study object is AHP implementation in the urban and public transport field. They found AHP-TOPSIS and F-AHP to be the most commonly used ones. Moreover, they propose strategies for improving sustainable urban public transportation. |
| [27] | 2021 | Sustainability assessment | Up to 2020 | Literature review | 280 | It surveys publications that apply MCDM to assess sustainability in seven different thematic fields, finding that energy is the field that applies this method the most. Transportation systems hold the fourth place, with 26 publications identified. |
| [21] | 2019 | Road transportation fuels and vehicles | Up to 2019 | Systematic reviews | 40 | This study analyzes MCDM application in road transportation fuels and vehicles. They propose the use of Life Cycle Sustainability Assessment (LCSA) as a basis for selecting criteria systematically. The predominant methods are WSM, TOPSIS, and AHP, in that order. |
| [25] | 2018 | Urban mobility | 2009–2016 | Systematic literature review | 19 | The paper discusses the application of F-AHP in the context of urban mobility systems. This method is more common in combination with other methods than individually. |

In regard to this exploration of previous literature reviews, there is only one review that addresses the same subject as this paper: the implementation of multi-criteria decision making in the decision making of urban logistics. This review, conducted by Jamshidi et al. [15], focuses on identifying and reviewing the criteria and multi-criteria approaches used to select sustainable alternatives in urban logistics.

However, it should be noted that this review by Jamshidi et al. [15] has certain limitations. First, it does not discuss the specific frameworks used in each publication. It also lacks information about the specific stage of the process at which each particular multi-criteria methodology is applied, which is essential to understand its practical application in urban logistics. Likewise, the review does not examine in more detail the stakeholders involved in decision making, nor does it classify nor identify the types of assessment alternatives that can be proposed to address the challenges of urban logistics. This literature review considers all these factors, and they constitute the differentiating factor of this work.

In this review, Jamshidi et al. only find five related publications, demonstrating the need to review the search strategy to identify other relevant papers in the field of study.

The literature review by Büyüközkan and Ilıcak [28] identifies some publications on smart urban logistics, and the authors indicate that the use of the multi-criteria analysis method in this type of research has been very uncommon. Likewise, in their literature review from 2000 to 2017, Jamshidi et al. [15] conclude that MCDM is not very commonly used for urban logistics planning, although other areas frequently apply this methodology. Danielis et al. [29] also state that multi-criteria analysis is not commonly used in city logistics policy evaluation.

Therefore, the analyzed literature reviews highlight the application of the multi-criteria methodology in urban logistics as a topic that has not been extensively covered and is beginning to emerge. The evolution of this research field has been significantly influenced

by recent events related to global warming and increased environmental awareness to address environmental challenges in urban logistics. At this point, MCDM plays an important role in supporting the search for sustainable solutions.

## 3. Literature Review Methodology

This section describes the methodology used for the systematic literature review, including three stages: identification of publications, descriptive analysis of the information, and, lastly, material classification and analysis to answer the research questions.

### *3.1. Stage I: Identification of Publications*

The first stage of this literature review consisted of identifying and selecting publications related to the research approach, conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. PRISMA is a valuable tool that allows for improving the quality of literature reviews and provides guidelines for aspects to be included, allowing the work to be replicable [30]. This process was carried out following a protocol previously published by the authors of this work in Alvarez and Maheut [31,32]. In addition, the guidelines provided by other studies, such as the work of Tricco et al. [33], were taken into consideration.

The main aspects taken into account in the protocol are the following [32]:

1. Selection of databases and information sources: Considered publications range from 2010 to 2022. Searches were carried out in the Scopus and Web of Science databases, restricted to journals and conference papers.
2. Keywords and key search terms definition: The search was conducted on the title, abstract, and keywords of publications, using the terms "urban logistics" and "multi-attribute" or "multi-criteria analysis", along with their related synonyms, words, and acronyms. Boolean logic was used to construct search equations.
3. Inclusion criteria: Papers that clearly applied the multi-criteria analysis methodology to evaluate urban freight logistics alternatives were included. Works that used multi-criteria methods to solve problems with a discrete set of options—i.e., a finite number of evaluation criteria and alternatives for solution— were considered.
4. Exclusion criteria: Systematic literature reviews, book chapters, theses, and publications focused on passenger transport logistics were excluded. Studies related to humanitarian logistics or risk assessment, such as flooding or landslides, were also excluded.
5. Relevant studies' selection: Once the database results were obtained, duplicates were removed. Inclusion and exclusion criteria were then applied, initially reviewing the title and abstract of the publications. In cases where it was unclear whether a publication was related to the required search, the full document was reviewed to finally select the works that focused on applying multi-criteria analysis methodologies to evaluate urban freight logistics alternatives.
6. Validation of the results obtained: A comparison was made to the only identified prior literature review related to urban freight logistics, published by Jamshidi et al. [15]. It was found that all the considered papers—published within the date range established in this study: between 2012 and 2020—matched the proposed search equation. Furthermore, an additional publication not included in the Web of Science or Scopus databases was identified. However, it was considered in the results obtained. This additional publication is the work of Parezanović et al. [34].

Validating the results using this comparison reinforces the reliability of the search equation used in this study. Including the additional publication in the results highlights the importance of considering supplementary sources beyond the initially selected databases.

The initial search provided a total of 412 works: 229 publications in Web of Science and 183 in Scopus. After removing 137 duplicate papers and adding a publication identified in a previous literature review by other authors, a set of 276 publications was obtained. Out of these, the full text of eight papers was unavailable, and thus they were excluded

from the analysis. The inclusion and exclusion criteria established in the study were then applied, leading to the final selection of 51 relevant publications. The main reason for exclusion was the lack of a research approach related to urban freight logistics, which left out 62% (165 papers) of the analyzed documents. This process of selecting and obtaining the relevant publications is illustrated in the PRISMA diagram shown in Figure 1.

