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Multicriteria evaluation of sustainability in last-mile logistics: a review

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Abstract
As cities continue to grow, there is a pressing need to enhance the quality of life for citizens while also tackling challenges such as the rising demand for urban freight deliveries and environmental sustainability goals. However, the competition between people and goods for limited space in urban areas creates pressure on local authorities and piques the interest of consultants and researchers. This study examines how sustainability is tackled when decision-makers and stakeholders assess alternative solutions with multi-criteria methods in different urban logistics contexts. A multi-step systematic review has been performed to examine the use of multi-criteria analysis in the specific multidisciplinary sector of urban freight logistics and how sustainability is defined and pursued by identifying 56 papers published between 2011 and 2023 addressing problems related to sustainable urban logistics solutions. Despite the growing number of applications and scientific publications, a standard methodological framework is lacking in selecting methods and criteria to evaluate sustainable logistics solutions. To fill this gap, this paper aims to map the problems addressed and the methods applied, the stakeholders involved as actors, their objectives, and the criteria chosen to support their choices. This paper investigates the decision-making process, actors and sources, and which criteria are chosen when the intent is to pursue sustainable solutions. Future research could delve deeper into the weighting process among criteria to elucidate the coherence between stated goals and actual decisions. Such research could offer valuable insights into how decisions are made and help identify areas for improvement.

1. Introduction

The continuous development of cities worldwide puts their authorities in front of the need to improve the quality of life while facing the downsides of population growth and related economic and social activities. According to the United Nations (UN) prospects, the world's population is now around 8 billion. It is expected to reach 9.7 billion in 2050 (UN Department of Economic and Social Affairs, 2022), with 68% living in urban areas (UN, Department of

Economic and Social Affairs, 2019). Each urban context is indeed unique, and the panorama is very heterogeneous. Still, common issues are linked to urbanization and the growth of people and goods flows in the cities worldwide.

With a higher demand for goods comes the need to deliver them to urban shops or final consumers. However, increased freight and commercial vehicles usually lead to higher traffic congestion and emissions levels (Bosona, 2020). In the European context, urban freight transport represents the most polluting part of the overall transport emissions (Dablanc, 2007), and it is a significant issue given that the transport sector accounts for one-quarter of total greenhouse gas emissions with 7.98 Gt of CO_2 in 2022[1] (IEA, 2023a), and road-related emissions represent the vast majority of the abovementioned transport emissions[2] (IEA, 2023b).

The term "sustainable development" became popular in the UN policy-making debate in the 80s after the work of the Brundtland Commission and the final report delivered in 1987 (Brundtland, 1987). One of the first globally known definitions was provided at the UN Conference on Environment and Development in Rio in 1992 as a multidimensional concept based on social equity, economic growth, and environmental protection (Drexhage & Murphy, 2010). Another fundamental step has been made in the 2030 agenda for sustainable development (UN General Assembly, 2015), in which the UN defined the 17 Sustainable Development Goals (SDGs). There is an ongoing debate about the hierarchy between the three dimensions. Some propose a pyramidal structure with the environment at the foundation as a necessary priority for other societal and economic systems (Obrecht et al., 2021). Others want to exceed the clear separations within these dimensions (Purvis et al., 2019). There is a common understanding of the interdependence of these three pillars, but the concept of three-bottom-line sustainable development is still vague and uncertain nowadays.

Since the beginning of the 2000s, transport studies started to refer to deliveries in urban contexts with the use of alternative words as "last-mile logistics", "urban logistics", and "city logistics", to refer to the physical distribution of goods concerning a set of objectives, such as cost-effectiveness of services and urban sustainable development in the frame of a market economy, with the support of advanced information systems and considering traffic congestion, the traffic safety and the energy consumption as critical aspects to improve (Taniguchi et al., 2001; Taniguchi, 2014). The main problems in last-mile logistics are represented by operational challenges, cost and efficiency issues, environmental and sustainability concerns, and regulatory issues. Operational challenges are represented by traffic congestion, as delivery vehicles face the downsides of congested urban streets, especially in peak hours; moreover, they are part of the congestion itself (Savelsbergh & Van Woensel, 2016). Another problem is the shortage of dedicated parking and loading space in cities (Dablanc, 2007) There are some inefficiencies, such as the low utilization rate, with vehicles often operating below capacity due to small individual deliveries (Olsson et al., 2019), inefficient routing, and more demanding delivery preferences, with a growing demand for deliveries directly to homes and with more flexibility (McKinnon, 2016). These inefficiencies lead to high delivery costs and environmental impact, with increased polluting emissions (Allen et al., 2018). Logistics activities in urban areas are directly affected by the requirements of sustainable development, with specific reference to the ninth SDG 9, "Industry, innovation and Infrastructure" and the eleventh SDG 11 "Sustainable Cities and Communities".

This paper addresses how the multidimensional concept of sustainability is translated into practice when decision-makers and stakeholders evaluate alternative policies in different urban logistics contexts. We aim to complement and extend five other literature reviews: the review of methodology to assess sustainability through multi-criteria methods (Lindfors, 2021), the review of last-mile strategies and solutions for urban delivery (Lagorio et al., 2016; Lyons & McDonald, 2023) , and the review of the use of multi-criteria analysis in the specific sector

[1] Global energy-related CO_2 emissions reached a new high of over 36.8 Gt in 2022, growing by 0.9%. These emissions are divided in four different sectors: power, industry, transport, and buildings.
[2] Transport emissions are divided into passenger road vehicles, aviation, road freight vehicles, rail, shipping, and other sources.

of urban freight logistics solutions (Jamshidi et al., 2019; Alvarez Gallo & Maheut, 2023). Our review aims to detect the main issues in choosing criteria when using multicriteria methods to achieve sustainability in this field and to find gaps and possible new configurations. The following questions have been addressed:

1. How do Decision Makers (DMs) and stakeholders address sustainability?
2. How is sustainability considered in the definition of alternatives and choice of criteria?
3. What is the balance of different typologies of criteria adopted?

This paper is structured as follows: Section 2 describes the methodology adopted to perform the systematic literature review, follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines, identifies inclusion and exclusion reasons for selecting the studies, and briefly describes the selected papers. Section 3 presents a meta-analysis of the findings, describing the corpus of selected papers and the main topics and methods that emerge from the analysis. Section 4 discusses the results of the literature review. Section 5 exposes the conclusions.

2. Methodology

The topic has been addressed through a multi-step Systematic Literature Review (SLR) structured in three stages: identification and selection of studies, description of the corpus of studies information, and content classification to address the research questions.

The studies were selected following the PRISMA guidelines (Moher et al., 2015; Page et al., 2021), a widely recognized tool to strengthen literature reviews by making them structured and replicable. A preliminary literature review was conducted on the topic and on the already existing literature reviews to identify useful keywords to implement the research strings. In the identification step, the keywords definitions and related synonyms were formulated with a focus on three aspects: 1) keywords related to sustainability, 2) keywords related to last-mile logistics, and 3) keywords related to multi-criteria analysis methodologies. Then, two major scientific databases, Scopus and Web of Science (WOS), were used, with the performance of queries with 19 keywords that resulted in 112 articles from WOS and 140 from Scopus on the 10th of November 2023. The timeframe of our search needed to be set, identifying articles between 2003 and October 2023 with a more significant presence of recent articles.

The keywords were searched with the Title-Abstract-Keywords command in the general search field and searched were grouped in three blocks regarding sustainability, last-mile logistics, and multicriteria evaluations techniques: "sustainable*", "green", "environmen*", "eco-friendly", "ecological" in the sustainability field, "last mile logistic*", "last-mile logistic*", "urban logistic*", "city logistic*", "urban consolidation cent*", "urban distribution", "city distribution", "urban deliver*", "city deliver*" in last-mile logistics field and "*criteria", "multicriteri*", "multi-criteri*", "mcda", "mcdm". The query in WOS was the following (TS=(sustainab* OR green OR environmen* OR ecofriendly OR ecological)) AND (TS=(«last mile logistic*» OR «last-mile logistic*» OR «urban logistic*» OR «city logistic*» OR «urban consolidation cent*» OR «urban distribution» OR «city distribution» OR «urban deliver*» OR «city deliver*»)) AND (TS=(*criteria OR multicriteri* OR multi-criteri*)), while the query in Scopus was (TITLE-ABS-KEY ((sustainab*) OR (green) OR (environmen*) OR (friendly) OR (ecological)) AND TITLE-ABS-KEY ((«last mile logistic») OR («last-mile logistic») OR («urban logistic*») OR («city logistic*») OR («urban consolidation cent*») OR («urban distribution») OR («city distribution») OR («urban deliver*») OR («city deliver*»)) AND TITLE-ABS-KEY (*criteria)) AND (LIMIT-TO (DOCTYPE,»ar») OR LIMIT-TO (DOCTYPE,»re»)) AND (LIMIT-TO (LANGUAGE,»English»)) AND (LIMIT-TO (SRCTYPE,»j»)).

All articles were read, reviewed, and analyzed in a spreadsheet file; 44 articles did not refer to or apply multicriteria methods (38), and others proved to be off-topic (6), leaving a total of 62 articles, of which 6 reviews, leaving 56 to form the review's corpus through the process as it is shown in Figure 1.

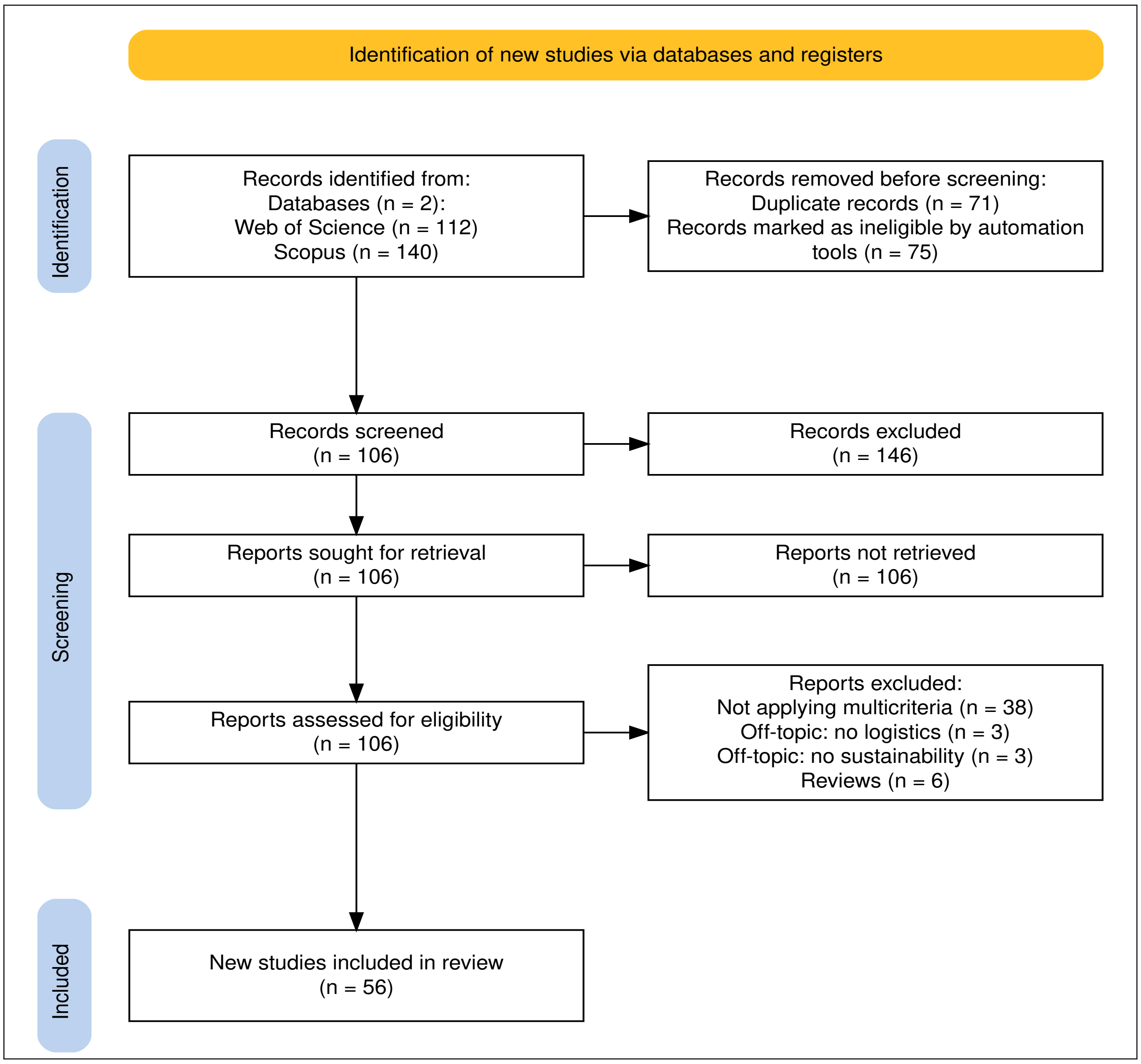

Figure 1. Papers selection process with PRISMA Flow Diagram tool (Haddaway et al., 2022).

The selection process continued with the screening and eligibility phase by applying objective filters. As a quality measure, only articles and reviews published in peer-reviewed journals were included, and the English language has been adopted as a filter. After removing duplicates of the two lists of papers, the process moves to the inclusion phase, in which studies in the field of urban logistics were included if they applied multi-criteria analysis methodology with a precise aim to evaluate sustainable alternatives.

The studies that do not apply multi-criteria decision analysis were excluded, for instance, studies that use optimization or simulation models without the evaluation of other options, but also off-topic studies, for example, with a focus on passenger transport rather than freight or if they only mention sustainability as a general premise or the use of more criteria, but not intending multi-criteria methodologies.

A spreadsheet file was set up to include general article information (e.g., title, publication year, publication source), information about the city or cities studied in the article (e.g., number and name of city/cities), information on the applied research multi-criteria methodology, which criteria were used, which alternatives were evaluated, and which stakeholders were considered. When other relevant data were available, the file included information on the mentioned data sources, the number of respondents in case a survey method was used, and the year of data collection. Table 1 provides a list of methods and summarizes the characteristics of the 56 selected papers.

Table 1. Methods adopted in the selected papers and summary of papers' characteristics

Paper (Alphabetic order)	Research Focus	Method (criteria/alternatives)	Info (Alternatives / Criteria; DM/Stakeholders)
(Aiello et al., 2021)	Vehicles	TOPSIS	6 vehicles batteries/ 2 criteria 1 DM (hypothetical)
(Aljohani, 2023)	Locations Strategies - Policies	AHP, TOPSIS	3 facility locations / 8 criteria 6 distribution strategies / 7 criteria 1 DM
(Aljohani & Thompson, 2019)	Vehicles	MAMCA, AHP, PROMETHEE	4 fleet configurations / 3-7 criteria (25 total) 6 stakeholders' categories
(Álvarez & de la Calle, 2011)	Single Policy	AHP	9 initiatives / 4 criteria 7 stakeholders' categories
(Awasthi & Chauhan, 2012)	Single Policy	AHP, TOPSIS	4 practices / 4 criteria + 16 sub criteria 5 DM (group) - stakeholders' categories
(Awasthi et al., 2011)	Location	TOPSIS	3 locations / 11 criteria + 16 sub criteria 5 DMs (group) - stakeholders' categories
(Bandeira et al., 2018)	Strategies - Policies	TOPSIS	2 distribution configurations / 10 criteria 1 DM
(Bartuška et al., 2023)	Single Policy	AHP	5 Policy / 43 indicators 1 DM
(Bennani et al., 2022)	Locations	CATWOE, F-VIKOR	8 locations / 11 criteria 7 stakeholders
(Boggio-Marzet et al., 2023)	Strategies - Policies	MAMCA	14 objectives / 12 criteria 25 experts – 5 stakeholders' categories
(Buyukozkan & Mukul, 2019)	Technologies	Fuzzy SAW	10 Technological requirements / 8 criteria 3 DMs
(de Araujo et al., 2022)	Strategies - Policies	F-AHP	5 distribution configurations / 6 criteria 27 experts
(de Carvalho et al., 2019)	Locations	MAMCA	2 locations / 5 criteria + 16 sub criteria 3 stakeholders' categories
(Deveci et al., 2022)	Single Policy	DIBR	3 policies / 16 criteria 3 experts
(Gatta et al., 2019)	Strategies - Policies	MAMCA, AHP	3 distribution configurations / 5-7 criteria (16 total) 4 stakeholders' categories

Follow **Table 1**. Methods adopted in the selected papers and summary of papers' characteristics

Paper (Alphabetic order)	**Research Focus**	**Method (criteria/alternatives)**	**Info (Alternatives / Criteria; DM/Stakeholders)**
(He et al., 2017)	Locations	AHP, TOPSIS	4 Locations / 4 Criteria + 13 sub criteria 5 DMs experts
(Hu et al., 2022)	Strategies - Policies	AHP, VIKOR	16 cities / 11 criteria 9 DMs experts
(Kijewska et al., 2018)	Single Policy	AHP, DEMATEL	16 measures / 3 criteria + 4 sub criteria 1 DM (public authority)
(Kin et al., 2017)	Single Policy	MAMCA, AHP, PROMETHEE	4 policy scenarios / 33 criteria 6 stakeholders' categories
(Kovač et al., 2021)	Strategies - Policies	MARCOS	12 deliveries configurations / 10 criteria 4 stakeholders' categories
(Kovač et al., 2023)	Locations	ADAM-MCDM	7 locations / 6 criteria 1 DM (theoretical)
(Krstic et al., 2021)	Single Policy	DELPHI, FARE, VIKOR	6 last mile solutions / 10 criteria 4 stakeholders' categories
(Lebeau et al., 2018)	Strategies - Policies	MAMCA, AHP, PROMETHEE	6 scenarios / 15 criteria (5-7 each) 5 stakeholders' categories
(Macharis & Milan, 2015)	Strategies - Policies	MAMCA, AHP, PROMETHEE	4 scenarios / 18 criteria 5 stakeholders' categories
(Macharis et al., 2014)	Strategies - Policies	MAMCA-CD, PROMETHEE – GDSS	4 scenarios / 17 criteria 5 stakeholders' categories
(Melkonyan et al., 2020)	Strategies - Policies	PROMETHEE, Simulation SD	3 delivery schemes / 16 criteria 2 companies
(Milan et al., 2015)	Strategies - Policies	MAMCA-CD, PROMETHEE – GDSS	4 scenarios / 10 criteria 5 DMs - 3 stakeholders' categories
(Moslem & Pilla, 2023)	Locations	SF-AHP	6 alternatives / 5 criteria 3 DMs
(Muerza & Guerlain, 2021)	Construction projects	AHP	3 projects / 4 criteria – 14 attributes 1 DM (theoretical)
(Nathanail & Karakikes, 2021)	Single Policy	AHP, DELPHI	11 policies / 9 criteria 3 stakeholders' categories (21 respondents)
(Novotna et al., 2022)	Locations	BWM-CRITIC-WASPAS	5 locations / 5 criteria 3 experts
(Pamučar et al., 2016)	Strategies - Policies	TSDSM, WLC, GIS	5 scenarios / 4 criteria + 21 sub criteria 6 DMs
(Perera & Thompson, 2021)	Single Policy	MAMCA	10 toll schemes / 21 criteria (5-7) 4 stakeholders' categories

Follow **Table 1**. Methods adopted in the selected papers and summary of papers' characteristics

Paper (Alphabetic order)	Research Focus	Method (criteria/alternatives)	Info (Alternatives / Criteria; DM/Stakeholders)
(Rao et al., 2015)	Locations	FMAGDM-THOWA-TOPSIS	4 locations / 13 criteria 1 DM (theoretical)
(Rześny-Cieplińska & Szmelter-Jarosz, 2019)	Services	AHP	24 Services (crowd logistics) / 20 criteria 7 stakeholders' categories
(Rześny-Cieplińska & Szmelter-Jarosz, 2020)	Strategies - Policies	AHP	20 criteria (focused only on criteria)
(Saha et al., 2023)	Vehicles	DHF-CEBOM-SDNMARCOS	4 vehicle types / 9 criteria 3 experts
(Salabun et al., 2019)	Vehicles	COMET	10 bikes / 8 criteria 1 expert
(Sárdi & Bóna, 2021)	Locations	AHP	4 urban zones / 43 criteria 18 experts
(Semanjski & Gautama, 2019)	Strategies - Policies	AHP	5 criteria (focused only on criteria)
(Senne et al., 2021)	Single Policy	AHP, Index	29 initiatives / 5 criteria (policies) 1 expert
(Serrano-Hernandez et al., 2021)	Strategies - Policies	AHP	6 routes / 3 criteria + 9 sub criteria 1 stakeholders' category
(Sgura Viana & Delgado, 2019)	Strategies - Policies	MCE-GIS, AHP	7 strategies / 7 criteria 1 DM (municipality)
(Shekhovtsov et al., 2020)	Vehicles	TOPSIS, VIKOR	10 bikes / 8 criteria 1 expert
(Silva et al., 2023)	Strategies - Policies	AHP, TOPSIS	4 alternatives / 9 criteria 9 experts
(Sopha et al., 2018)	Location	TOPSIS	4 locations / 10 criteria 4 DMs
(Svadlenka et al., 2020)	Strategies - Policies	PFS	6 alternatives / 20 criteria 10 DMs
(Szmelter-Jarosz & Rześny-Cieplińska, 2020)	Strategies - Policies	DEMATEL, AHP	20 criteria (focused only on criteria) 6 stakeholders' categories
(Tadić et al., 2022)	Strategies - Policies	BWM, CODAS	4 city logistics concepts / 11 criteria 4 stakeholders' categories
(Tadić et al., 2023)	Single Policy	AHP, MARCOS	12 initiatives / 10 criteria 4 stakeholders' categories
(Tadić et al., 2014)	Strategies - Policies	DEMATEL, VIKOR	4 city logistics concepts / 10 criteria 1 DMs (theoretical)
(Urzúa-Morales et al., 2020)	Vehicles	AHP	5 vehicles / 3 criteria 1 DMs (theoretical)

Follow **Table 1**. Methods adopted in the selected papers and summary of papers' characteristics

Paper (Alphabetic order)	Research Focus	Method (criteria/alternatives)	Info (Alternatives / Criteria; DM/Stakeholders)
(Uyanik et al., 2020)	Locations	DEMATEL, TOPSIS	4 locations / 16 criteria 4 DMs - stakeholders' categories
(C.-N. Wang et al., 2023)	Locations	OPA, MARCOS	5 strategies / 12 criteria 4 experts
(Y. Wang et al., 2023)	Strategies - Policies	BWM, MultiObj	26 locations, 4 criteria 1 DM (municipality)
(Watróbski et al., 2017)	Vehicles	PROMETHEE II, fuzzy TOPSIS	10 vehicles / 4 criteria + 9 sub criteria 1 DM (municipality)

3. Meta-analysis

3.1. Trends in literature

At the beginning of 2000, Taniguchi and other leading researchers in logistics (2003) recognized the need to develop and apply mathematical models to support urban planning activity and evaluate city logistics initiatives on a solid rational basis. The decision-making process to pursue a more sustainable transportation system has been at the center of the work of Kennedy et al. (2005) , who identified the four pillars of governance, financing, infrastructure, and neighborhoods that metaphorically support the triangle of environment, economy, and society involved in sustainable urban transportation. All these pillars are necessary and present trade-offs that must be tackled in an integrated planning. Some studies adopted simulation (Karakikes et al., 2018), optimization (Rifki et al., 2020; Sawik et al., 2022) , or economic methods (Handoko et al., 2016; Gatta et al., 2019; Isa et al., 2021), but have been excluded from this study to restrict the focus on those that applied multi-criteria decision-making methods.

The articles selected are categorized in both databases, WOS and Scopus, under several categories, confirming the multidisciplinary nature of the topic. In WOS the main categories are Green Sustainable Science Technology, Environmental Studies, Environmental Sciences, Transportation, Operations Research Management Science, Transportation Science Technology, Economics, Energy Fuels, Engineering Electrical Electronic, Computer Science, and in Scopus, the main categories are Engineering, Social Sciences, Environmental Science, Energy, Computer Science, Business-Management-Accounting, Mathematics, Decision Sciences and Economics- Econometrics-Finance.

Over the last decade, there has been a significant increase in the number of studies that have explored the use of multicriteria methods for evaluating sustainable solutions in the urban logistics sector. Many case studies have been conducted to confirm the feasibility and effectiveness of multicriteria methods in evaluating sustainable solutions in urban logistics. The most present journals were *Sustainability* (18 documents), *Research on Transportation Economics* (4), Case *Studies on Transport Policy* (3), *Promet – Traffic&Transportation* (2), *Journal of Industrial Engineering and Management* (2), *Research in Transportation Business and Management* (2), *Transportation Research Part D: Transport and Environment* (2) and *Energies* (2). These studies have demonstrated a growing trend of interest in this topic in the last decade (Figure 2).

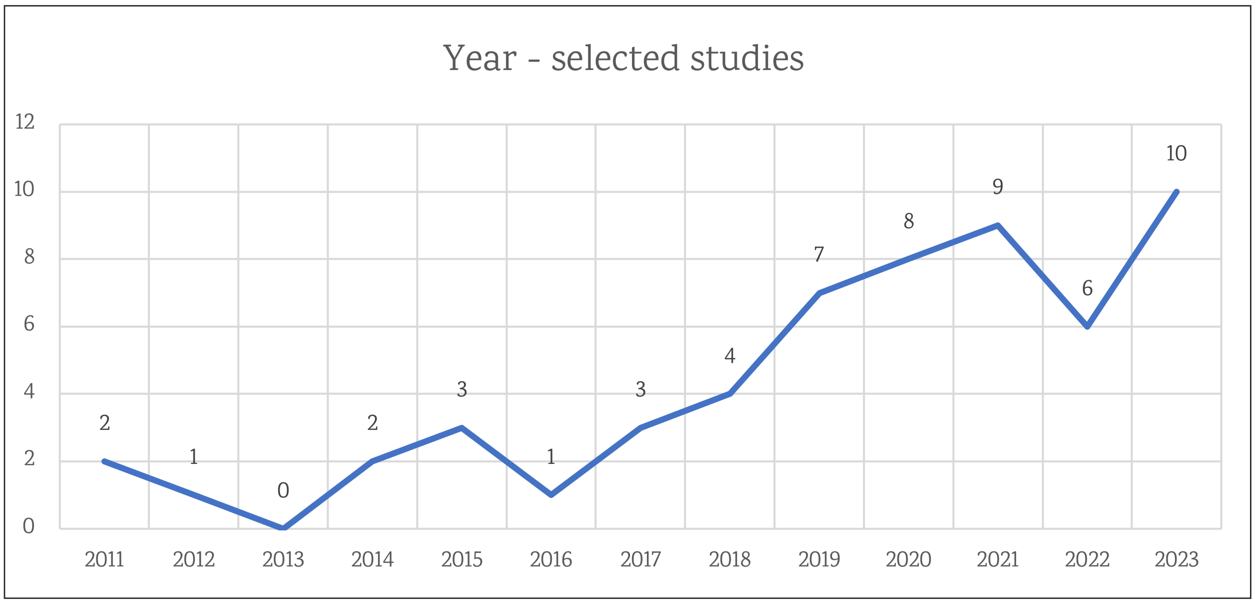

Figure 2. The number of papers per year.

3.2. Objectives and alternatives evaluated

Urban freight systems are complex and dynamic, and several literature reviews on the topic have been performed in the last decades. According to Lagorio et al. (2016), the classification of different methodologies divided the studies into several categories: case study, conceptual study, literature review, quantitative modeling, simulation, and survey. The application of several multi-criteria analyses usually relies on a specific urban context and is structured as case studies regarding municipalities or companies planning activities or pilot cases. Conceptual studies regard schemes for methodological approach. The quantitative model's group refers to the solution to routing, location, and cost modeling through quantitative data. In contrast, the survey group comprises discrete choice problems based on revealed or stated preferences. This review focuses on the application of Multicriteria Decision-Aiding (MCDA)MCDA methods and most of the selected articles consist of case studies. Upon reviewing multiple papers, it was observed that twenty-two of them primarily focus on comprehensive distribution strategies that are defined in integrated city logistics plans as a combination of multiple sustainable policies, rather than a single specific policy intervention. Such strategies consider several aspects, such as the environment, efficiency, and quality of services, and they are used as alternatives to achieve the objectives explicitly defined for each problem. Lyons and McDonald (2023) grouped the last-mile delivery strategies into four categories: innovative vehicles, urban goods consolidation, technological and routing improvements in city logistics, and emerging planning tools and policies. They highlighted the importance of understanding the different ways to intervene and the relevance of policy measures, identifying twenty-two last-mile delivery strategies, namely freight cycles, alternative fuel freight vehicles, autonomous freight vehicles, delivery drones, modular freight vehicles, portering and walking delivery, freight trams, light commercial vehicles, underground freight pipeline, urban consolidation centers, parcel lockers, pickup points, collaborative logistics, vehicle routing problem improvements, crowd-shipping, mobile depots, temporal changes, enhanced use of existing infrastructure, urban access restrictions, urban loading zones, parking regulations, certification requirements. Those attempts to classify and identify the groups of policies are particularly relevant given the many innovative policy measures identified in European projects such as STRAIGHTSOL (2014), CITYLOG (2012), ENCLOSE (2014), BESTUFS (2008), C-LIEGE (2014), FREIGHLOT (2011), and CITYLAB (2015), to mention some that appear in the selected papers. However, it is concerning that not all interested decision-makers are aware of or interested in considering this variety of policy measures. Another objective, addressed in eleven papers, involves evaluating different aspects or configurations of a specific single policy. This objective focuses on exploring different policy options and their potential outcomes rather than combining several policies into one comprehensive strategy.