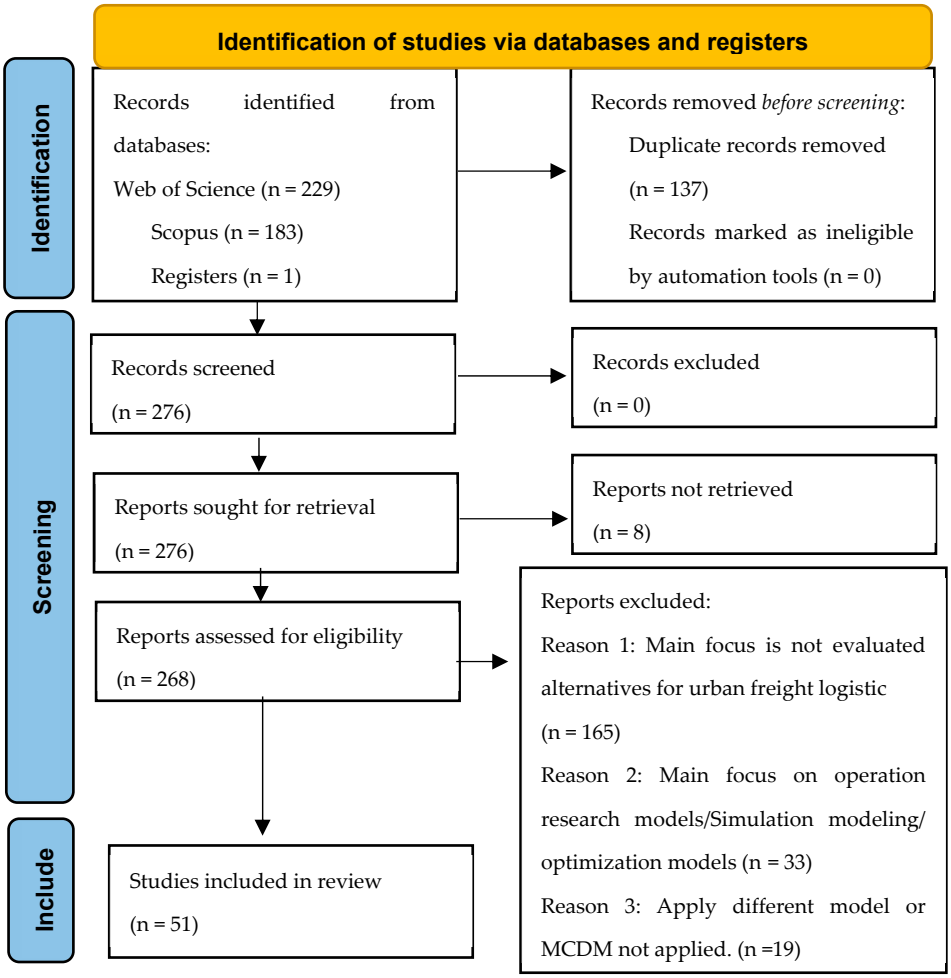


**Figure 1.** Flow diagram for paper selection [35].

### *3.2. Stage II: Descriptive Analysis of the Information*

This stage of the literature review entails performing a descriptive analysis of the information collected to obtain an overview of the results. In this regard, a bibliometric analysis is carried out using the R Bibliometrix software version 4.1.3, allowing the results to be analyzed and interpreted [36]. This analysis includes the identification of the most-cited authors and papers, the authors' institutional affiliation countries, and the number of publications per year.

### *3.3. Stage III: Classification and Analysis of the Information*

The main purpose of this stage is to answer the research questions proposed in the literature review. For this purpose, the analysis methodology of this literature review involved grouping, classifying, and categorizing different elements found in the selected studies. This process allowed performing a qualitative and quantitative synthesis of the results, identifying patterns and relationships, and obtaining a more complete understanding of the multi-criteria analysis subject applied to urban freight logistics. Subsequently, the results obtained are interpreted by discussing the implications of the findings in relation to the research questions.

The classification and analysis methodology used in this literature review in more detail was based on the following steps:

1. Objectives' grouping: The objectives defined in the selected publications were grouped into 12 thematic categories. This categorization made it possible to identify the main issues addressed in the literature reviewed.
2. Actors or interested parties' classification: The actors or interested parties mentioned in the selected studies were classified into 13 categories. This categorization helped to understand which actors engage in decision making in urban freight logistics.
3. Categorization of alternatives for solutions: The alternatives for solutions proposed in the selected studies were classified into 7 categories, which allowed the identification of common approaches and strategies used to address urban freight logistics challenges.
4. Qualitative synthesis of criteria: A qualitative synthesis of the criteria used in the selected studies was performed: they were linked to the research objectives and grouped by thematic categories. The most relevant criteria used to evaluate the proposed alternatives for solutions were identified.
5. Quantitative synthesis of MCDM methods: A quantitative synthesis of the MCDM methods used in the selected studies was performed, considering their implementation frequency. In addition, a correlation analysis was conducted between the methods used and the different research focal points, seeking to identify possible relationships between them.
6. Framework analysis: The common stages used throughout the research studies were identified.

## 4. Descriptive Analysis of the Information

In total, the results of the search were 51 publications. Regarding document types, most contributions are academic papers, which represent a total of 40 documents. Eleven papers were presented at conferences.

In addition, 34 different sources were found in the work selected for this literature review. Among these, seven main sources account for the largest number of papers. The sources with the highest number of publications were "Sustainability (Switzerland)" with seven papers and "Transportation Research Procedia" with six papers. Additionally, there were other relevant sources with a smaller number of publications, such as "Research in Transportation Economics", "Case Studies on Transport Policy", "Energies", "Journal of Cleaner Production", and "Transportation Research Part D: Transport and Environment".

### *4.1. Annual Scientific Production*

Figure 2 represents annual scientific production. According to this figure, during the first years (2012–2015), there was a small number of publications: only one to four papers per year. However, as of 2016, an increase in the number of publications can be seen, reaching a total of eight papers. This increase suggests a growing interest in the subject or study area addressed in these publications. As of 2017, the number of publications remains relatively stable, with slight variations in the following years (2019–2022). Although an increase in research has been observed in this field, it is important to note that the number of publications is still relatively low when compared to the importance and relevance of the topic.

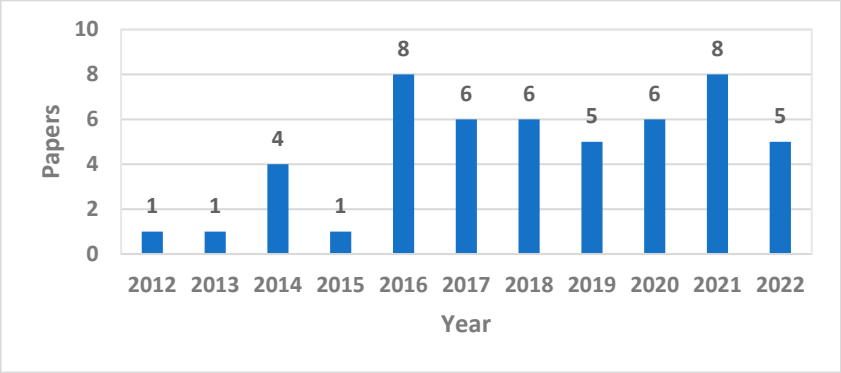


**Figure 2.** Papers' distribution by year of publication.

### *4.2. Authors with the Most Publications*

In the 51 articles selected in the literature review, 135 different authors have been identified. Among these, only one article stands out for being single authored, while the rest of the articles have been published in collaboration with multiple authors. This pattern is evident in the average and mode values: 2.7 authors per article and 4 authors, respectively, which suggests a clear tendency towards cooperation in the creation process of the articles under analysis. This tendency could be explained by the complexity of decision making in urban freight logistics.