As noted in thirteen publications, the second most common objective is to evaluate the best location for a selected project or service. This objective is essential as it helps determine the most optimal location for a particular service, which can reduce logistics costs and improve overall efficiency. The location of warehouses along the supply chain and the distance from the urban centers deeply affect the activities related to freight movements. This problem is addressed in different papers (Awasthi et al., 2011; Rao et al., 2015; He et al., 2017; Sopha et al., 2018; de Carvalho et al., 2019; Uyanik et al., 2020; Sardi & Bona, 2021; Bennani et al., 2022; Novotna et al., 2022; Aljohani, 2023; Kovač et al., 2023; Moslem & Pilla, 2023; Y. Wang et al., 2023). In the work of Aljohani and Thompson (2016), the literature review focuses on the phenomenon of logistic sprawl, where the relocation of logistics facilities outside the urban area is led by unaffordable land prices for logistics purposes in the inner part of cities. It's interesting to note that last-mile logistics is often considered the supply chain's most costly and inefficient aspect. This is due to various factors, including freight traffic congestion, distance, lack of infrastructure, and the need for personalized delivery options. According to some authors, delivering a single package to a remote location can be more expensive than delivering a large volume of packages to a business center (Gonzalez et al., 2023; Tadić et al., 2023). This rising phenomenon of single package deliveries to remote locations changes the geography of urban freight movements. It produces an increase in the distances traveled by truck and related adverse impacts, and so forth, with the need for other infrastructures, such as the urban consolidation centers, to reduce distances and the number of vehicles between one place and the other.

Furthermore, seven papers study the types of vehicles suitable for city logistics operations (Watróbski et al., 2017; Aljohani & Thompson, 2019; Salabun et al., 2019; Shekhovtsov et al., 2020; Urzúa-Morales et al., 2020; Aiello et al., 2021; Saha et al., 2023). This objective is related to evaluating environmentally friendly vehicles or selecting the type of transport for freight delivery, mainly traditional land transport with vans, cargo bicycles, and recent alternative solutions such as drones. The aim is to identify the most suitable vehicle type that can help reduce pollution and improve the overall efficiency of logistics operations in urban areas.

Six systematic literature reviews were present in the screened papers and address relevant elements for this review, such as the last-mile strategies for urban freight deliveries (Lyons & McDonald, 2023), criteria and decision-making methods for sustainable city logistics (Jamshidi et al., 2019; Hauge et al., 2021) or, more specifically, multi-criteria analysis in sustainable logistics solutions (Alvarez Gallo & Maheut, 2023) on weighting the city context in the criteria (Gonzalez et al., 2023), and on identifying the smartness of city logistics (Xenou et al., 2022). A review of MCDA problems with a description of the most employed criteria to select sustainable city logistics initiatives is provided by Jamshidi et al. (2019), which also highlights the multiple natures of economic, technical, environmental, and social criteria, reviewing over a hundred criteria.

Some residual studies in the selected papers focus on specific aspects or sectors, such as the evaluation of three construction projects and related last-mile logistics, which were addressed by Muerza and Guerlain (2021), as well as the assessment of technological requirements (Buyukozkan & Mukul, 2019) or the choice of last-mile delivery services provided by twenty companies (Rześny-Cieplińska & Szmelter-Jarosz, 2019). The objectives and the kind of alternatives that have been addressed in the selected papers are reported in Table 2.

Table 2. The main objective of selected papers

	Tot.	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Alternatives	**56**	**2**	**1**	**0**	**2**	**3**	**1**	**3**	**4**	**7**	**8**	**9**	**6**	**10**
Strategies - Policies	**22**				2	2			2	3	4	3	2	4
Locations	**13**	1					1	1	1	1	2	1	1	4
Single Policy	**11**	1	1			1		1	1			2	3	1
Vehicle types	**7**							1		2	2	2		
Construction projects	**1**											1		
Technologies	**1**									1				
Services	**1**													1

3.3. Categories of Stakeholders involved

All the selected papers mention the importance of considering the multifaceted stakeholder categories. Still, the type and number of stakeholders involved depend on the specific case and the kind of resources and method adopted. To ensure the successful implementation of these measures, engaging all stakeholders and promoting awareness of the benefits of these policy interventions is crucial. There is a group of papers (Kin et al., 2017; Aljohani & Thompson, 2019; de Carvalho et al., 2020; Boggio-Marzet et al., 2023) that, by definition, adopted a multi-stakeholders perspective through the Multi-Actor Multi-Criteria Analysis (MAMCA), which is a method first developed by Macharis (2005) that allows for incorporating different points of view and shows advantages and disadvantages in their opinion. Another literature review also considers the stakeholders' perspective. For example, the work of Arvidsson (2013) analyzed the point of view of road haulers as actors that both suffer and contribute to the downsides of freight transport and investigated the intricate relationship between the costs and benefits related to measures for improving transport efficiency and sustainability.

In the selected papers, there is a prevalence of the involvement of the public and local authorities (25 papers) as the municipalities and regional institutions that oversee the policy planning or the evaluation of projects. These institutions play a central role in shaping regulations, infrastructure development, and sustainability policies. They are followed by the logistic providers (21), underscoring the critical role of the executors of the delivery process and their need to adapt to policy changes and operational demands. Citizenships is another frequently mentioned stakeholder group (20), witnessing the increasing importance of public perception and participation and direct impact of logistics operations on urban communities in terms of overall quality of life. Retailers and receivers of the logistics services (17) are directly affected by the efficiency and cost-effectiveness of urban logistics solutions. Experts, intended as a general group of practitioners, consultants, and researchers (16), with some that specifically refer to academia (4). Also, the carriers and shippers are included (13), which gives insights into workers and people involved in coordinating transportation and delivery activities. Some theoretical papers refer to potential stakeholders, not specifically identifying the type but referring to decision makers (8) or other general interest in the topic (4).

It is important to note that there are no mandatory procedures for how stakeholders should be involved or how criteria should be selected in evaluating urban logistics solutions. While institutional guidelines, such as those from the European Union and other international organizations, recommend the involvement of diverse stakeholders, such as public authorities, logistics providers, and local communities, these recommendations remain advisory rather than compulsory.

3.4. Criteria considered for the evaluation of alternatives.

When evaluating the sustainability of a policy or project, it is essential to consider carefully selected criteria that reflect economic efficiency, environmental preservation, and social considerations. The requirements can be measured on either a quantitative or qualitative scale, depending on the project's characteristics. Social criteria such as job creation, job quality, and neighborhood quality of life ought to be chosen for the sustainability of last-mile logistics. Environmental criteria that deserve attention include energy consumption, GHG emissions, NOx emissions, PM emissions, and noise pollution. Regarding economic criteria, the average delivery cost of the business model, traffic congestion, urban storage, and parking space, financial internal rate of return, shop retail benefits, delivery time, and delivery reliability within the time windows must be considered. All these factors are of utmost importance since the economic dimension can significantly impact all stakeholders involved in the last-mile logistics industry, including retailers, consumers, and logistic operators. These are just a few examples of the 738 criteria adopted in the selected papers, with the first evident result that many definitions and interpretations of the criteria are tailored case by case. Table 3 lists the five most frequent criteria in the selected papers.

Table 3. The five most frequent criteria for each category

Economic	
Cost (Operational/Maintenance, employees, Transportation, Deliveries, Receiving, Measures implementation, infrastructures, tolls)	51
Urban Economy / Business Attractiveness	16
Economic sustainability/Viability	12
Quality of job / Employees Satisfaction	9
Cooperation	8

Environmental	
Co_2 Emissions / Air Pollution	37
Environmental Impact (total) / Externalities	28
Noise	20
Congestion	10
Use of loading space / space occupancy	7

Operational	
Quality of Service / Reliability	21
Time/Speed of Deliveries	19
Delivery Flexibility/Accessibility	18
Implementation/Expansion possibility	14
Proximity to delivery/customers	13

Social	
Traffic Safety (accidents)	26
Livable City (local auth)	13
Prosperity of region /country	13
Delivery Security (workers/receivers)	11
Quality of life (citizens)	9

Territorial	
Urban and spatial planning	34
Infrastructure development	6
Infrastructure availability /Delivery points	4
Park guidance / spots	2
Number of hub / delivery points	2

The criteria categories and their types as presented in each paper were analyzed been analyzed. The largely recognized three-bottom-line social, economic, and environmental criteria are evenly represented in the selected papers, but there are also two additional categories of "operational" and "territorial" criteria. Most papers that unambiguously considered operational criteria refer to them as part of the economic sphere, given that organizational and technological aspects are strictly linked to performance. As for the territorial ones, they are more hybrid, and they are linked to environmental and social spheres. Figure 3a reports the presence of a single criterion under each category as reported by the authors, with the same frequency of economic, environmental, and social criteria and the largest number of specific operational criteria. Figure 3b shows how many papers considered that category, again finding a perfect balance between the three traditional categories and another quarter of papers that included the operational and territorial criteria. Also, the declared source of the choices of criteria has been analyzed, and three kinds of sources have been identified: from the existing scientific and grey literature, from the experts and practitioners involved in the case, and direct sources from DM or stakeholders involved. The use of existing scientific and non-scientific literature as a source for criteria selection is present in 25 papers, same as the involvement of experts/authors as consultants to adopt certain criteria. A smaller number of papers (18) adopted criteria chosen directly by DMs and stakeholders involved in projects and decisions. Three-quarters of the selected papers mentioned only one of these sources, suggesting a one-fifth considered two, and just a few (4%) mentioned all three sources together.

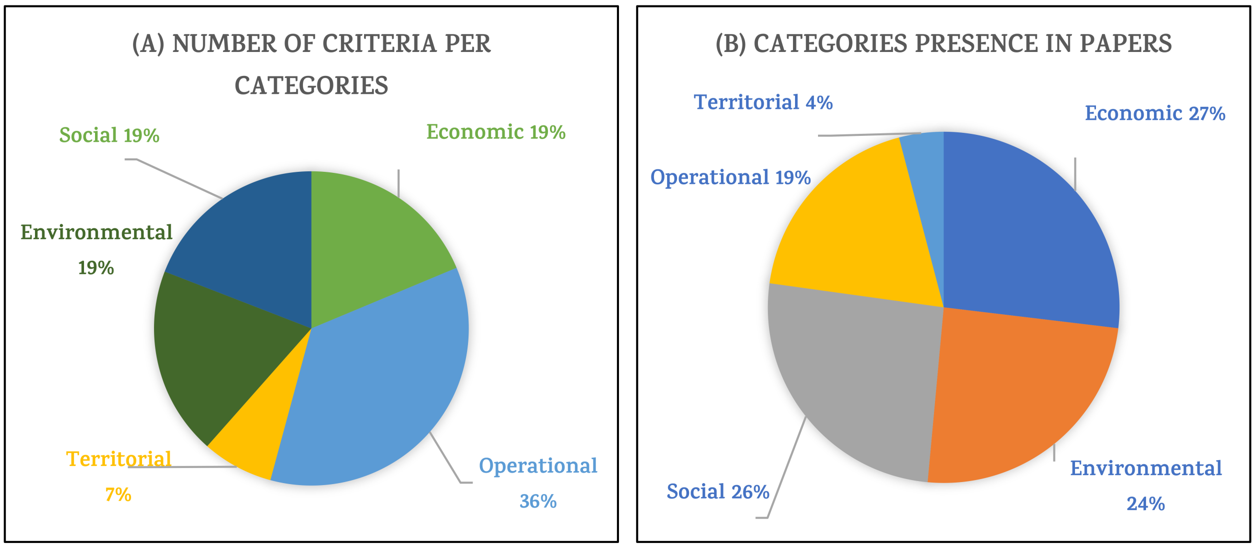

Figure 3. Criteria analysis: (A) Percentage of criteria per category; (B) Number of papers per category of criteria.

4. Discussion

The analysis identified 56 papers that addressed the problems related to sustainable urban logistics solutions. Efficient and sustainable management of urban areas is of utmost importance for the city's and its inhabitants' well-being. Policymakers are crucial in improving the community's quality of life while considering the effects of solutions on people and businesses (de Carvalho et al., 2020; Serrano-Hernandez et al., 2021). They must address customer needs and ensure the logistics process runs smoothly and efficiently while considering the environmental impact of last-mile delivery (Kin et al., 2017). The policy measures are not perceived as a booster for business, so there is some resistance to change and the problem of the perception of different stakeholders has caught the attention of many scholars.

One of the most comprehensive works on urban logistics is by Lagorio, Pinto, and Golini (2016). In their work, the authors regrouped the selected papers in seventeen main topics: green vehicles, Limited Traffic Zones, e-commerce, Information and Communication Technologies (ICT), emissions/pollutions, Urban Distribution/Consolidation Centers (UDC/UCC), solutions performance assessment and comparison, stakeholders involvement, Vehicle Routing Problems (VRP) solutions, drones (Kovač et al., 2021; Serrano-Hernandez et al., 2021), tram for goods, road pricing, multi-use lanes, bike delivery, night delivery, Loading / Unloading (L/U) areas, and pick-up points. These evaluated solutions highlight the complex nature of urban logistics problems and the necessity of a multidisciplinary approach for decision-makers and stakeholders.

Different competencies are required to address logistics problems, and this issue motivates the research work made by Hauge et al. (2021), who aimed to develop a multi-layer framework to interpret the complexity of the decision-making process. The studies on urban logistics processes and related planning activities have been addressed through different approaches and methods, such as survey-based ones, simulation models, heuristics-based methods, life cycle assessments, cost models, and multicriteria-aiding approaches. Jamshidi et al. (2019) have provided a comprehensive literature review of the application of these models in urban logistics. The MCDA approach is helpful in situations where there are multiple alternatives to evaluate. This approach belongs to the operations research branch and considers various quantitative and qualitative criteria to aid decision-making (Yannis et al., 2020). Regarding urban logistics, it's essential to acknowledge that every problem is unique. Different internal and external factors determine the logistics of a city, including physical aspects like geography and infrastructure, as well as zoning regulations and government policies.

Therefore, evaluating each issue case-by-case basis is essential to develop effective logistics solutions that consider all relevant factors (Alvarez Gallo & Maheut, 2023). The capability to assess sustainability through multi-criteria methods is at the core of the work of Lindfors (2021) that analyses the methodological choices behind the selected papers, only a few about logistics, regarding the stated reasons to apply Multi-Criteria Analysis (MCA): how the alternatives are designed, how criteria are selected and areas of sustainability, the choice of interpretation, ranking, and scoring method and why that specific method among others, if and how weighting of criteria took place, how uncertainty is managed and how incommensurability, compensability and incompatibility among criteria are tackled.

Furthermore, the sustainability of logistics in the urban context has gained much attention in the last decades (Rześny-Cieplińska & Szmelter-Jarosz, 2020), pushed by these different phenomena that all cities are facing, as the effects of the growth of population, urbanization, and globalization, growth of online and omnichannel retailing commerce (Schöder et al., 2016), and in general urban economic development. The flow of people and goods compete for the same space in the urban context. The increasing level of freight movements is causing more pressure on local authorities and increasing interest from consultants and researchers. Also, urban stakeholders have increased their awareness of the environmental backsides of the transport sector. Still, the supply chains need to be flexible to answer to market fluctuations, such as energy prices, and critical events, such as wars and pandemic disruptions, which have made logistics more acknowledged in everyday life (Ren et al., 2019; Moncef & Monnet Dupuy, 2021).

Thus, multiple stakeholders with different objectives and perspectives in urban freight transport underline the need for coordination or cooperation among public institutions and private operators to establish a friendly urban freight transport system (Knoppen et al., 2021). To analyze city logistics solutions, several elements need to be considered: Information and Communication Technologies (ICT), behavioral aspects regarding changing logistic managers' and operators' mindsets, and regulatory and legal aspects required for public-private partnerships or simply for incentivizing more efficient solutions (Gonzalez-Feliu et al., 2014).