Figure 3 shows the authors with two or more publications focusing on the implementation of MCDM methodologies to evaluate alternatives in the urban freight logistics field. Mladen Krstić and Snežana Tadić stand out as the most active authors, leading the list with seven papers each, which correspond to 13.73% of the total number of publications. They are followed by Cathy Macharis, who has also made a valuable contribution with six publications that account for 11.76%.

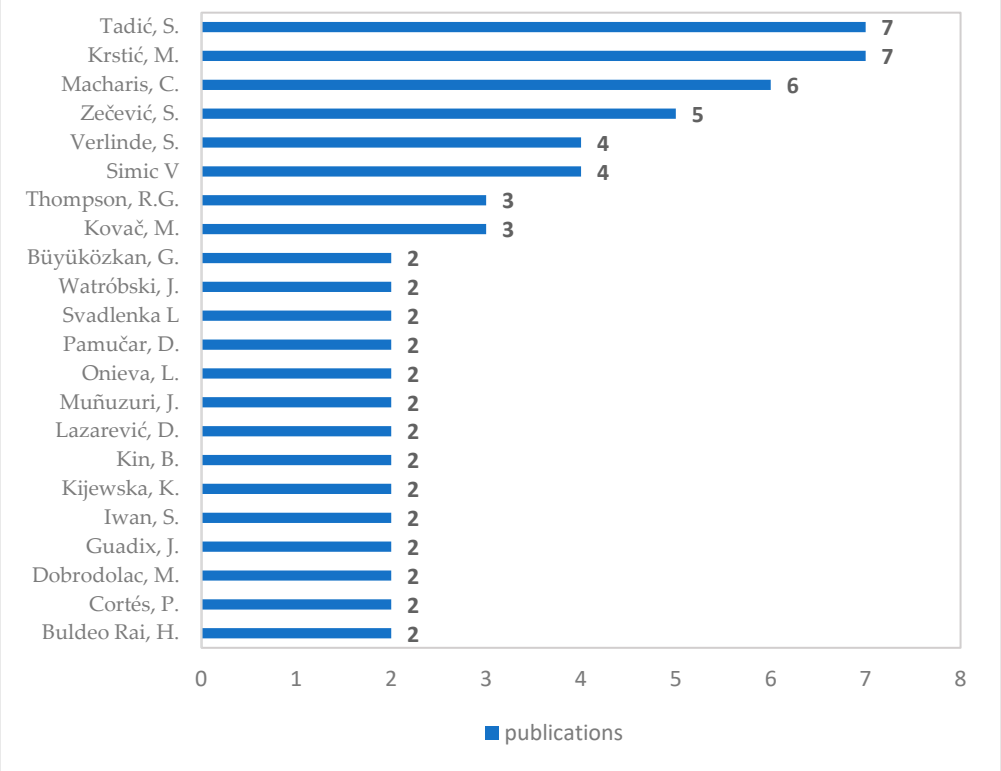


**Figure 3.** Number of publications per author.

### *4.3. Publications by Country and Continent*

When analyzing the data collected, it is evident that the highest proportion of contributions in the field of urban logistics comes from authors affiliated with European institutions, accounting for 68% of the publications reviewed. Serbia's contribution is particularly significant, with 13 publications. Snežana Tadić and Mladen Krstića are among the noted authors of this country. They have contributed to 7 out of 13 Serbian publications. Their research focuses on developing innovative and sustainable initiatives for urban logistics. Interestingly, they have used several multi-criteria methods to choose alternatives, albeit with a similar research focus. This suggests that there is no strong preference for a specific methodology and that researchers are exploring new evaluation methods.

On the other hand, Belgium has also made a notable contribution with six publications. In this case, the participation of the author Cathy Macharis, who has been involved in all these publications, stands out. She focuses exclusively on the application of the multi-actor multi-criteria analysis methodology. Her research covers topics such as applications for urban logistics sustainability, collaborative logistics (crowd logistics), freight transport in urban areas, after-hours deliveries, and the implementation of a mobile warehouse. It is important to note that Macharis is recognized as the pioneer in the development of this methodology.

In addition to the outstanding contributions from Serbia and Belgium, the participation of Turkey stands out with five contributions, followed by Australia, Brazil, the Czech Republic, Poland, and Spain, all with four contributions, respectively. It is also relevant to note that countries such as China, Italy, and the United States have three publications each, with authors affiliated with institutions in those countries. France and Greece are represented by two publications each.

### *4.4. Publications with the Highest Number of Citations Per Year*

Table 2 presents the publications selected in the literature review that exceed ten citations per year. This table includes relevant information such as the research approach, the number of citations received, and the MCDM methods used in each of them. The most-cited publication, by Tadić et al. [37], is particularly noteworthy. This work presents a fuzzy MCDM model that combines the following methodologies: Decision Making Trial and Evaluation Laboratory (DEMATEL), Fuzzy Analytical Network Process (F-ANP), and Fuzzy Višekriterijumska Optimizecija I Kompromisno Rešenje (F-VIKOR). In contrast to previous work that analyzed individual alternatives, this research from 2014 considers multiple alternatives.

In addition, the publications in the table include the paper by Simić et al. [38], with a rate of 10.3 citations per year, standing out as one of the most recent publications with the most citations (published in 2021). This paper proposes the Weighted Aggregated Sum Product Assessment (WASPAS) method under the Picture Fuzzy (PF) framework for assessing the last-mile delivery mode. According to the authors, this method allows any number of evaluation alternatives and defined criteria to be used.

In Table 2, the most relevant publications show a common approach in the implementation of fuzzy methods. All the selected papers apply at least one of the multi-criteria methods with a fuzzy approach. Likewise, the diversity of the methods utilized is notable. Fuzzy Technique for Order Preference by Similarity to an Ideal Solution (F-TOPSIS) was the only method to be repeated in other publications. However, it should be noted that it is never applied individually but is always combined with other methodologies such as AHP, F-AHP, DEMATEL, Fuzzy Entropy Weight (F-EW), and Preference Ranking Organization Method for Enrichment of Evaluations II (PROMETHEE II).

Using fuzzy methods in multi-criteria analysis can significantly impact the quality and efficiency of decision making in urban freight logistics. Concerning decision quality, fuzzy methods address uncertainty and imprecision in data in a constantly changing or difficult-to-predict urban environment [39]. Additionally, these methods facilitate the inclusion of the perceptions of stakeholders who have different opinions and that are often characterized

by information lacking precision, either obtained from experts or individuals with limited knowledge on the subject [40], which contributes to a higher degree of satisfaction in the choices made.

**Table 2.** Most-cited scientific papers, research focus, and MCDM method used.

| Paper | Research Focus | Citations | Citations/ Year | MCDM Fuzzy Model | AHP | F-EW, F-AHP | F-ANP | F-DEMATEL | F-VIKOR | F-TOPSIS | PROMETHEE II | PF-WASPAS | FMAGDM | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tadić et al. [37] | City logistics concept selection | 220 | 22.0 | | | | x | x | x | | | | | 3 |
| Rao et al. [41] | Logistics center location | 186 | 20.7 | | | | | | | | | | x | 1 |
| Awasthi and Chauhan [42] | Improvement of freight transport and reducing impact | 170 | 14.2 | | x | | | | | x | | | | 2 |
| Watróbski et al. [43] | Electric vehicles' assessment for freight transport | 81 | 11.6 | | | | | | | x | x | | | 2 |
| He et al. [44] | Shared distribution center location choice | 70 | 10.0 | | | x | | | | x | | | | 2 |
| Bandeira et al. [45] | Choice of sustainable configurations for freight transport | 67 | 11.2 | x | | | | | | | | | | 1 |
| Simić et al. [38] | Determination of the best sustainable last-mile delivery mode | 31 | 10.3 | | | | | | | | | x | | 1 |
| | Total | | | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | |

In terms of efficiency, they allow adaptation to rapid changes in urban conditions by considering fuzzy intervals instead of exact values, which results in more relevant solutions. In urban logistics, fuzzy multi-criteria decision-making methods offer advantages in complex and uncertain situations since the decision information provided by stakeholders is often fuzzy, making it essential to apply these techniques in decision-making processes.

## 5. Classification and Analysis of the Information Obtained from the Selected Publications

The following subsections answer the research questions raised in the literature review.

### *5.1. Objectives Proposed in the Definition of Public Policies for Urban Freight Logistics*

The objectives followed in the selected work were classified into 12 categories for identification. Table 3 shows the results below.

It is observed that 29% of the reviewed papers (15 publications) focus on defining integrated city logistics plans. They take into account aspects such as the environment and the efficiency and quality of services, which entail a combination of sustainable alternatives for solutions.

The second most-recurring objective—registered in 11 publications—is evaluating types of vehicles suitable for city logistics operations. This objective is related to evaluating environmentally friendly vehicles or selecting the type of transport for freight delivery, particularly traditional land transport, bicycles, and drones.

**Table 3.** Objectives defined in the selected publications, categorized by publication year.

| No. | Objective | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | Overall Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Evaluate comprehensive city logistics proposal | | | 3 | | 1 | 3 | 1 | 2 | 1 | 3 | | 15 |
| 2 | Evaluate vehicle types | | | | | | 2 | 1 | 2 | 2 | 3 | | 11 |
| 3 | Select a logistics center location | | 1 | | 1 | | 1 | 1 | | 3 | | | 9 |
| 4 | Improve city freight transport and its impact | 1 | | | | 3 | | 2 | | | | | 7 |
| 5 | Evaluate after-hours deliveries | | | | | 1 | | | 1 | | | | 2 |
| 6 | Determine delivery routes to reduce impact | | | | | 1 | | | | | | | 1 |
| 7 | Establish truck tolling schemes in urban areas | | | | | | | | | | 1 | | 1 |
| 8 | Evaluate the impact of implementing an operational shared logistics platform on parcel delivery | | | | | | | 1 | | | | | 1 |
| 9 | Evaluate the concept of load sharing | | | | | 1 | | | | | | | 1 |
| 10 | Evaluate the use of mobile warehouse implementation | | | 1 | | | | | | | | | 1 |
| 11 | Evaluating policy measures to support electrical freight vehicles | | | | | 1 | | | | | | | 1 |
| 12 | Propose a city logistics scheme with drones | | | | | | | | | | 1 | | 1 |
| | Overall total | 1 | 1 | 4 | 1 | 8 | 6 | 6 | 5 | 6 | 8 | 0 | 51 |

Other relevant objectives include selecting logistics center locations (nine publications) and improving freight transport in the city (seven publications). These objectives concern reduction of the negative impact on the environment, reduction of flows, solutions to accessibility and parking issues, and overall optimization of transport systems, including electrical vehicle usage.

In addition, there were publications with the following objectives: evaluating after-hours delivery alternatives (two publications), determining delivery routes to reduce impact, evaluating the use of mobile warehouse implementation, evaluating the shared load concept, evaluating policy measures intended to support battery electric freight vehicles, evaluating the impact of implementing a shared logistics platform on last-mile parcel delivery, establishing truck tolling schemes in urban areas and evaluating a city logistics proposal using drones. Each of these objectives was considered in a publication.

Finally, it should be noted that 2021 and 2016 were the years that supplied the most publications aligned with the purpose of the research, both with a contribution of eight publications per year.

### *5.2. Stakeholders or Interested Parties That Participate in Decision Making for Urban Freight Logistics*

Table 4 shows the stakeholders involved in the evaluation of urban logistics' alternatives for solutions. The most-mentioned stakeholders (30 out of 51 publications) are public administrators as representatives of government authorities, which can be explained because they are aware of the public sector projections and interests in terms of city logistics. These circumstances make their participation essential for the decision to be viable.

Following in order as per the number of publications featuring them, the most relevant stakeholders are companies receiving goods, end consumers, people living in urban areas, transport operators or carriers, logistics service providers, and consultants or experts.

Among the articles selected in this literature review, there were seven publications lacking details about the type of stakeholder involved in the evaluation of alternatives for solutions. However, it is important to note that it would be beneficial to include this information in the publications, as it would provide the reader with a more accurate contextualization for the analysis process carried out in each article.