Recently, with the advent of technologies and digital markets, the focus of specific studies (e.g., Buldeo Rai and Dablanc (2023) is on e-commerce data in urban logistics and on the challenges and opportunities in gathering data through different instruments, comparing them and exploiting them of use for policy planning purposes. Moreover, on the production and transportation side, introducing Industry 4.0 solutions[3] could enable cooperation among different actors, with several benefits in optimizing usage, fulfillment time, and energy consumption (Deja et al., 2021). In the last decades, researchers and practitioners have pushed the interest in urban logistics, confirmed by several literature reviews that stress different aspects and perspectives. The uniqueness of each urban logistics context makes addressing sustainability very challenging, and some researchers highlighted how numerous urban-related case studies stimulate research from a broader point of view with cross-case assessments (Nathanail et al., 2021).

The categories of interested stakeholders have been identified, highlighting that there is a heterogeneity of approaches in terms of how many stakeholders are involved and in which part of the process they are involved. Sometimes, there is only one type of decision-maker, most frequently the public authority or the logistics service providers, which are the clients of the consultant or expert hired to assist in choosing methods and criteria to analyze a particular problem. For some specific methods, such as the MAMCA ones, the involvement of various stakeholders is part of the multicriteria method. To better understand how decision-makers and stakeholders address sustainability, this review mapped the problems addressed and the methods applied, the stakeholders involved as actors, their objectives, and the criteria chosen to support their choices when the intent is to pursue sustainable solutions for cities.

To this end, sustainable development, based on the three pillars of social equity, economic growth, and environmental protection, offers a promising approach to address these challenges. However, from the analysis of the selected studies, it emerged that the authors sometimes rely on something other than the three-bottom-line categories, such as the operational and territorial criteria that do not uniquely refer to one of the three traditional categories. Also, there is an ongoing debate about the hierarchy of these dimensions and the best way to achieve sustainable solutions. Besides the economic, environmental, and social criteria, the most significant number of criteria are in operational and technical categories (Aljohani & Thompson, 2019; Awasthi & Chauhan, 2012), or some referred to as implementation or capability criteria (Deveci et al., 2022). Moreover, some researchers adopted the territorial type of criteria to include urbanistic aspects and to explore new applications for location problems (Bennani et al., 2022), but also, from the comparison between different papers, it is evident how the boundaries between different types of criteria are not so rigid, and sometimes some researchers refer to a generic economic category while including some criteria that many other researchers consider as operational or social (Awasthi & Chauhan, 2012; He et al., 2017; Bandeira et al., 2018; Bartuška et al., 2023).

Another example is provided by Boggio-Marzet (2023), where some operational and territorial criteria were placed under the economic and social criteria of the more traditional three bottom-line divisions. Some researchers also introduced criteria related to cultural heritage for the specific focus on historical city centers (de Carvalho et al., 2020), taking into account some criteria that are considered environmental, territorial, and social criteria in other works. One of the most relevant and recent contributions to the topic is represented by the work of Gonzalez et al. (2023), which considers the city context as a relevant element affecting the weighting of sustainability criteria through a comparison between cities involved in the LEAD project. Also, it highlights how some criteria, such as traffic congestion in the example, could be intended as an economic criterion, while many authors consider it an environmental or social criterion.

[3] Efficient reception, storage, sorting, and freight shipment have become critical to logistics operations. In this regard, industry 4.0 modern technologies such as Cyber-Physical Systems (CPS), Cognitive Big Data Management and Analytics for Human-Smart Manufacturing and Services (CBMHS), Internet of Things (IoT), Digital Twins, Big Data, Data Mining, Blockchain, and Autonomous Mobile Robots (AMR) have emerged as key enablers for streamlining these processes and enhancing logistics efficiency.

So, another finding is that an agreement on the exact nature of the criteria is still lacking. Despite growing applications and scientific publications, a standard methodological framework for selecting methods and criteria to evaluate sustainable logistics solutions is unavailable. However, it could be interesting to deepen the analysis by searching if the choice of specific methods or the addressing of certain problems leads to the choice of criteria and sustainable solutions in specific ways.

5. Conclusion

This study provides an overview on topic of sustainability in urban logistics. The aim was firstly to increase the knowledge on the use of multicriteria methods to account the complexity of the logistics problem, secondly to understand which problems were addressed and which criteria were chosen. The analysis of existing documents showed that this choice is influenced by various factors, such as the specific urban setting, the issue being addressed, the stakeholders involved, and the chosen evaluation method. Multicriteria approaches that combine qualitative and quantitative analysis can be effective, even if determining the appropriate number of criteria is a critical issue in this field. Adopting fewer criteria makes the method more straightforward to implement, but there may be a trade-off between the quality of analysis and practicality. Conversely, using more criteria can overload information and hinder interpretation.

The analysis of how DMs and stakeholders approach sustainability in urban logistics highlighted the use of a mix of social, environmental and economic criteria. However, as seen in many papers reviewed, DMs often extend beyond the traditional three-bottom-line approach to include operational and territorial criteria. DMs must answer to the concerns with the impact of last-mile logistics on traffic congestion, emissions and service quality and must balance short-term economic gains with long-term environmental sustainability and social well-being. Many studies emphasize that while sustainability is used as a guiding principle, many policy measures are not always perceived as business-friendly, leading to resistance from stakeholders. This contrast underlines the importance of stakeholders' engagement and awareness in decision-making to ensure that sustainability objectives are feasible and desirable. It could be interesting to analyze how different stakeholders adopt or prefer some criteria over others when methods that allow different criteria are adopted. It could also be interesting to analyze the mediation process between different stakeholders in the convergence of selected criteria when methods that require shared criteria are adopted.

This literature review enumerates the types and numbers of criteria selected. The balance of criteria adopted in the evaluation of sustainable solutions show a near-even distribution between economic, environmental, social criteria and additional categories, as operational and territorial, in the majority of paper analyzed. Despite the current study limits the analysis to the results of these criteria selection processes it helps to highlight that sustainability is a concept built during the construction of problems through criteria choices and that it could not be limited to the three-bottom-line lenses. It could be interesting to analyze which type is most prioritized, with what strength, and for which reasons. One of the significant limits of the replicability of MCDA approaches in different contexts is that it is not always clear why one method is chosen over the others, whether it is proposed by the consultant or expert involved or based on imitation of existing applications. This lack of explanations in the literature could represent a gap that need to be addressed in further research that could also be extended into the criteria selection and weighting process of performed by different categories of stakeholders. This would provide valuable insights into understanding stakeholders' diverse perspectives and priorities towards sustainability. In spite of its limitations, the study offers insights into decision-making and it could also serve as support in understanding the multidimensional nature of the concepts of sustainability and urban logistics.

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Nomenclatures

AHP | Analytic Hierarchy Process
BWM | Best–Worst Method
COMET | Characteristic Objects Method
CODAS | Combinative Distance-Based Assessment
CRITIC | Criteria Importance Through Intercriteria Correlation
CEBOM | Cross-entropy-based optimization model
CATOWE | Customer–Actors–Transformation process–World view–Owners–Environmental constraints
DEMATEL | Decision Making Trial and Evaluation Laboratory
DIBR | Defining Interrelationships Between Ranked Criteria
DELPHI | Delphi method
DHF | Dual hesitant fuzzy
FARE | Factor Relationship
F-AHP | Fuzzy Analytic Hierarchy Process
FMAGDM | Fuzzy multi-attribute group decision-making
F-SAW | Fuzzy Simple Additive Weighting
GDSSs | Group Decision Support Systems
GHG | Green House Gases
NOx | Nitrogen Oxide
PM | Particulate Matter
LML | Last-Mile Logistics
MARCOS | Measurement of Alternatives and Ranking according to Compromise Solution
MAMCA-CD | Multi-Actor Multi-Criteria Analysis - City Distribution
MAMCA | Multi-Actor Multi-Criteria Analysis MCDA | Multi Criteria Decision Aiding
MCE-GIS | Multi-Criteria Evaluation in Geographic Information System
PFSs | Picture Fuzzy Sets
PROMTHEE | Preference Ranking Organization Method for Enrichment of Evaluations
PRISMA | Preferred Reporting Items for Systematic Reviews and Meta-Analysis
SDGs | Sustainable Development Goals
SDNMARCOS | Score-based double normalized measurement alternatives and ranking according to the compromise solution
SF-AHP | Spherical Fuzzy Analytic Hierarchy Process
SLR | Systematic Literature Review
TOPSIS | Technique for Order Preference by Similarity to an Ideal Solution
TSDSM | Transport Spatial Decision Support Model
THOWA | Tuple hybrid ordered weighted averaging
UDC/UCC | Urban Distribution Center / Urbans Consolidation Center
UN | United Nations
VIKOR | Višekriterijumska Optimizacija i kompromisno Rešenje
WASPAS | Weighted Aggregated Sum Product Assessment
WLC-GIS | Weighted Linear Combination - Geographic information system

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valori e valutazioni
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Società Italiana di Estimo e Valutazione

Valutazione multicriterio della sostenibilità nella logistica dell'ultimo miglio: una rassegna

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Abstract
Con il continuo sviluppo delle città, diventa fondamentale migliorare la qualità della vita dei cittadini, affrontando al contempo sfide come l'aumento della domanda di consegne urbane e il raggiungimento degli obiettivi di sostenibilità ambientale. Tuttavia, la competizione per lo spazio limitato tra persone e merci nelle aree urbane crea pressione sulle autorità locali e stimola l'interesse di consulenti e ricercatori. Questo studio esamina come viene affrontata la sostenibilità quando i decisori e gli stakeholder valutano soluzioni alternative con metodi multicriterio in diversi contesti di logistica urbana. È stata condotta una rassegna sistematica multi-step per esaminare l'uso dell'analisi multicriterio nel settore multidisciplinare della logistica urbana e come la sostenibilità viene definita e perseguita, identificando 56 articoli pubblicati tra il 2011 e il 2023 che trattano problemi legati a soluzioni logistiche urbane sostenibili. Nonostante il crescente numero di applicazioni e pubblicazioni scientifiche, manca un quadro metodologico standard nella scelta dei metodi e dei criteri per valutare le soluzioni logistiche sostenibili. Per colmare questa lacuna, il presente articolo mira a mappare i problemi affrontati e i metodi applicati, gli attori coinvolti come stakeholder, i loro obiettivi e i criteri scelti per supportare le loro scelte. L'articolo indaga sul processo decisionale, sugli attori e sulle fonti, e sui criteri scelti quando l'intento è perseguire soluzioni sostenibili. Future ricerche potrebbero approfondire il processo di ponderazione tra i criteri per chiarire la coerenza tra gli obiettivi dichiarati e le decisioni effettive, offrendo così preziosi spunti su come vengono prese le decisioni e aiutando a individuare aree di miglioramento.

1. Introduzione

Il continuo sviluppo delle città in tutto il mondo pone le autorità di fronte alla necessità di migliorarne la qualità della vita, affrontando al contempo gli aspetti negativi della crescita della popolazione e delle attività economiche e sociali correlate. Secondo le previsioni delle Nazioni Unite (UN, Department of Economic and Social Affairs, 2022), la popolazione mondiale è attualmente di circa 8 miliardi e si prevede che raggiungerà i 9,7 miliardi entro il 2050, di cui il 68% vivrà in aree urbane (UN Department of Economic and Social Affairs, 2019). Ogni contesto urbano è unico e il panorama è molto eterogeneo, ma ci sono questioni comuni legate all'urbanizzazione e all'aumento dei flussi di persone e merci nelle città di tutto il mondo.

Con una domanda maggiore di beni cresce anche la necessità di consegnarli ai negozi o ai consumatori finali. Tuttavia, l'aumento dei veicoli commerciali e per il trasporto di merci porta spesso a una maggiore congestione del traffico e a livelli più elevati di emissioni (Bosona, 2020). Nel contesto europeo, il movimento di merci urbano rappresenta la parte più inquinante del trasporto complessivo (Dablanc, 2007) e costituisce una problematica rilevante, dato che il settore dei trasporti è responsabile di un quarto delle emissioni globali di gas serra, con 7,98 Gt di CO_2 nel 2022[1] (IEA, 2023a), e le emissioni legate alla movimentazione su gomma rappresentano la stragrande maggioranza delle emissioni menzionate[2] (IEA, 2023b).

Il termine "sviluppo sostenibile" è diventato popolare nel dibattito politico delle Nazioni Unite negli anni '80, in seguito al lavoro della Commissione Brundtland e al rapporto finale pubblicato nel 1987 (Brundtland, 1987). Una delle prime definizioni riconosciute a livello globale è stata fornita durante la Conferenza ONU su Ambiente e Sviluppo di Rio nel 1992, come concetto multidimensionale basato su equità sociale, crescita economica e protezione ambientale (Drexhage & Murphy, 2010). Con l'Agenda 2030 per lo sviluppo sostenibile (UN General Assembly, 2015), in cui l'ONU ha definito i 17 Obiettivi di Sviluppo Sostenibile (SDGs), è stato compiuto un altro passo fondamentale. Esiste un dibattito tuttora in corso sulla gerarchia delle tre dimensioni: alcuni esperti propongono una struttura piramidale con l'ambiente alla base come priorità necessaria rispetto agli ambiti sociale ed economico (Obrecht et al., 2021); altri auspicano di superare le nette separazioni tra queste dimensioni (Purvis et al., 2019). C'è una comprensione condivisa dell'interdipendenza di questi tre pilastri, ma il concetto rimane ancora vago e incerto.

Dai primi anni 2000, gli studi sui trasporti hanno iniziato a riferirsi alle consegne in contesti urbani con termini alternativi come "logistica dell'ultimo miglio", "logistica urbana" e "city logistics", per riferirsi alla distribuzione fisica delle merci rispetto a un insieme di obiettivi, come l'efficienza dei servizi e lo sviluppo urbano sostenibile nell'ambito di un'economia di mercato, con il supporto di sistemi informativi avanzati e considerando la congestione del traffico, la sicurezza stradale e il consumo energetico come aspetti critici da migliorare (Taniguchi et al., 2001; Taniguchi, 2014). I principali problemi nella logistica dell'ultimo miglio sono rappresentati dalle sfide operative, dalle problematiche di costo ed efficienza, dalle preoccupazioni ambientali e di sostenibilità e dalle questioni normative. Le sfide operative consistono nella congestione del traffico, poiché i veicoli per le consegne affrontano le difficoltà delle strade urbane bloccate, specialmente nelle ore di punta, e contribuiscono essi stessi agli ingorghi (Savelsbergh & Van Woensel, 2016). Un altro problema è la scarsità di spazi dedicati al parcheggio e al carico/scarico nelle città (Dablanc, 2007). Esistono inefficienze come il basso tasso di utilizzo dei veicoli, che frequentemente operano al di sotto della capacità spesso a causa delle piccole consegne individuali (Olsson et al., 2019), ma anche nei percorsi e nelle preferenze di recapito sempre più esigenti, con una crescente domanda di consegne a domicilio e con maggiore flessibilità (McKinnon, 2016). Queste inefficienze portano a costi di consegna elevati e a un impatto ambientale negativo, con un aumento delle emissioni inquinanti (Allen et al., 2018). Le attività logistiche nelle aree urbane sono direttamente influenzate dai requisiti dello sviluppo sostenibile, con specifico riferimento all'SDG 9 "Industria, innovazione e infrastruttura" e all'SDG 11 "Città e comunità sostenibili".