**Table 4.** Stakeholders involved in the decision-making process of the paper.

| Stakeholders Involved in the Decision-Making Process of the Paper | Total Number of Publications |
|---|---|
| Public administrators, local authorities | 30 |
| Recipients: retailers, merchants, stores, local businesses | 24 |
| End consumers: citizens, residents, or people who work in the area | 23 |
| Transport operators or carriers | 19 |
| Logistics service providers | 14 |
| Logistics and transportation consultants and experts | 14 |
| Scholars | 9 |
| Forwarders: wholesalers | 7 |
| Information technology service providers | 2 |
| Industrial and commercial chambers and associations | 2 |
| Infrastructure and logistics facility providers | 1 |
| Toll operators | 1 |

### *5.3. Criteria Considered for the Evaluation of Alternatives in Urban Freight Logistics*

In this study, in the 11 selected publications whose primary objective is to evaluate the type of freight transport vehicle best suited for urban areas, several fundamental criteria have been taken into account for the analysis of possible alternatives. These criteria encompass key aspects related to vehicle performance, purchase price, operation and maintenance costs, warranties offered, characteristics of the batteries, technical aspects of the engine, weight of the vehicle, cargo volume, fuel consumption, logistics system profitability, and service time.

On the other hand, one of the evaluated publications [46] performs a selection of differentiated criteria according to the type of actors involved in the evaluation of various configurations of sustainable fleets for consolidated deliveries. These criteria are based on the specific needs and interests of each actor.

Furthermore, other publications focus on the choice of sustainable or new technology transport modes for the city center. To that end, criteria have been classified into different categories. From an economic point of view, criteria such as shipping costs, delivery time, economic savings, required investment, and load optimization are considered. The social dimension considers criteria such as public safety, occupational health, public health, employment opportunities, and road use. In environmental terms, criteria such as environmental, noise, and visual pollution, as well as compliance with current legislation, are evaluated [38,47,48]. Lastly, criteria such as service availability, flexibility, and urban impact are considered in the technical aspect [38].

In the 22 publications selected in the literature review related to the choice of an urban freight logistics model or solutions for freight transport improvement and the minimization of its impact, it was observed that the used evaluation criteria include economic, environmental, and social aspects in most cases. Other studies include spatial, technical, operational, political, or legal aspects, where the actors participating in the analysis define different evaluation criteria according to the specific alternatives to be evaluated and the interests of the parties. Criteria defined at a general level include: sustainable transport, congestion, freeing public spaces, vehicle load factor and cargo volume, vehicle architecture and associated ICT, investment for development and control, fleet acquisition cost, insurance and taxes, operational costs, road pricing, revenue, freight shipping costs, delivery and waiting time, quality of logistics service—efficiency, effectiveness, flexibility, reliability, and accuracy of delivery—air pollution, waste generation, energy saving, noise and vibration, road and occupational safety aspect, operation complexity, connectivity, degree of integration, feasibility of implementation, intermodal transportation, land use, customer coverage, flow of goods transformation degree and impact on attractiveness, development and effectiveness for the city, implementation time, maintenance cost, specialized technical requirements, requirement for synergy among all interested parties, freight consolidation possibility, adequate facilities, infrastructure utilization, existing policies and actions, con-

sistency with urban planning, proposal accessibility on physical terms, regulatory and organizational aspects, fiscal benefits, employee satisfaction, and competitive advantage.

Sgura et al.'s [49] publication can be found among the work that contributes to the definition of city logistic strategies. In their work, they use multi-criteria analysis combined with geographic information systems, which defines evaluation factors of operational delivery characteristics in terms of frequency, schedules, and spaces for loading and unloading, establishments' typology, transportation mode/vehicle type, road design and characteristics, and inventory behavior. Likewise, Büyüközkan and Mukul's research [39] determines customer requirements, such as road user charges, lane management, public transport priority, parking orientation, travel and traffic information, network robustness, and road safety and traceability.

Furthermore, some papers define criteria for each stakeholder involved in decision making and their corresponding evaluation indicators [50–54]. In these cases, the Multi-Actor Multi-Criteria Analysis (MAMCA) method was used.

The nine papers whose objective is choosing a logistic center location propose the following analysis criteria: conditions and possibility of land expansion, resources' availability, suitability for construction, market accessibility, social impact on urban traffic, acceptability to the local community, contribution to employment, architectural impacts, proximity to the city, proximity to transportation systems and logistics exchange centers, suppliers and customers, availability of cargo bikes, environmental impact on energy use, waste, noise, visual pollution, natural conditions, operation, intermodal transport management and connectivity, investment and transport costs, accessibility to labor, contribution to economic development, political, economic, and social stability, safety, condition of public facilities, compliance with legal standards and environmental regulations, accident risk and safety, parking facilities, existing infrastructure, use of technology, and service level.

### *5.4. Categories of Alternatives for Solutions*

The urban freight logistics alternatives for solutions that were evaluated in the selected publications were grouped into the eight categories described below:

Organizational: Involves operational decisions of transport companies or shippers, including the definition of both centralized and decentralized storage systems, development and implementation of intermodal transport [37], use of urban mobile warehouses for deliveries and pickups [55–58], micro-hubs in parking lots [59], route planning for vehicles [47,60,61], after-hours deliveries, [51,59,62,63], overnight deliveries [52,53,61,64,65], use of shared vehicles or deliveries [50,52,54,65–67], supply consolidation [34,46,68], crowdsourcing [58,69], location alternatives for freight distribution centers [41,44,70–75], and load unit standardization [74].

Technological development: Seeks to promote innovative technology implementation strategies, which include the connection of information on transported goods and delivery locations with road traffic data, implementation of web-based tools to optimize distribution flows [52], grouping flows using web platforms [50,68], infrastructure for the implementation of vehicle access restriction, systems for logistics management and route optimization [61], surveillance systems to allow vehicle inspection [49], freight transport communication systems [67], demand and access management systems, traffic management systems, safety and emergency systems, smart public transportation systems, lane management systems, parking management systems, road and weather tracking sensors, electronic detection systems [39], and introduction of new technologies into existing logistics systems [76].

Public administration measures: Strategic solutions defined by local authorities, such as the plan for urban freight transport and distribution, labor organizations and collaboration among actors for the definition of transport projects, urban planning considering sustainable transport [52], lane assignment for freight transport [61,64], implementation and strategic plan for freight delivery in low-emission zones [34,64,77,78], bike lanes [77], online booking of loading zones [65], registration required for usage of unloading zones [50],

suspension of diesel financial support [77], collaborative governmental policies [67], and optimization and integration of business operations and defined public restrictions [78].

Information and campaigns: Related to communication and training to support sustainable urban freight logistics, sustainable transportation awareness campaigns, eco-driving training, designated routes and relevant road information for trucks such as maps and road signs [52,61], social communication channels, environmental education [67], information about electric freight vehicle costs, related government benefits, or their financing [77].