Questo articolo affronta il modo in cui il concetto multidimensionale di sostenibilità viene tradotto in pratica quando decisori e stakeholder valutano politiche alternative in diversi contesti di logistica urbana. Il nostro obiettivo è quello di completare ed estendere cinque altre rassegne della letteratura: la rassegna della metodologia per valutare la sostenibilità attraverso metodi multicriterio

[1] Le emissioni globali di CO2 legate all'energia hanno raggiunto un nuovo massimo di oltre 36,8 Gt nel 2022, con una crescita dello 0,9%. Queste emissioni sono suddivise in quattro diversi settori: energia, industria, trasporti ed edilizia.

[2] Le emissioni dei trasporti sono suddivise in veicoli stradali per passeggeri, aviazione, veicoli stradali per merci, ferrovie, spedizioni e altre fonti

(Lindfors, 2021), la rassegna delle strategie e delle soluzioni per le consegne urbane dell'ultimo miglio (Lagorio et al., 2016; Lyons & McDonald, 2023) e la rassegna dell'uso dell'analisi multicriterio nel settore specifico delle soluzioni logistiche urbane (Jamshidi et al., 2019; Alvarez Gallo & Maheut, 2023). La nostra rassegna mira a individuare le principali problematiche nella scelta dei criteri quando si utilizzano metodi multicriterio per raggiungere la sostenibilità in questo campo e a evidenziare lacune e possibili nuove configurazioni. Sono state affrontate le seguenti domande:

1. In che modo i decisori (DMs) e gli stakeholder affrontano la sostenibilità?
2. Come viene considerata la sostenibilità nella definizione delle alternative e nella scelta dei criteri?
3. Qual è la proporzione delle diverse tipologie di criteri adottati?

Il presente articolo è strutturato come riportato di seguito: la Sezione 2 descrive la metodologia adottata per eseguire la rassegna sistematica della letteratura, seguendo le linee guida PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis), identificando i motivi di inclusione ed esclusione per la selezione degli studi e descrivendo brevemente gli articoli selezionati. La Sezione 3 presenta una meta-analisi dei risultati, descrivendo il corpus degli articoli selezionati e i principali argomenti e metodi che emergono dalla ricerca. La Sezione 4 discute i risultati della rassegna della letteratura. La Sezione 5 espone le conclusioni.

2. Metodologia

Il tema è stato affrontato attraverso una rassegna sistematica della letteratura (Systematic Literature Review, SLR) strutturata in tre fasi: identificazione e selezione degli studi, descrizione delle informazioni del corpus di studi e classificazione del contenuto per rispondere alle domande di ricerca.

Gli studi sono stati selezionati seguendo le linee guida PRISMA (Moher et al., 2015; Page et al., 2021), un tool riconosciuto per rafforzare le rassegne della letteratura, rendendole strutturate e replicabili. Una rassegna preliminare della letteratura è stata condotta per identificare le parole chiave da utilizzare nella formulazione delle stringhe di ricerca. Nella fase di individuazione, le parole chiave e i sinonimi correlati sono stati definiti con un focus su tre aspetti: 1) parole chiave legate alla sostenibilità, 2) parole chiave legate alla logistica dell'ultimo miglio, e 3) parole chiave legate alle metodologie di analisi multicriterio. Successivamente, sono stati utilizzati due principali database scientifici, Scopus e Web of Science (WOS), con ricerche che hanno portato a individuare 112 articoli su WOS e 140 su Scopus al 10 novembre 2023. Il periodo di ricerca è stato definito dal 2003 all'ottobre 2023, trovando una particolare presenza di articoli negli anni più recenti.

Le parole chiave sono state cercate utilizzando il comando "Title-Abstract-Keywords" nel campo di ricerca generale e sono state raggruppate in tre blocchi riguardanti sostenibilità, logistica dell'ultimo miglio e tecniche di valutazione multicriterio: "sustainable*", "green", "environmen*", "eco-friendly", "ecological" per il blocco sulla sostenibilità, "last mile logistic*", "last-mile logistic*", "urban logistic*", "city logistic*", "urban consolidation cent*", "urban distribution", "city distribution", "urban deliver*", "city deliver*" nella logistica di ultimo miglio e "*criteria", "multicriteri*", "multi-criteri*", "mcda", "mcdm" per la parte multicriteri. La query su WOS è stata la seguente: (TS=(sustainab* OR green OR environmen* OR ecofriendly OR ecological)) AND (TS=(«last mile logistic*» OR «urban logistic*» OR «city logistic*» OR «urban consolidation cent*» OR «urban distribution» OR «city distribution» OR «urban deliver*» OR «city deliver*»)) AND (TS=(*criteria OR multicriteri* OR multi-criteri*)), mentre su Scopus è stata formulata in modo simile, con (TITLE-ABS-KEY ((sustainab*) OR (green) OR (environmen*) OR (friendly) OR (ecological)) AND TITLE-ABS-KEY ((«last mile logistic») OR («last-mile logistic») OR («urban logistic*») OR («city logistic*») OR («urban consolidation cent*») OR («urban distribution») OR («city distribution») OR («urban deliver*») OR («city deliver*»)) AND TITLE-ABS-KEY (*criteria)) AND (LIMIT-TO (DOCTYPE,»ar») OR LIMIT-TO (DOCTYPE,»re»)) AND (LIMIT-TO (LANGUAGE,»English»)) AND (LIMIT-TO (SRCTYPE,»j»)).

Tutti gli articoli sono stati letti, revisionati e analizzati in un foglio di calcolo: 44 articoli non si riferivano o non applicavano metodi multicriterio (38), o non erano pertinenti (6), lasciando un totale di 62 articoli, di cui 6 erano rassegne della letteratura, arrivando quindi a 56 articoli nel corpus finale della rassegna. Il processo di selezione è illustrato in Figura 1.

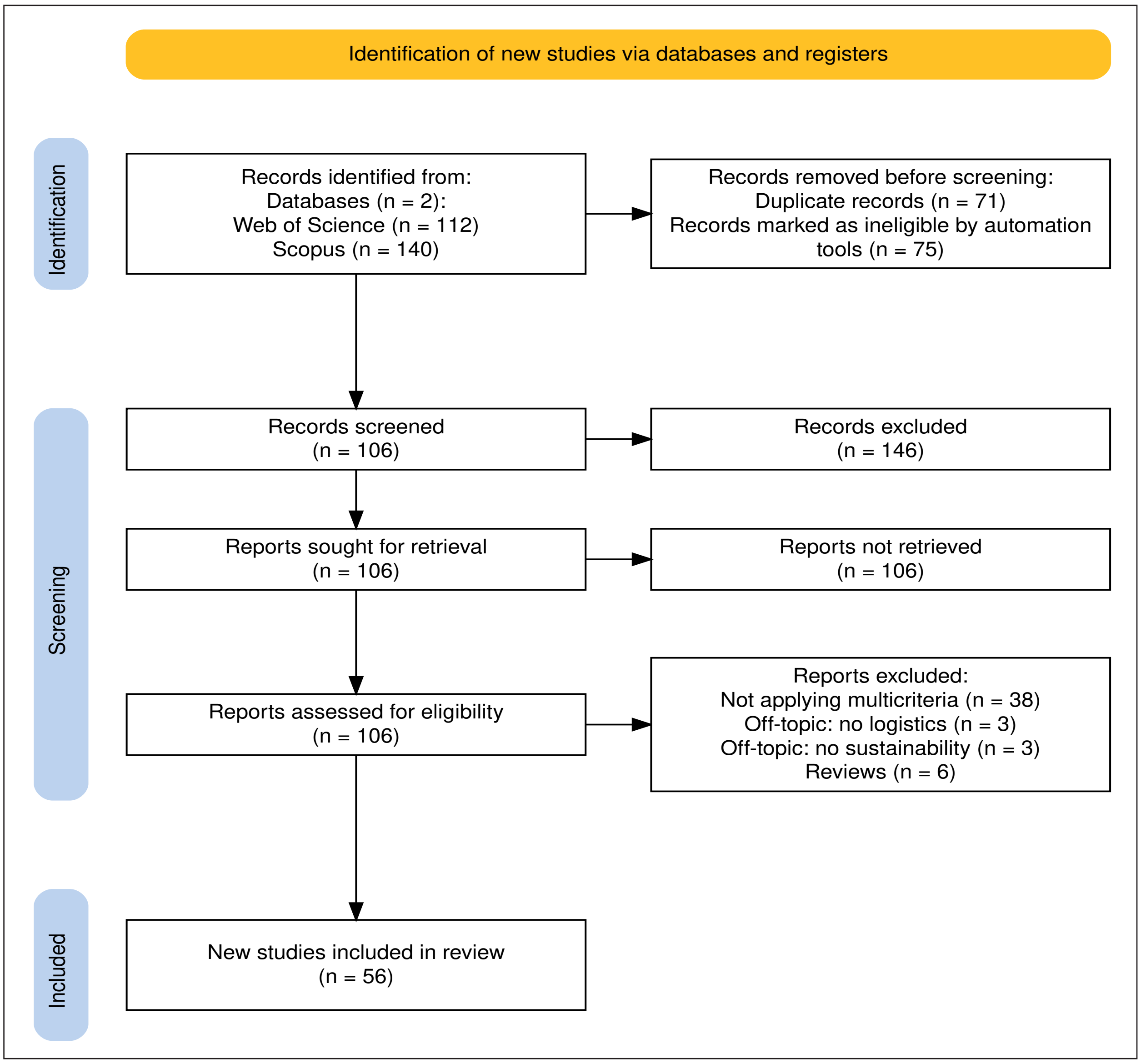

Figura 1. Processo di selezione degli articoli con lo strumento PRISMA Flow Diagram (Haddaway et al., 2022).

Il processo di selezione è proseguito con la fase di screening ed eleggibilità, applicando filtri oggettivi. Come misura di qualità, sono stati inclusi solo articoli e rassegne pubblicati in riviste peer-reviewed, adottando la lingua inglese come filtro. Dopo la rimozione dei duplicati tra le due liste di articoli, il processo è passato alla fase di inclusione, nella quale sono stati selezionati gli studi nell'ambito della logistica urbana se applicavano metodologie di analisi multicriterio con l'obiettivo preciso di valutare alternative sostenibili. Sono stati esclusi gli studi che non utilizzavano l'analisi decisionale multicriterio, come quelli che impiegavano modelli di ottimizzazione o simulazione senza valutare altre opzioni, oltre agli studi off-topic, come quelli focalizzati sul trasporto passeggeri anziché merci o che menzionavano la sostenibilità solo come premessa generale o l'uso di più criteri, ma non di metodologie multicriterio.

È stato creato un foglio di calcolo per includere le informazioni generali sugli articoli (ad es., titolo, anno di pubblicazione, fonte di pubblicazione), le informazioni sulla città o sulle città studiate (ad es., numero e nome delle città), i dettagli sulla metodologia di analisi multicriterio applicata, i criteri utilizzati, le alternative valutate e gli stakeholder considerati.

Quando erano disponibili altri dati rilevanti, il foglio includeva anche informazioni sulle fonti di dati menzionate, il numero di rispondenti nel caso fosse stato utilizzato un metodo di indagine e l'anno di raccolta dei dati. La Tabella 1 fornisce un elenco dei metodi impiegati e riassume le caratteristiche dei 56 articoli selezionati.

Tabella 1. Metodi adottati negli articoli selezionati e sintesi delle caratteristiche degli articoli

Articoli (Ordine alfabetico)	Focus della ricerca	Metodi (criteri/alternative)	Info (Alternative / Criteri; DM/Stakeholders)
(Aiello et al., 2021)	Veicoli	TOPSIS	6 batterie di veicoli / 2 criteri 1 DM (ipotetico)
(Aljohani, 2023)	Localizzazione Strategie - Policies	AHP, TOPSIS	3 luoghi / 8 criteri 6 strategie multi-policy / 7 criteri 1 DM
(Aljohani & Thompson, 2019)	Veicoli	MAMCA, AHP, PROMETHEE	4 configurazioni della flotta / 3-7 criteri (25 in totale), 6 categorie di stakeholder
(Álvarez & de la Calle, 2011)	Policy Singola	AHP	9 iniziative / 4 criteri 7 categorie di stakeholder
(Awasthi & Chauhan, 2012)	Policy Singola	AHP, TOPSIS	4 pratiche / 4 criteri + 16 sub criteri 5 DM (gruppo) – categorie di stakeholder
(Awasthi et al., 2011)	Localizzazione	TOPSIS	3 luoghi / 11 criteri + 16 sub criteri 5 DM (gruppo) – categorie di stakeholders
(Bandeira et al., 2018)	Strategie - Policies	TOPSIS	2 strategie multi-policy / 10 criteri 1 DM
(Bartuška et al., 2023)	Policy Singola	AHP	5 Policy / 43 indicatori 1 DM
(Bennani et al., 2022)	Localizzazione	CATWOE, F-VIKOR	8 luoghi / 11 criteri 7 stakeholder
(Boggio-Marzet et al., 2023)	Strategie - Policies	MAMCA	14 obiettivi / 12 criteri 25 esperti - 5 categorie di stake-
(Buyukozkan & Mukul, 2019)	Tecnologia	Fuzzy SAW	10 Requisiti tecnologici / 8 criteri 3 DM
(de Araujo et al., 2022)	Strategie – Policies	F-AHP	5 strategie multi-policy / 6 criteri 27 esperti
(de Carvalho et al., 2019)	Localizzazione	MAMCA	2 luoghi / 5 criteri + 16 sub criteri 3 categorie di stakeholder
(Deveci et al., 2022)	Policy Singola	DIBR	3 iniziative / 16 criteri 3 esperti

Segue **Tabella 1**. Metodi adottati negli articoli selezionati e sintesi delle caratteristiche degli articoli

Articoli (Ordine alfabetico)	Focus della ricerca	Metodi (criteri/alternative)	Info (Alternative / Criteri; DM/Stakeholders)
(Gatta et al., 2019)	Strategie – Policies	MAMCA, AHP	3 schemi di consegna / 5-7 criteri (16 tot) 4 categorie di stakeholder
(He et al., 2017)	Localizzazione	AHP, TOPSIS	4 luoghi / 4 Criteri + 13 sub criteri 5 DM esperti
(Hu et al., 2022)	Strategie - Policies	AHP, VIKOR	16 politiche di città / 11 criteri 9 DM esperti
(Kijewska et al., 2018)	Policy Singola	AHP, DEMATEL	16 misure/ 3 criteri + 4 sub criteri 1 DM (Enti Pubblici)
(Kin et al., 2017)	Policy Singola	MAMCA, AHP, PROMETHEE	4 scenari / 33 criteri 6 categorie di stakeholder
(Kovač et al., 2021)	Strategie - Policies	MARCOS	12 schemi di consegna / 10 criteri 4 categorie di stakeholder
(Kovač et al., 2023)	Localizzazione	ADAM-MCDM	7 luoghi / 6 criteri 1 DM (ipotetico)
(Krstic et al., 2021)	Policy Singola	DELPHI, FARE, VIKOR	6 iniziative / 10 criteri 4 categorie di stakeholder
(Lebeau et al., 2018)	Strategie - Policies	MAMCA, AHP, PROMETHEE	6 scenari / 15 criteri (5-7 ognuno) 5 categorie di stakeholder
(Macharis & Milan, 2015)	Strategie - Policies	MAMCA, AHP, PROMETHEE	4 scenario / 18 criteri 5 categorie di stakeholder
(Macharis et al., 2014)	Strategie - Policies	MAMCA-CD, PROMETHEE – GDSS	4 scenari / 17 criteri 5 categorie di stakeholder
(Melkonyan et al., 2020)	Strategie - Policies	PROMETHEE, Simulation SD	3 schemi di consegna / 16 criteri 2 aziende
(Milan et al., 2015)	Strategie - Policies	MAMCA-CD, PROMETHEE – GDSS	4 scenari/ 10 criteri 5 DMs - 3 categorie di stakeholder
(Moslem & Pilla, 2023)	Localizzazione	SF-AHP	6 alternative / 5 criteri 3 DM
(Muerza & Guerlain, 2021)	Progetti di costru-zione	AHP	3 progetti / 4 criteri – 14 attributi 1 DM (ipotetico)
(Nathanail & Karakikes, 2021)	Policy Singola	AHP, DELPHI	11 policies / 9 criteria 3 categorie di stakeholder (21 soggetti)
(Novotna et al., 2022)	Localizzazione	BWM-CRITIC-WASPAS	5 luoghi / 5 criteria 3 esperti
(Pamučar et al., 2016)	Strategie - Policies	TSDSM, WLC, GIS	5 scenari / 4 criteri + 21 sub criteri 6 DM
(Perera & Thompson, 2021)	Policy Singola	MAMCA	10 schemi pedaggi / 21 criteri (5-7) 4 categorie di stakeholder
(Rao et al., 2015)	Localizzazione	FMAGDM-THOWA-TOPSIS	4 luoghi / 13 criteri 1 DM (ipotetico)

Segue **Tabella 1**. Metodi adottati negli articoli selezionati e sintesi delle caratteristiche degli articoli

Articoli (Ordine alfabetico)	Focus della ricerca	Metodi (criteri/alternative)	Info (Alternative / Criteri; DM/Stakeholders)
(Rześny-Cieplińska & Szmelter-Jarosz, 2019)	Servizi	AHP	24 servizi di crowd logistics / 20 criteri 7 categorie di stakeholder
(Rześny-Cieplińska & Szmelter-Jarosz, 2020)	Strategie - Policies	AHP	20 criteri (focus solo sui criteri)
(Saha et al., 2023)	Veicoli	DHF-CEBOM-SDNMARCOS	4 tipi di veicoli / 9 criteri 3 esperti
(Salabun et al., 2019)	Veicoli	COMET	10 veicoli leggeri-due ruote / 8 criteri 1 esperti
(Sárdi & Bóna, 2021)	Localizzazione	AHP	4 zone urbane / 43 criteri 18 esperti
(Semanjski & Gautama, 2019)	Strategie - Policies	AHP	5 criteri (focus solo sui criteri)
(Senne et al., 2021)	Policy Singola	AHP, Index	29 iniziative / 5 criteri 1 esperto
(Serrano-Hernandez et al., 2021)	Strategie - Policies	AHP	6 percorsi / 3 criteri + 9 sub criteri 1 categorie di stakeholder
(Sgura Viana & Delgado, 2019)	Strategie - Policies	MCE-GIS, AHP	7 strategie / 7 criteri 1 DM (municipalità)
(Shekhovtsov et al., 2020)	Veicoli	TOPSIS, VIKOR	10 veicoli leggeri-due ruote / 8 criteri 1 esperto
(Silva et al., 2023)	Strategie - Policies	AHP, TOPSIS	4 alternative / 9 criteri 9 esperti
(Sopha et al., 2018)	Localizzazione	TOPSIS	4 luoghi / 10 criteria 4 DM
(Svadlenka et al., 2020)	Strategie - Policies	PFS	6 alternative / 20 criteri 10 DM
(Szmelter-Jarosz & Rześny-Cieplińska, 2020)	Strategie - Policies	DEMATEL, AHP	20 criteria (focused only on criteria) 6 categorie di stakeholder
(Tadić et al., 2022)	Strategie - Policies	BWM, CODAS	4 strategie multi-policy / 11 criteri 4 categorie di stakeholder
(Tadić et al., 2023)	Strategie - Policies	AHP, MARCOS	12 iniziative / 10 criteri 4 categorie di stakeholder
(Tadić et al., 2014)	Strategie - Policies	DEMATEL, VIKOR	4 strategie multi-policy / 10 criteri 1 DM (ipotetico)
(Urzúa-Morales et al., 2020)	Veicoli	AHP	5 veicoli / 3 criteri 1 DM (ipotetico)
(Uyanik et al., 2020)	Localizzazione	DEMATEL, TOPSIS	4 luoghi / 16 criteri 4 DM - categorie di stakeholder

Segue **Tabella 1**. Metodi adottati negli articoli selezionati e sintesi delle caratteristiche degli articoli

Articoli (Ordine alfabetico)	Focus della ricerca	Metodi (criteri/alternative)	Info (Alternative / Criteri; DM/Stakeholders)
(C.-N. Wang et al., 2023)	Strategie - Policies	OPA, MARCOS	5 strategie multi-policy / 12 criteri 4 esperti
(Y. Wang et al., 2023)	Localizzazione	BWM, MultiObj	26 luoghi, 4 criteri 1 DM (municipalità)
(Watróbski et al., 2017)	Veicoli	PROMETHEE II, fuzzy TOPSIS	10 veicoli/ 4 criteri + 9 sub criteri 1 DM (municipalità)

3. Meta-analisi

3.1. Tendenze nella letteratura

All'inizio degli anni 2000, Taniguchi e altri importanti ricercatori del settore logistico (2003) hanno riconosciuto la necessità di sviluppare e applicare modelli matematici a supporto delle attività di pianificazione urbana e per valutare le iniziative di logistica in città su basi razionali solide. Il processo decisionale per perseguire un sistema di trasporto più sostenibile è stato al centro del lavoro di Kennedy et al. (2005), che ha identificato i quattro pilastri di governance, finanziamento, infrastrutture e quartieri, che sostengono metaforicamente il triangolo ambiente, economia e società, coinvolti nel trasporto urbano sostenibile. Tutti questi ambiti sono necessari e presentano compromessi che devono essere affrontati in una pianificazione integrata. Alcuni studi hanno adottato metodi di simulazione (Karakikes et al., 2018), di ottimizzazione (Rifki et al., 2020; Sawik et al., 2022) o economici (Handoko et al., 2016; Gatta et al., 2019; Isa et al., 2021), ma sono stati esclusi da questo studio per focalizzarsi su quelli che applicano metodi decisionali multicriterio.

Gli articoli selezionati sono stati classificati in entrambi i database, WOS e Scopus, sotto diverse categorie, confermando la natura multidisciplinare del tema. In WOS, le principali categorie sono Green Sustainable Science Technology, Environmental Studies, Environmental Sciences, Transportation, Operations Research Management Science, Transportation Science Technology, Economics, Energy Fuels, Engineering Electrical Electronic, Computer Science; in Scopus, le prevalenti sono Engineering, Social Sciences, Environmental Science, Energy, Computer Science, Business-Management-Accounting, Mathematics, Decision Sciences, e Economics-Econometrics-Finance.

Nell'ultimo decennio, si è registrato un significativo aumento del numero di studi che hanno esplorato l'uso dei metodi multicriterio per la valutazione di soluzioni sostenibili nel settore della logistica urbana. Numerosi studi di caso sono stati condotti per confermare la fattibilità e l'efficacia dei metodi multicriterio nella valutazione delle soluzioni sostenibili in questo ambito. Le riviste maggiormente ricorrenti nella ricerca sono state *Sustainability* (18 documenti), *Research on Transportation Economics* (4), *Case Studies on Transport Policy* (3), *Promet – Traffic&Transportation* (2), *Journal of Industrial Engineering and Management* (2), *Research in Transportation Business and Management* (2), *Transportation Research Part D: Transport and Environment* (2) e *Energies* (2). Questi studi hanno dimostrato un interesse crescente per questo argomento nell'ultimo decennio (Figura 2).

3.2. Obiettivi e alternative valutate

I sistemi urbani di trasporto merci sono complessi e dinamici, e negli ultimi decenni sono state condotte diverse rassegne della letteratura sull'argomento. Secondo Lagorio et al. (2016), la classificazione delle diverse metodologie ha diviso gli studi in svariate categorie: studi di caso, studi concettuali, rassegne della letteratura, modelli quantitativi, simulazioni e sondaggi. L'applicazione di differenti analisi multicriterio si basa generalmente su un contesto urbano specifico ed è strutturata come casi di studio riguardanti attività di pianificazione di comuni o aziende oppure casi pilota. Gli studi

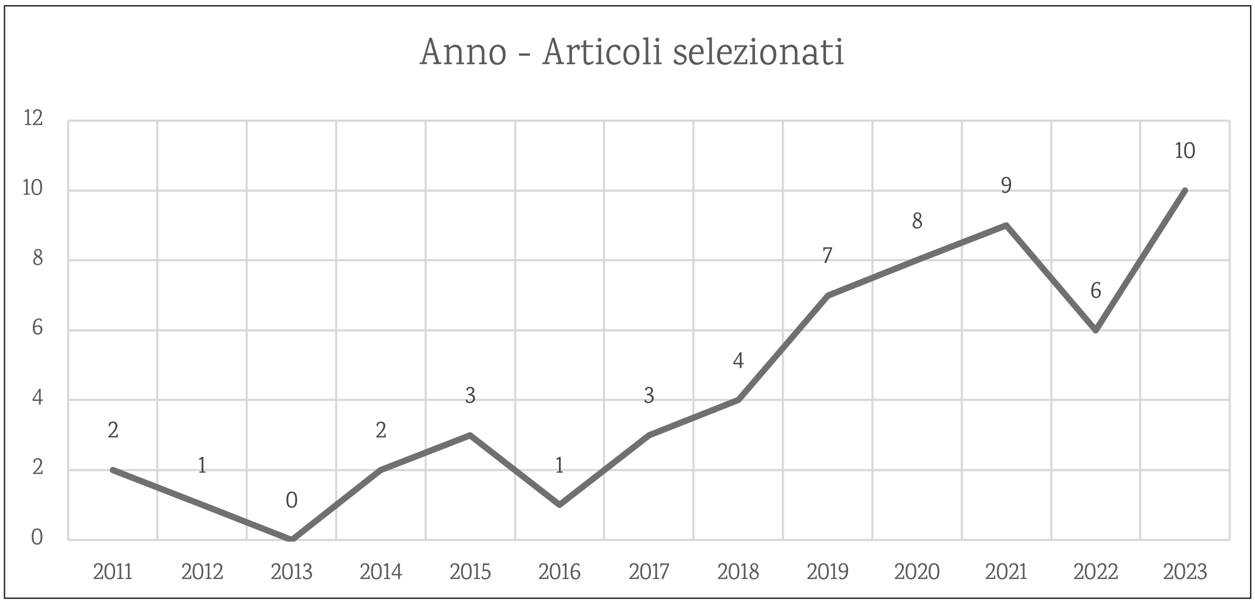

Figura 2. Numero di articoli per anno.

concettuali trattano schemi di approccio metodologico. Il gruppo dei modelli quantitativi si riferisce alla soluzione di problemi di instradamento, ubicazione e modellazione dei costi attraverso dati quantitativi. Al contrario, l'insieme delle *survey* comprende problemi di scelta discrezionale basati su preferenze dichiarate o palesate. Questa rassegna si concentra sull'applicazione dei metodi Multicriteria Decision-Aiding (MCDA) e la maggior parte degli articoli selezionati è costituita da casi di studio.

Dall'analisi di più articoli, è emerso che ventidue di essi si concentrano principalmente su strategie di distribuzione complete, definite nei piani di logistica urbana integrata come una combinazione di più *policies*, piuttosto che su un singolo intervento specifico di *policy*. Tali strategie considerano vari aspetti, come l'ambiente, l'efficienza e la qualità dei servizi, e vengono utilizzate come alternative per raggiungere gli obiettivi esplicitamente definiti per ciascun problema. Lyons e McDonald (2023) hanno raggruppato le strategie di consegna dell'ultimo miglio in quattro categorie: veicoli innovativi, consolidamento delle merci urbane, miglioramenti tecnologici e di instradamento nella logistica urbana, nuovi strumenti e politiche di pianificazione emergenti. Hanno evidenziato l'importanza di comprendere le diverse modalità di intervento e la rilevanza delle misure politiche, identificando ventidue strategie di consegna dell'ultimo miglio, tra cui: cicli per le merci, veicoli merci a combustibile alternativo, veicoli merci autonomi, droni per le consegne, veicoli merci modulari, consegna pedonale o a portatori, tram per il trasporto merci, veicoli commerciali leggeri, pipeline sotterranee per il trasporto merci, centri di consolidamento urbano, armadietti per pacchi, punti di ritiro, logistica collaborativa, miglioramenti al problema di instradamento dei veicoli, crowd-shipping, depositi mobili, variazioni temporali, uso migliorato delle infrastrutture esistenti, restrizioni all'accesso urbano, zone di carico/scarico, regolamentazioni sui parcheggi, requisiti di certificazione. Questi tentativi di classificare e identificare i gruppi di politiche sono particolarmente rilevanti dato il numero di misure politiche innovative identificate in progetti europei come STRAIGHTSOL (2014), CITYLOG (2012), ENCLOSE (2014), BESTUFS (2008), C-LIEGE (2014), FREIGHLOT (2011) e CITYLAB (2015), per citarne alcuni che appaiono negli articoli selezionati. Tuttavia, il rischio che non tutti i decisori coinvolti siano consapevoli o interessati a considerare questa varietà di misure politiche è un aspetto critico.

Un altro obiettivo, affrontato in undici articoli, consiste nella valutazione di diversi aspetti o configurazioni di una singola politica specifica. Questo obiettivo si concentra sull'esplorazione di diverse opzioni di *policies* e dei loro potenziali risultati anzichè che sulla combinazione di più *policies* in una strategia completa.

Come riportato in tredici pubblicazioni, il secondo obiettivo più comune è valutare la localizzazione migliore per un progetto o un servizio selezionato. Questo obiettivo è fondamentale poiché contribuisce a determinare la posizione ottimale per un particolare servizio, il che può ridurre i costi logistici e migliorare l'efficienza complessiva. La collocazione dei magazzini lungo la catena di approvvigionamento e la distanza dai centri urbani influenzano profondamente le attività legate ai movimenti delle merci. Questo problema è affrontato in diversi articoli (Awasthi et al., 2011; Rao et al., 2015; He et al., 2017; Sopha et al., 2018; de Carvalho et al., 2019; Uyanik et al., 2020; Sardi & Bona, 2021; Bennani et al., 2022; Novotna et al., 2022; Aljohani, 2023; Kovač et al., 2023; Moslem & Pilla, 2023; Y. Wang et al., 2023). Nel lavoro di Aljohani e Thompson (2016), la rassegna della letteratura si concentra sul fenomeno dello *sprawl* logistico, in cui il trasferimento delle strutture logistiche fuori dalle aree urbane è dovuto ai prezzi dei terreni proibitivi per scopi logistici nella parte interna delle città. È interessante notare che la logistica dell'ultimo miglio è spesso considerata l'aspetto più costoso e inefficiente della catena di approvvigionamento. Questo è dovuto a vari fattori, tra cui la congestione del traffico merci, la distanza, la mancanza di infrastrutture e la necessità di opzioni di consegna personalizzate. Secondo alcuni autori, consegnare un singolo pacco in una località remota può risultare più costoso che consegnare un grande volume di pacchi in un centro commerciale (Gonzalez et al., 2023; Tadić et al., 2023). Questo fenomeno modifica la geografia dei movimenti delle merci urbane e produce un aumento delle distanze percorse dai camion, con conseguenti impatti negativi e la necessità di infrastrutture aggiuntive, come i centri di consolidamento urbano, per ridurre le distanze e il numero di veicoli tra un luogo e l'altro.