Incentives: Involve every decision that motivates the private sector to use low-emission urban transport, such as incentives related to loading, unloading, and transit for environmentally responsible transport companies, financing systems for vehicle purchases, recognition or certification labels for companies that use environmentally friendly vehicles [52,77], exemption from road pricing for electric vehicles [53], electric vehicles' usage incentives, alternative fuel financial support [67], access privileges for electric vehicles during night-time or in low-noise and zero-emission areas, support for electric vehicle projects, and rigorousness in electric vehicle tenders [77].

Restrictive: Defined regulation to reduce the negative social and environmental impact of urban logistics, including measures such as monitoring the vehicle's load factor [64], urban toll collection [53,55,64,65,67], toll schemes [79], congestion charge schedules, vehicle size restrictions [42], restrictions on loading/unloading and transit access to the area [49,52,64], spatial and temporal constraints [61], installation of parking meters in urban areas [54], time windows for access to the city center, police control to ensure carriers follow regulations [65], passenger vehicle restriction, freight vehicle restriction, parking restriction, low-occupancy vehicle restriction [67].

Means and type of transportation: Involve means of transportation and typology of vehicles used, such as the use of cargo trams and electric vehicles [37,69,76], choice of environmentally friendly vehicle types for urban logistics [43,45,46,53,58,76,80,81], evaluation of light commercial vehicles from different manufacturers [82], bicycle distribution [38,46–48,52,56,58,69,83], cargo bike configuration alternatives [84], non-motorized vehicles [59], drone deliveries [38,47,48,56–58,69], rail and land shared transport in urban areas [58,66], intermodal distribution [45,57,58], self-driving delivery vehicles [48,69], freight forwarding in urban public transportation [38,56,67], use of electric freight vehicles [77,85], specialized aircraft for freight delivery [57,58], river transport [58].

Infrastructure: Involves the physical adaptation necessary for the development of urban logistics, including the assembly of cargo infrastructure, repair shop assembly and services [77], use of consolidation and deconsolidation or urban distribution centers [34,37,42,50,51,53,61,62,65,67,74,78,86], micro consolidation centers [57,58,77,87], urban logistics platform [59], package lockers [38,50,58,61,67,69], intermodal terminal modernization, city logistics terminal development, relocation of ports and rail stations [76], underground parking [67], underground logistics systems [57,58,74].

### *5.5. Multi-Criteria Analysis Methods Used*

The multi-criteria methods used for the evaluation of urban freight logistics alternatives for solutions in the publications in this literature review were: Forces Decision Matrix Method (FDMM), Decision Making Trial and Evaluation Laboratory (DEMATEL), Fuzzy Decision Making Trial and Evaluation Laboratory (F-DEMATEL), Fuzzy Analytical Network Process (F-ANP), Višekriterijumska Optimizacija i kompromisno Rešenje (VIKOR), F-VIKOR, Multi-Actor Multi-Criteria Analysis (MAMCA), interactive MAMCA, Fuzzy Technique for Order Preference by Similarity to an Ideal Solution (F-TOPSIS), Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), Weighted Linear Combination (WLC), Combinative Distance-Based Assessment (CODAS), Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE), Group Decision Support Systems (GDSSs), Best–Worst Method (BWM), Evaluation based on Distance from Average Solution (EDAS), Weighted Sum Approach (WSA), Defining Interrelationships Between

Ranked Criteria (DIBR), Stepwise Weight Assessment Ratio Analysis (SWARA), F-SWARA, Fuzzy Analytic Hierarchy Process (F-AHP), Analytic Hierarchy Process (AHP), discrete choice methods, Simple Additive Weighting (SAW), Fuzzy Simple Additive Weighting (F-SAW), Extent Analysis Method (EAM), hierarchical decision structure, Picture Fuzzy Sets (PFSs), Criteria Importance Through Intercriteria Correlation (CRITIC), Characteristic Objects Method (COMET), Fuzzy Multi-Attribute Group Decision Making (F-MAGDM), Fuzzy Entropy Weight (F-EW), Picture Fuzzy Weighted Aggregated Sum Product Assessment (PF-WASPAS), Spherical Fuzzy Measurement of Alternatives and Ranking according to Compromise Solution (SF-MARCOS), Fuzzy Factor Relationship (F-FARE), Spherical Fuzzy Sets (SFSs), Picture Fuzzy Combined Compromise Solution (PF-CoCoSo) and Type-2 Neutrosophic Numbers Combined Compromise Solution (T2NNs CoCoSo), Picture Fuzzy Criteria Weighting (PF-Criteria Weighting), Fuzzy MCDM (F-MCDM), and Fuzzy Multi-Attribute Group Decision Making (FMAGDM).

From the abovementioned methods, AHP and F-AHP—peer comparison methods—are the most frequently applied ones. They account for 31% of the selected papers. The majority of them (13 out of 16 publications) combine AHP and F-AHP with other multi-criteria methods, mainly with F-TOPSIS, MAMCA, and one each with DEMATEL, SWARA, WLC, PROMETHEE, EW, EAM, WSA, and F-MCDM.

It should be considered that the AHP method becomes exponentially more complex as the number of criteria and alternatives increases [64], and decisions taken do not consider the interdependency of factors [52]. For its part, the F-AHP method can practically only be used if the number of criteria and alternatives is low enough [34]; therefore, in certain cases, it is advisable to combine it with other methods to overcome its shortcomings.

The second most used method in decision-making method is MAMCA, with 24% of the total number of publications. This method considers the different viewpoints of the stakeholders independently, taking into account that it is not recommended to analyze generic interest groups as they would not provide fully accurate conclusions. Thus, segmentation into smaller stakeholder groups is important [54]. Out of the 12 publications that apply this methodology, 6 combine them with other methods, such as the AHP tool, as well as DEMATEL and PROMETHEE. Other publications combine different methodologies that complement decision making based on the alternative to be evaluated, as is the case of Cruz-Daraviña and Bocarejo Suescun [59] who combine parking supply and demand analysis and loading and unloading performance analysis or level of service analysis to evaluate strategies to improve land use.

Literature analysis also shows that the choice of the MAMCA method is linked to its authors. Such is the case of Cathy Macharis, the author of 6 of 12 of the publications where this method was identified, which is to be expected given that she is the one who developed MAMCA as an analysis tool. Arguably, the selection of a multi-criteria method can often be driven by the decision maker's knowledge of a given method or by the availability of the software required for its application [88].