Inoltre, sette articoli studiano i tipi di veicoli adatti per le operazioni di logistica urbana (Watróbski et al., 2017; Aljohani & Thompson, 2019; Salabun et al., 2019; Shekhovtsov et al., 2020; Urzúa-Morales et al., 2020; Saha et al., 2023; Aiello et al., 2021). Questo obiettivo è correlato alla valutazione di veicoli ecologici o alla selezione del tipo di trasporto per la consegna delle merci, principalmente il terrestre tradizionale con furgoni, biciclette da carico e recenti soluzioni alternative come i droni. L'obiettivo è identificare il tipo di veicolo più adatto che possa contribuire a ridurre l'inquinamento e migliorare l'efficienza complessiva delle operazioni logistiche nelle aree urbane.

Nei documenti selezionati erano presenti sei rassegne sistematiche della letteratura che trattano elementi rilevanti per il presente lavoro, come le strategie dell'ultimo miglio per le consegne urbane (Lyons & McDonald, 2023), i criteri e i metodi decisionali per la logistica urbana sostenibile (Jamshidi et al., 2019; Hauge et al., 2021), o, più specificamente, l'analisi multicriterio nelle soluzioni logistiche sostenibili (Alvarez Gallo & Maheut, 2023), la ponderazione del contesto urbano nei criteri (Gonzalez et al., 2023) e l'identificazione dell'intelligenza della logistica urbana (Xenou et al., 2022). Una rassegna dei problemi MCDA con una descrizione dei criteri più utilizzati per selezionare le iniziative di logistica urbana sostenibile è fornita da Jamshidi et al. (2019), che evidenzia anche la molteplicità dei criteri economici, tecnici, ambientali e sociali, recensendone oltre un centinaio di criteri.

Alcuni studi residuali negli articoli selezionati si concentrano su aspetti o settori specifici, come la valutazione di tre progetti di costruzione e della logistica dell'ultimo miglio correlata, affrontata da Muerza e Guerlain (2021), così come la valutazione dei requisiti tecnologici (Buyukozkan & Mukul, 2019) o la scelta dei servizi di consegna dell'ultimo miglio forniti da venti diverse aziende (Rześny-Cieplińska & Szmelter-Jarosz, 2019). Gli obiettivi e i tipi di alternative trattati negli articoli selezionati sono riportati nella Tabella 2.

Tabella 2. Principali obiettivi di analisi negli articoli selezionati

	Tot.	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Alternative	**56**	**2**	**1**	**0**	**2**	**3**	**1**	**3**	**4**	**7**	**8**	**9**	**6**	**10**
Strategie - Policies	**22**				2	2			2	3	4	3	2	4
Localizzazione	**13**	1					1	1	1	1	2	1	1	4
Policy Singola	**11**	1	1			1		1	1			2	3	1
Tipi di veicolo	**7**							1		2	2	2		
Costruzioni	**1**											1		
Tecnologie	**1**									1				
Servizi	**1**													1

3.3. Categorie di stakeholders coinvolti

Tutti gli articoli selezionati menzionano l'importanza di considerare le categorie di stakeholder in modo sfaccettato. Tuttavia, il tipo e il numero di portatori di interesse coinvolti dipendono dal caso specifico e dal tipo di risorse e metodi adottati. Per garantire il successo dell'implementazione di queste misure, è cruciale coinvolgere tutti gli stakeholder e promuovere la consapevolezza dei benefici degli interventi politici. Un gruppo di articoli (Kin et al., 2017; Aljohani & Thompson, 2019; de Carvalho et al., 2020; Boggio-Marzet et al., 2023) ha adottato, per definizione, una prospettiva multi-stakeholder attraverso l'analisi multicriterio multi-attore (MAMCA), un metodo sviluppato da Macharis (2005) che permette di incorporare diversi punti di vista, evidenziando vantaggi e svantaggi nelle opinioni degli stakeholder. Un'altra rassegna della letteratura considera la prospettiva degli stakeholder. Ad esempio, il lavoro di Arvidsson (2013) ha analizzato il punto di vista dei trasportatori stradali come attori che allo stesso tempo subiscono e contribuiscono agli aspetti negativi del trasporto merci, indagando la complessa relazione tra i costi e i benefici delle misure per migliorare l'efficienza e la sostenibilità del trasporto.

Negli articoli selezionati, prevale il coinvolgimento del pubblico e delle autorità locali (25 articoli), come Comuni e Istituzioni regionali responsabili della pianificazione politica o della valutazione di progetti. Questi enti svolgono un ruolo centrale nella definizione delle normative, nello sviluppo delle infrastrutture e nelle politiche di sostenibilità. Seguono i fornitori logistici (21), evidenziando il ruolo critico degli esecutori del processo di consegna e la loro necessità di adattarsi ai cambiamenti normativi e alle esigenze operative. Un altro gruppo di stakeholder frequentemente menzionato è la cittadinanza (20), che testimonia l'importanza crescente della percezione pubblica e della partecipazione, così come l'impatto diretto delle operazioni logistiche sulle comunità urbane in termini di qualità complessiva della vita. I rivenditori e i destinatari dei servizi logistici (17) sono direttamente influenzati dall'efficienza e dalla convenienza economica delle soluzioni logistiche urbane. Sono inclusi anche esperti, intesi come un gruppo generale di professionisti, consulenti e ricercatori (16), di cui alcuni si riferiscono specificamente al mondo accademico (4). Sono inoltre compresi i vettori e gli spedizionieri (13), fornendo informazioni su lavoratori e persone coinvolte nel coordinamento delle attività di trasporto e consegna. Alcuni articoli teorici fanno riferimento a potenziali stakeholder senza identificare specificamente il tipo, ma riferendosi ai decisori politici (8) o ad altri soggetti di interesse generale (4).

È importante notare che non esistono procedure obbligatorie per come coinvolgere gli stakeholder o come selezionare i criteri nella valutazione delle soluzioni logistiche urbane. Sebbene le linee guida istituzionali, come quelle dell'Unione Europea e di altre organizzazioni internazionali, raccomandino il coinvolgimento di diversi stakeholder, come autorità pubbliche, fornitori logistici e comunità locali, queste raccomandazioni restano di carattere consultivo più che obbligatorio.

3.4. Criteri considerati per la valutazione di alternative

Nel valutare la sostenibilità di una politica o di un progetto, è essenziale considerare criteri selezionati con cura che riflettano l'efficienza economica, la conservazione ambientale e le considerazioni sociali. I criteri possono essere misurati su una scala quantitativa o qualitativa, a seconda delle caratteristiche del progetto. I criteri sociali, come la creazione di posti di lavoro, la qualità del lavoro e la qualità della vita nel quartiere, dovrebbero essere scelti per la sostenibilità della logistica dell'ultimo miglio. I criteri ambientali che meritano attenzione includono il consumo energetico, le emissioni di gas serra (GHG), le emissioni di NOx, le emissioni di PM e l'inquinamento acustico. Per quanto riguarda i criteri economici, è necessario considerare il costo medio di consegna del modello di business, la congestione del traffico, lo stoccaggio urbano e lo spazio di parcheggio, il tasso di rendimento interno finanziario, i benefici per il commercio al dettaglio, i tempi di consegna e l'affidabilità della consegna entro le finestre temporali stabilite. Tutti questi fattori sono di fondamentale importanza, poiché la dimensione economica può influenzare significativamente tutti gli stakeholder coinvolti nel settore della logistica dell'ultimo miglio, inclusi rivenditori, consumatori e operatori logistici.

Questi sono solo alcuni esempi dei 738 criteri adottati negli articoli selezionati, con il primo risultato evidente che molte definizioni e interpretazioni sono adattate caso per caso. La Tabella 3 elenca i cinque criteri più frequenti negli articoli selezionati. Le categorie di criteri e le loro tipologie state analizzate per come sono state presentate in ogni articolo. I criteri delle tre dimensioni ampiamente riconosciute — sociale, economica e ambientale — sono equamente rappresentati negli articoli selezionati, ma sono presenti anche due ulteriori categorie: criteri "operativi" e "territoriali". La maggior parte degli articoli che considerano esplicitamente i criteri operativi li include come parte della sfera economica, poiché gli aspetti organizzativi e tecnologici sono strettamente collegati alla performance. I criteri territoriali, invece, sono più ibridi e si collegano sia alla sfera ambientale che sociale.

Tabella 3. I cinque criteri più frequenti per ogni categoria

Economici	
Costi (Operativi/di Manutenzione, Personale, Trasporto, Consegna, Ricezione, Implementazione misure, Infrastruttura, pedaggi)	51
Economia urbana / Attrattività del Business	16
Sostenibilità economica/Fattibilità	12
Qualità del lavoro / Soddisfazione del personale	9
Livello di cooperazione	8

Ambientali	
Emissioni Co_2 / Qualità dell'aria	37
Impatto ambientale (totale) / Esternalità	28
Inquinamento acustico	20
Congestione	10
Uso dello spazio di carico / occupazione spazio	7

Operativi	
Qualità del servizio / Affidabilità	21
Tempo/Velocità di Consegna	19
Flessibilità/Accessibilità di Consegna	18
Possibilità di Espansione	14
Vicinanza ai punti di consegna	13

Sociali	
Sicurezza del traffico (incidenti)	26
Vivibilità della Città (autorità locali)	13
Prosperità della Regione/Paese	13
Sicurezza nella consegna (lavoratori/clienti)	11
Qualità di vita (cittadinanza)	9

Territoriali		
Pianificazione urbana dello spazio	34	
Sviluppo infrastrutture	6	
Disponibilità infrastrutture e punti (	4	gna
Gestione parcheggi	2	
Numero di hub e punti di consegna	2	

La Figura 3a mostra la presenza di un singolo criterio sotto ciascuna categoria come riportato dagli autori, con la stessa frequenza per i criteri economici, ambientali e sociali e il maggior numero di criteri specifici di natura operativa. La Figura 3b indica quanti articoli hanno considerato quella categoria, riscontrando nuovamente un perfetto equilibrio tra le tre categorie tradizionali, mentre un quarto degli articoli ha incluso i criteri operativi e territoriali.

È stata inoltre analizzata la fonte dichiarata per la scelta dei criteri, identificandone tre tipi di fonti: dalla letteratura scientifica e grigia esistente, dagli esperti e dai professionisti coinvolti nel caso, fonti dirette dai decisori o dagli stakeholder coinvolti. L'uso della letteratura esistente, scientifica e non scientifica, come fonte per la selezione dei criteri è presente in 25 articoli, lo stesso numero di quelli che hanno coinvolto esperti/autori come consulenti per l'adozione di determinati criteri. Un numero minore di articoli (18) ha adottato criteri scelti direttamente dai decisori e dagli stakeholder coinvolti nei progetti e nelle decisioni. Tre quarti degli articoli selezionati menzionano solo una di queste fonti, mentre un quinto ne considera due, e solo pochi articoli (4%) menzionano tutte e tre le fonti insieme.

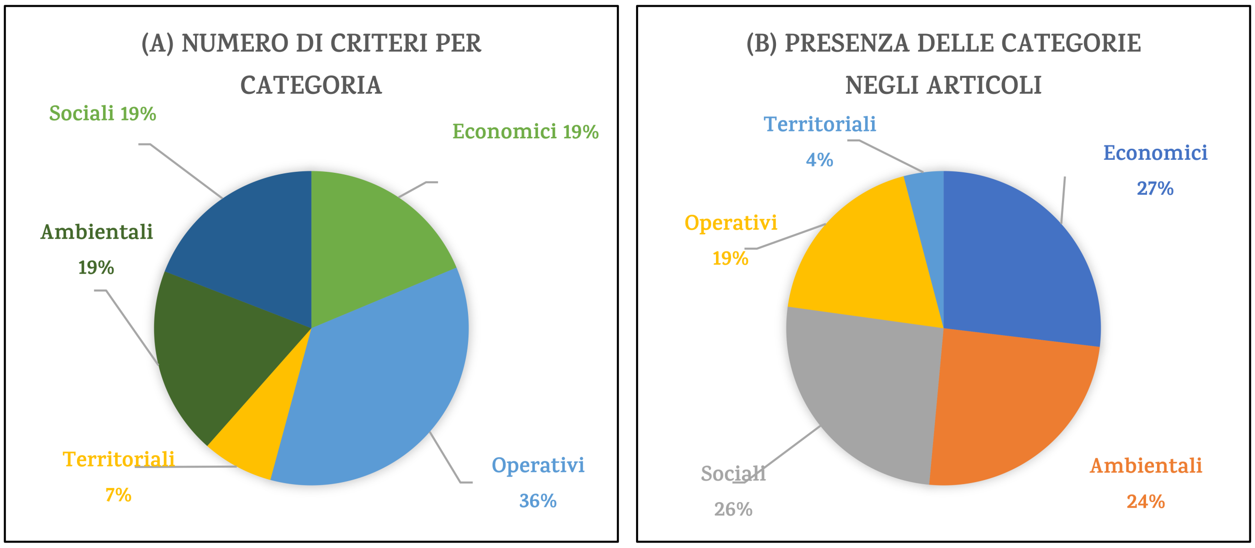

Figura 3. Analisi dei criteri: (A) Percentuale dei criteri per categoria; (B) Numero di articoli per categoria di criteri.

4. Discussione

L'analisi ha identificato 56 articoli e affrontato le problematiche legate alle soluzioni sostenibili per la logistica urbana. Una gestione efficiente delle aree urbane è di fondamentale importanza per il benessere della città e dei suoi abitanti. I decisori politici giocano un ruolo cruciale nel migliorare la qualità della vita della comunità, considerando al contempo gli effetti su persone e imprese (de Carvalho et al., 2020; Serrano-Hernandez et al., 2021). Devono infatti rispondere alle esigenze dei clienti e garantire che il processo logistico si svolga in modo fluido ed efficiente, considerando l'impatto ambientale delle consegne dell'ultimo miglio (Kin et al., 2017). Le misure politiche non sono però percepite come un incentivo per il business, e ciò genera una certa resistenza al cambiamento. La percezione diversa degli stakeholder ha attirato l'attenzione di numerosi studiosi.

Uno dei lavori più completi sulla logistica urbana è quello di Lagorio, Pinto e Golini (2016), in cui gli autori hanno raggruppato gli articoli selezionati in diciassette principali argomenti: veicoli ecologici, zone a traffico limitato (ZTL), e-commerce, tecnologie dell'informazione e comunicazione (ICT), emissioni/inquinamento, centri di distribuzione/consolidamento urbano (UDC/UCC), valutazione delle prestazioni delle soluzioni, coinvolgimento degli stakeholder, soluzioni al problema dell'instradamento dei veicoli (VRP), droni (Kovač et al., 2021; Serrano-Hernandez et al., 2021), tram per le merci, pedaggi stradali, corsie multiuso, consegna in bicicletta, consegne notturne, aree di carico/scarico e punti di ritiro. Le soluzioni valutate evidenziano la complessità dei problemi della logistica urbana e la necessità di un approccio multidisciplinare per i decisori e gli stakeholder.