Finally, the distance-based methods F-TOPSIS and F-VIKOR come third and fourth as the most-used multi-criteria analysis methodologies, respectively.

It should be noted that 51% of the total number of publications are developed with hybrid multi-criteria methodologies, showing the authors' great interest in improving the efficiency of the application of these methods.

Table 5 shows the selected work, the central focus of each publication in urban freight logistics, and the respective analysis methods or tools applied. It was not possible to identify a direct correlation between the decision problem to be analyzed and the multi-criteria methods used since different methods were used for similar research focuses. For the method choice, it is advisable to consider the data diversity of the criteria (types, scale of measurement, among others). For instance, if data are uncertain (non-deterministic), analysis can be approached with fuzzy methods [89].

**Table 5.** Research focus and methods used at different stages of alternative analysis in the selected publications.

| Paper | Research Focus | Relationship between Criteria and/or Weights | Evaluation/Ranking of Alternatives | Other Methods or Tools |
|---|---|---|---|---|
| [37] | City logistics concept | F-ANP, F-DEMATEL | F-VIKOR | |
| [42] | Freight transport and reducing impact | AHP | F-TOPSIS | |
| [55] | Mobile warehouse implementation | MAMCA | PROMETHEE-GDSS | |
| [43] | Type of electric vehicles | F-TOPSIS<br>PROMETHEE II | F-TOPSIS<br>PROMETHEE II | |
| [60] | City delivery routes to reduce impact | WLC | | Dijkstra algorithm |
| [62] | After-hours delivery in LEZ | Interactive MAMCA | Interactive MAMCA | |
| [52] | Reducing transport negative impact | AHP, DEMATEL | AHP, DEMATEL | |
| [66] | Load sharing in rail and land transport modes | MAMCA, AHP | MAMCA | |
| [53] | Streamline freight transport to reduce emissions | MAMCA | MAMCA | |
| [76] | Streamline processes and create an efficient logistics system | F-AHP | F-TOPSIS | |
| [63] | Support for after-hours urban deliveries | MAMCA | PROMETHEE-GDSS | |
| [61] | Sustainable urban freight logistics plan | Unspecified | Unspecified | |
| [73] | Logistics center location | BWM | EDAS | |
| [64] | Sustainability of CL political initiatives | F-AHP | F-SWARA | Delphi method |
| [80] | Vehicle type assessment | AHP | WSA | |
| [54]. | Retail parking and accessibility | MAMCA | MAMCA | |
| [49] | City division strategies | AHP, WLC | AHP, WLC | GIS |
| [86] | Logistics center location | DEMATEL, F-TOPSIS | F-TOPSIS | |
| [81] | Types of electric vehicles for businesses | SAW | VIKOR | 2-Tuple linguistic |
| [82] | Vehicle type | FDMM | FDMM | |
| [65] | Urban transport solutions | Discrete choice methods | | Nested logit model |
| [34] | Sustainable city logistics measures | AHP | F-TOPSIS | |
| [46] | Sustainable fleet configuration for consolidated delivery | MAMCA, EAM F-AHP | MAMCA, PROMETHEE | |
| [45] | Sustainable transport configurations | Fuzzy multi-criteria model | Fuzzy multi-criteria model | |
| [51] | Urban freight distribution alternatives | MAMCA, AHP | MAMCA | |
| [50] | Urban freight distribution sustainability | MAMCA | MAMCA | |
| [77] | Policies to support electric freight vehicles | Unspecified | Unspecified | |
| [70] | Logistics center location | Hierarchical decision structure | | Statistical techniques |
| [68] | Impact of a shared logistics platform | MAMCA, AHP | MAMCA | |
| [71] | Logistics center location | AHP | F-TOPSIS | |
| [72] | Logistics center location | F-MCDM | F-MCDM | |
| [56] | Sustainable last-mile delivery mode | PF -Criteria Weighting | PF- CoCoSo | |
| [83] | Electric bicycle types for urban transport | COMET | COMET | |
| [39] | Smart city logistic solutions | F-SAW | | House of Quality matrix |
| [74] | Infrastructure initiatives | F-Delphi | F-VIKOR | |
| [85] | Transport system optimization | AHP | AHP | |
| [59] | Loading and unloading operations | MAMCA | MAMCA | Parking analysis, level of service analysis |

**Table 5.** *Cont.*

| Paper | Research Focus | Relationship between Criteria and/or Weights | Evaluation/Ranking of Alternatives | Other Methods or Tools |
|---|---|---|---|---|
| [41] | Logistics center location | FMAGDM | FMAGDM | |
| [44] | Logistics center location | F-EW, F-AHP | F-TOPSIS | |
| [38] | Sustainable delivery mode | PF-WASPAS | PF-WASPAS | |
| [84] | Modular electric cargo bikes | TOPSIS | TOPSIS | |
| [79] | Truck toll levels | MAMCA | MAMCA | |
| [47] | Modes of transport and appropriate routes | AHP | AHP | |
| [67] | Integrated transportation of freight and passengers | AHP | AHP | |
| [57] | Drone-based CL concepts | SFS | SF-MARCOS | SWAM |
| [75] | Urban distribution center location | F-SWARA, F-Entropy | F-VIKOR | CATWOE |
| [78] | Freight transport efficiency and sustainability | DIBR | T2NNs CoCoSo | |
| [69] | Industry 4.0 technologies applicable to CL | BWM | CODAS | |
| [87] | Micro-hub location | BWM, CRITIC | WASPAS | |
| [48] | Modern transport technologies | Unspecified | Unspecified | |
| [58] | Last-mile sustainable solutions | F-FARE | F-VIKOR | F-Delphi |

Additionally, Table 5 details the multi-criteria methods used at different stages of the alternative analysis. These methods are utilized in the phase of identifying the relationship between criteria and their weights, as well as in the classification and final selection of alternatives.

### *5.6. Frameworks Developed to Support Decision Making*

The first stage of the frameworks developed in most of the selected works consists of the preselection of alternatives for solutions and the respective definition of evaluation criteria. In the case of the MAMCA method, this stage involves the determination of all relevant stakeholders and their objectives, which are converted into criteria.

Likewise, the publications all have the following step in common: weights of criteria by the interested parties, using different methods such as EAM, F-AHP, MAMCA, F-SWARA, F-AHP, SAW, F-FARE, DIBR, BWM, and CRITIC. Some apply the DEMATEL method to analyze interdependencies between factors or criteria. It should be noted that publications that use hybrid methods, including AHP, use these methods mainly for the weights of criteria, which is consistent with the findings presented in the literature review by Moslem et al. [18].