Per affrontare i problemi logistici sono richieste competenze diverse, e questa necessità ha motivato il lavoro di ricerca di Hauge et al. (2021), che mirava a sviluppare un quadro multilivello per interpretare la complessità del processo decisionale. Gli studi sui processi logistici urbani e sulle relative attività di pianificazione sono stati affrontati tramite diversi approcci e metodi, come indagini basate su sondaggi, modelli di simulazione, metodi basati euristici, valutazioni del ciclo di vita, modelli di costo e approcci di supporto multicriterio. Jamshidi et al. (2019) hanno fornito una rassegna completa della letteratura sull'applicazione di questi modelli nella logistica urbana. L'approccio MCDA è utile in situazioni con molteplici alternative da valutare, poiché appartiene alla ricerca operativa e considera vari criteri quantitativi e qualitativi per supportare il processo decisionale (Yannis et al., 2020).

Per quanto riguarda la logistica urbana, è fondamentale riconoscere che ogni problema è unico. Diversi fattori interni ed esterni determinano la logistica di una città, inclusi aspetti fisici come geografia e infrastrutture, regolamentazioni urbanistiche e politiche governative. Pertanto, è essenziale valutare ogni questione caso per caso per sviluppare soluzioni logistiche efficaci che considerino tutti i fattori rilevanti (Alvarez Gallo & Maheut, 2023). La capacità di valutare la sostenibilità tramite metodi multicriterio è al centro del lavoro di Lindfors (2021), che analizza le scelte metodologiche dei documenti selezionati, riguardanti la progettazione delle alternative, la selezione dei criteri, le aree della sostenibilità, la scelta del metodo di interpretazione, classificazione e punteggio, il peso dei criteri, la gestione dell'incertezza e il modo in cui si affrontano l'incommensurabilità, la compensabilità e l'incompatibilità tra i criteri.

Inoltre, la sostenibilità della logistica in contesti urbani ha ricevuto molta attenzione negli ultimi decenni (Rzesny-Cieplinska & Szmelter-Jarosz, 2020), spinta da fenomeni come la crescita della popolazione, l'urbanizzazione e la globalizzazione, l'aumento del commercio online e multicanale (Schöder et al., 2016) e lo sviluppo economico urbano. I flussi di persone e merci competono per lo stesso spazio in contesti urbani. L'aumento dei movimenti merci esercita pressione sulle autorità locali e aumenta l'interesse di consulenti e ricercatori. Anche gli stakeholder urbani hanno una maggiore consapevolezza delle conseguenze ambientali del settore dei trasporti, ma le catene di approvvigionamento devono essere flessibili per rispondere alle fluttuazioni del mercato, come i prezzi dell'energia, e agli eventi critici come le guerre e le interruzioni causate dal COVID-19, che hanno reso la logistica sempre più rilevante nella vita quotidiana (Ren et al., 2019; Moncef & Monnet Dupuy, 2021).

La presenza di numerosi stakeholder con obiettivi e prospettive differenti nel trasporto merci urbano sottolinea la necessità di coordinamento o cooperazione tra istituzioni pubbliche e operatori privati per creare un sistema di trasporto merci urbano sostenibile (Knoppen et al., 2021). Per analizzare le soluzioni di logistica urbana, occorre considerare diversi elementi: le tecnologie dell'informazione e comunicazione (ICT), aspetti comportamentali per cambiare la mentalità dei gestori e degli operatori logistici, e aspetti normativi e legali per le partnership pubblico-private o per incentivare soluzioni più efficienti (Gonzalez-Feliu et al., 2014).

Recentemente, con l'avvento delle tecnologie e dei mercati digitali, studi specifici si sono concentrati sui dati e-commerce nella logistica urbana, analizzando le sfide e le opportunità nella raccolta dei dati tramite diversi strumenti e il loro utilizzo per scopi di pianificazione politica (Buldeo Rai & Dablanc, 2023). Inoltre, l'introduzione di soluzioni dell'Industria 4.0[3] nel settore della produzione e dei trasporti potrebbe favorire la cooperazione tra diversi attori, con benefici nell'ottimizzazione dei tempi di esecuzione, del consumo energetico e dell'utilizzo delle risorse (Deja et al., 2021). Negli ultimi decenni, l'interesse per la logistica urbana è cresciuto, confermato da numerose rassegne della letteratura che evidenziano vari aspetti e prospettive. L'unicità di ogni contesto rende la sostenibilità una sfida complessa e alcuni ricercatori hanno sottolineato come numerosi studi di caso stimolino la ricerca su scala più ampia con valutazioni incrociate (Nathanail et al., 2021).

Le categorie di stakeholder interessati sono state identificate, evidenziando la varietà di approcci in termini di quanti e quali stakeholder siano coinvolti e in quali fasi del processo. A volte c'è solo un tipo di decisore, spesso l'autorità pubblica o i fornitori di servizi logistici, clienti del consulente o esperto incaricato di assistere nella scelta di metodi e criteri per analizzare un particolare problema. In alcuni metodi specifici, come quelli MAMCA, il coinvolgimento di vari stakeholder fa parte del metodo multicriterio. Questa rassegna ha mappato i problemi affrontati, i metodi applicati, gli stakeholder coinvolti come attori, i loro obiettivi e i criteri scelti per supportare le loro scelte, con l'intento di perseguire soluzioni sostenibili per le città.

[3] La ricezione, lo stoccaggio, la selezione e la spedizione delle merci sono diventati elementi cruciali per le operazioni logistiche. In questo contesto, le moderne tecnologie dell'Industria 4.0, come i Sistemi Ciber-Fisici (CPS), la Gestione e Analisi Cognitiva dei Big Data per la Produzione e i Servizi Intelligenti per l'Uomo (CBMHS), l'Internet delle Cose (IoT), i Gemelli Digitali, i Big Data, il Data Mining, la Blockchain e i Robot Mobili Autonomi (AMR), si sono affermate come abilitatori chiave per ottimizzare questi processi e migliorare l'efficienza logistica.

A tal fine, lo sviluppo sostenibile, basato sui tre pilastri dell'equità sociale, della crescita economica e della protezione ambientale, offre un approccio promettente per affrontare queste sfide. Tuttavia, dall'analisi degli studi selezionati, è emerso che gli autori a volte non si limitano a queste sole tre categorie dei tre pilastri tradizionali, ma includono altri criteri operativi e territoriali che non si riferiscono unicamente a una di esse. Inoltre, esiste un dibattito in corso sulla gerarchia di queste dimensioni e sul miglior modo per raggiungere soluzioni sostenibili. Oltre ai criteri economici, ambientali e sociali, un numero significativo di criteri rientra nelle categorie operative e tecniche (Awasthi & Chauhan, 2012; Aljohani & Thompson, 2019), o in quelli che alcuni autori definiscono criteri di implementazione o capacità (Deveci et al., 2022). Inoltre, alcuni ricercatori hanno adottato il tipo di criteri territoriali per includere aspetti urbanistici e per esplorare nuove applicazioni per problemi di localizzazione (Bennani et al., 2022). Dalla comparazione tra diversi articoli, emerge anche come i confini tra i diversi tipi di criteri non siano così rigidi, e a volte alcuni ricercatori fanno riferimento a una generica categoria economica includendo criteri che altri ricercatori considerano operativi o sociali (Awasthi & Chauhan, 2012; He et al., 2017; Bandeira et al., 2018; Bartuška et al., 2023).

Un altro esempio è fornito da Boggio-Marzet (2023), in cui alcuni criteri operativi e territoriali sono stati collocati sotto quelli economici e sociali delle più tradizionali divisioni dei tre pilastri. Alcuni ricercatori hanno inoltre introdotto criteri relativi al patrimonio culturale per uno specifico focus sui centri storici (de Carvalho et al., 2020), considerando criteri che in altri lavori sono considerati ambientali, territoriali e sociali. Uno dei contributi più rilevanti e recenti sull'argomento è rappresentato dal lavoro di Gonzalez et al. (2023), che considera il contesto urbano come un elemento rilevante per la ponderazione dei criteri di sostenibilità attraverso un confronto tra città coinvolte nel progetto LEAD. Viene inoltre evidenziato come alcuni criteri, come la congestione del traffico nell'esempio, possano essere intesi come criteri economici, mentre molti autori lo considerano un criterio ambientale o sociale.

Un altro risultato è che manca un accordo sulla natura esatta dei criteri. Nonostante il crescente numero di applicazioni e pubblicazioni scientifiche, non esiste ancora un quadro metodologico standard per la selezione di metodi e criteri per valutare le soluzioni logistiche sostenibili. Tuttavia, potrebbe essere interessante approfondire l'analisi cercando di capire se la scelta di metodi specifici o l'indirizzamento di determinati problemi conduca alla selezione di criteri e soluzioni sostenibili in modi specifici.

5. Conclusione

Il presente studio fornisce una panoramica sul tema della sostenibilità nella logistica urbana. Gli obiettivi principali erano, da un lato, ampliare la conoscenza sull'uso dei metodi multicriterio per affrontare la complessità dei problemi logistici e, dall'altro, comprendere quali problematiche sono state affrontate e quali criteri sono stati scelti. L'analisi dei documenti esistenti ha mostrato che questa scelta è influenzata da vari fattori, come il contesto urbano specifico, la questione trattata, gli stakeholder coinvolti e il metodo di valutazione scelto. Gli approcci multicriterio che combinano analisi qualitative e quantitative possono essere efficaci, anche se determinare il numero appropriato di criteri rappresenta una questione critica in questo campo. L'adozione di un numero minore di criteri rende il metodo più semplice da implementare, ma potrebbe comportare un compromesso tra qualità dell'analisi e attuazione. Al contrario, l'uso di più criteri può sovraccaricare le informazioni e ostacolarne l'interpretazione.

L'analisi di come i decisori e gli stakeholder affrontano la sostenibilità nella logistica urbana ha evidenziato l'uso di una combinazione di criteri sociali, ambientali ed economici. Tuttavia, come osservato in molti degli articoli esaminati, i decisori spesso vanno oltre il tradizionale approccio dei tre pilastri, includendo criteri operativi e territoriali. I decisori devono rispondere alle preoccupazioni riguardanti l'impatto della logistica dell'ultimo miglio sulla congestione del traffico, sulle emissioni e sulla qualità del servizio, bilanciando i guadagni economici a breve termine con la sostenibilità ambientale e il benessere sociale a lungo termine. Molti studi sottolineano che, sebbene la sostenibilità venga utilizzata come principio guida, numerose misure politiche non sono sempre percepite come favorevoli alle imprese, causando resistenza da parte degli stakeholder. Questo contrasto sottolinea l'importanza del coinvolgimento e della consapevolezza degli stakeholder nel processo decisionale per garantire che gli obiettivi di sostenibilità siano realizzabili e desiderabili. Studi futuri potrebbero essere interessati ad analizzare come diversi stakeholder adottano o preferiscono alcuni criteri rispetto ad altri quando si utilizzano metodi che consentono scelte diverse. Altri sul come esaminare il processo di mediazione tra diversi stakeholder nella convergenza dei criteri selezionati quando vengono adottati metodi che richiedono criteri condivisi.

Questa rassegna della letteratura elenca i tipi e il numero di criteri selezionati. L'equilibrio dei criteri adottati nella valutazione delle soluzioni sostenibili mostra una distribuzione quasi uniforme tra criteri economici, ambientali, sociali e categorie aggiuntive, come criteri operativi e territoriali, nella maggior parte degli articoli analizzati. Sebbene il presente studio limiti l'analisi ai risultati di questi processi di selezione dei criteri, esso aiuta a evidenziare che la sostenibilità è un concetto costruito durante la definizione dei problemi attraverso la scelta dei criteri e non può essere limitato ai tre soli pilastri. Potrebbe essere quindi interessante analizzare ulteriormente quale tipo di criterio viene prioritizzato, con quale intensità e per quali motivi. Uno dei limiti significativi della replicabilità degli approcci MCDA in contesti diversi è che non sempre è chiaro perché un metodo venga scelto rispetto agli altri, se proposto dal consulente o dall'esperto coinvolto o basato sull'imitazione di applicazioni esistenti. Questa mancanza di spiegazioni nella letteratura potrebbe rappresentare una lacuna che deve essere affrontata in ricerche future, che potrebbero estendersi anche ai processi di selezione e ponderazione dei criteri effettuati dalle diverse categorie di stakeholder. Ciò fornirebbe preziose informazioni per comprendere le prospettive e le priorità degli stakeholder riguardo alla sostenibilità. Nonostante i suoi limiti, lo studio offre spunti sul processo decisionale e può fornire supporto a studi futuri nella comprensione della natura multidimensionale dei concetti di sostenibilità e logistica urbana.

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Contributo degli autori

Concettualizzazione, F.C., C.D. e L.G.; Metodologia, F.C., C.D. e L.G.; Analisi Formale, F.C.; Cura dei Dati, F.C.; Supervisione, C.D. e L.G.; Redazione—preparazione della bozza originale, F.C.; Redazione—revisione e modifica, F.C. e C.D.

Abbreviazioni

AHP | Analytic Hierarchy Process
BWM | Best–Worst Method
COMET | Characteristic Objects Method
CODAS | Combinative Distance-Based Assessment
CRITIC | Criteria Importance Through Intercriteria Correlation
CEBOM | Cross-entropy-based optimization model
CATOWE | Customer–Actors–Transformation process–World view–Owners–Environmental constraints
DEMATEL | Decision Making Trial and Evaluation Laboratory
DIBR | Defining Interrelationships Between Ranked Criteria
DELPHI | Delphi method
DHF | Dual hesitant fuzzy
FARE | Factor Relationship
F-AHP | Fuzzy Analytic Hierarchy Process
FMAGDM | Fuzzy multi-attribute group decision-making
F-SAW | Fuzzy Simple Additive Weighting
GDSSs | Group Decision Support Systems
GHG | Green House Gases
NOx | Nitrogen Oxide
PM | Particulate Matter
LML | Last-Mile Logistics
MARCOS | Measurement of Alternatives and Ranking according to Compromise Solution
MAMCA-CD | Multi-Actor Multi-Criteria Analysis - City Distribution
MAMCA | Multi-Actor Multi-Criteria Analysis MCDA | Multi Criteria Decision Aiding
MCE-GIS | Multi-Criteria Evaluation in Geographic Information System
PFSs | Picture Fuzzy Sets
PROMTHEE | Preference Ranking Organization Method for Enrichment of Evaluations

PRISMA | Preferred Reporting Items for Systematic Reviews and Meta-Analysis
SDGs | Sustainable Development Goals
SDNMARCOS | Score-based double normalized measurement alternatives and ranking according to the compromise solution
SF-AHP | Spherical Fuzzy Analytic Hierarchy Process
SLR | Systematic Literature Review
TOPSIS | Technique for Order Preference by Similarity to an Ideal Solution
TSDSM | Transport Spatial Decision Support Model
THOWA | Tuple hybrid ordered weighted averaging
UDC/UCC | Urban Distribution Center / Urbans Consolidation Center
UN | United Nations
VIKOR | Višekriterijumska Optimizacija i kompromisno Rešenje
WASPAS | Weighted Aggregated Sum Product Assessment
WLC-GIS | Weighted Linear Combination - Geographic information system

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