Finally, for the assessment of alternatives, any MCDA method could be applied to perform the analysis of possible scenarios, such as the PROMETHEE method—indicating how one alternative is preferred over another one [46,55]—and the SF-MARCOS method.

For those who handle hybrid methods, including VIKOR [37,42], TOPSIS, CODAS, EDAS, and WASPAS methods, these are usually used in the final stage to rank alternatives and ultimately choose the most suitable option.

There are also some publications that, once the final choice has been made, perform a sensitivity analysis with modifications on the weights of criteria according to a recommended strategy to verify the stability and cogency of the results obtained and to overcome possible biases [42,46,48,51,71,73,75,85]. Other publications make comparisons with the implementation of other methods [44].

## 6. Discussion and Conclusions

Urban logistics is increasingly gaining interest due to its impact on the economy and its influence on the competitiveness of organizations. This increase in interest is also explained by the need to reduce urban logistics' impact, which has made stakeholders increasingly

interested in defining strategies to improve it. In this respect, multi-criteria analysis can play an important role as a decision-making tool to obtain more appropriate results with less bias since it considers all the criteria or factors that influence the decision-making process.

This paper provides a comprehensive literature review in the field of MCDM in urban freight logistics. By applying a rigorous protocol, 51 publications covering the period from 2012 to 2022 were analyzed.

This review identified prominent publications, the main authors in the field, and their countries of affiliation. In addition, the impact in the literature of the publications over the years under study was analyzed.

After analyzing the information gathered, the following conclusions were reached. Although there is great potential in the applicability of the MCDM methodology in urban freight logistics, the literature review results suggest that this topic still requires further exploration, making it a promising field for future research. In addition, a relatively low number of publications is observed, which remains very stable throughout 2016 up to 2022.

Among the actors involved in decision making in the selected work, the frequent participation of local authorities is noteworthy. It is essential to consider that these authorities have extensive knowledge, decision-making power, and regulatory influence, making them a critical factor to consider.

The evaluation criteria defined in a multi-criteria analysis are related to the pursued objective or the intended decision, and they also depend on the stakeholders considering them. Usually, local authorities are more concerned with environmental and social criteria, while transport service providers clearly prefer economic and operational aspects that allow them to improve their efficiency. However, the criteria may vary and include other criteria depending on the specific context being evaluated, also considering technological, legal, and spatial matters.

The publications allowed the identification of several alternatives for solutions proposed for the improvement of urban logistics, including organizational measures, advances in technological development, urban logistics planning actions by the authorities, information campaigns, incentives, restrictions, choice of means and type of transportation used for freight forwarding, as well as the necessary infrastructure requirements, showing that new and improved solution options are increasingly being chosen, which adds complexity to decision making.

Based on the identified publications, the most widely used multi-criteria analyses in urban logistics are AHP and F-AHP, in most cases combined with other methods to mitigate their shortcomings. MAMCA is the second most used method, highlighting the importance of stakeholder participation in decision making for this type of analysis.

According to the analysis of the results, there is a broad interest in using fuzzy and combined or hybrid multi-criteria methods to improve the results obtained. Fuzzy methods are recurrent in urban logistics decision making, where the criteria assessment carried out by evaluators is often subjective or inexact.

It is evident that there is no correlation between the objectives pursued in the solution of urban logistics problems and the selected MCDM method, i.e., different multi-criteria analysis methods were proposed for the same research approach. This conclusion concurs with Kornyshova and Salinesi's (2007) statements [88]: they indicate that it is not possible to define a single method for a choice of alternatives problem, but that it must be chosen taking into consideration all the details and specific information available on the situation to be solved.

The general framework used by the selected studies to develop the multi-criteria methodology consists of the following steps:

- Definition of the problem, including objectives and possible alternatives for solutions;
- Identification of evaluation criteria;
- Criteria weights;
- Classification or ranking of alternatives by analyzing possible scenarios;
- Sensitivity analysis;

- Definitive choice of the most appropriate alternative for solutions considering the results obtained.

While this paper successfully conducted the proposed literature review, there were some limitations. First, although the search equation covers multi-criteria analysis and its correlated concepts, it does not explicitly incorporate the distinctive terms of the various existing multi-criteria methods. This omission could result in excluding some publications that employ such methods, as they may lack the terms "multi-criteria analysis" or other related expressions in their titles, abstracts, or keywords. Moreover, the literature review could be extended to years prior to 2012, which would allow considering how the application of these methodologies in urban freight logistics has evolved.

On that note, it is suggested to broaden the literature search by gathering additional data from other databases to find other relevant publications. It is also advisable to include books and doctoral work.

For future research, it is recommended to conduct a thorough analysis that examines in detail the advantages and disadvantages of MCDM methods for the evaluation of alternatives in the urban logistics field. It would be valuable to identify the advisable method combinations and the specific cases where their application is suggested. Furthermore, it is important to determine another possible line of future research: the review of the relevance and rationale behind the choice of criteria in various studies. The objective would be to develop a protocol that can be proposed to decision makers, thus ensuring a fair and comprehensive evaluation of the alternatives under consideration. Additionally, it is suggested to explore the criteria analysis and its assignment of values—either qualitative or quantitative—within the framework of a multi-criteria approach. This approach would require thoroughly considering the nature of the problem and the alternatives for solutions under evaluation. The primary purpose would be to identify when it is appropriate to use a specific type of value and what the results would be in terms of the effectiveness of the analysis.

Likewise, it would also be interesting to conduct an exhaustive literature review on the application of multi-criteria analysis in urban logistics, covering both freight and passenger transport. This review would allow a comparative analysis between both approaches, identifying divergences in objectives, alternatives for solutions, decision criteria, and methods used. In addition, this review would make it possible to identify the possible consequences of certain decisions in these specific contexts.

These potential future research lines could contribute to the urban logistics field and provide additional guidelines for evaluation of alternatives in this context.

The most remarkable contribution of the authors of this literature review is their proposal of seven categories to classify the alternatives for solutions in the urban freight logistics context. These categories have the potential to be applied in related research, and they are as follows: (1) organizational and operational solutions, (2) technological development, (3) public administration measures, (4) infrastructure, (5) informative strategies and campaigns, (6) incentives and restrictions, and (7) means and type of transportation.

**Author Contributions:** Both authors collaborated in developing the methodology, formulating the research questions, and defining the scope of the systematic literature review. S.A.G. conducted the literature review and drafted the manuscript under the guidance of J.M. J.M. performed the final review, approved the final version, and made significant contributions to its editing. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Conflicts of Interest:** The authors declare no conflict of interest.

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