



Multi-Objective Facility Location Problems: Systematic Literature Review and research agenda

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ABSTRACT

Facility Location deals with the design of mathematical models and solution techniques to find the optimal placement for one or more facilities to be selected from a set of potential candidate sites. Besides their theoretical relevance, Facility Location problems have been intensively studied due to their wide-ranging practical applications in both the private and public sectors, supporting complex and strategic decision-making. As there are often multiple, potentially conflicting, objectives to consider at the modelling stage in these contexts, research in the area of Multi-Objective Facility Location Problems (MOFLPs) is extensive and growing fast. In this study, we aim to delineate the boundaries of existing contributions by focusing on modelling and algorithmic aspects, while also considering the managerial contexts that contribute to the Multi-Objective nature of the resulting problems. To this end, we conduct a thorough Systematic Literature Review of 288 relevant papers published in international peer-reviewed academic journals between 2011 and 2025. Alongside assessing the state of the art, the analysis revealed relevant gaps in the structured integration of uncertainty, time-based dynamics and fairness-oriented metrics, which limits the real-world applicability of MOFLP solutions. To identify the methodological and practical implications of these limitations, we outline key research priorities, including the development of tailored solution strategies, the integration of equity and robustness considerations, and the stronger incorporation of Multi-Criteria Decision Analysis within optimisation processes. Finally, we discuss how these challenges may affect the application of MOFLP approaches in designing Supply Chains and planning public services.

1. Introduction

Location Science is one of the most active branches of Mathematical Optimisation and, within this framework, Facility Location represents an important and flourishing area of research (Daskin, 1995; Nickel et al., 2019). It deals with designing models and algorithms to determine the optimal location for a finite set of facilities selected from a set of potential candidate locations. Notably, in *Continuous* Facility Location problems, it is assumed that the facilities can be located anywhere, resulting in an infinite set of candidate locations (Drezner, 2022).

Beyond their conceptual importance, Facility Location problems are widely studied because of their numerous practical applications in various sectors, such as Humanitarian Supply Chain, Green Logistics, Healthcare, Public Transport, as reported in Nickel et al. (2019). Most private and public organisations regularly face location-related decisions for facilities, assets, and resources — factors critical to both strategic and operational success. This is the case for public bodies and

government agencies that need to determine the optimal location of public and essential facilities such as fire stations (Şen et al., 2011; Yao et al., 2019), ambulances (Navazi et al., 2018; Olivos & Caceres, 2022), waste disposal centres (Rossit et al., 2017; Sgalambro et al., 2025; Zaeimi & Rassafi, 2021). Similarly, private companies must determine the location of all the facilities needed to plan and operate their supply chains (Gital Durmaz & Bilgen, 2020; Mogale et al., 2018), including warehouses (Boonmee & Kasemset, 2020), manufacturing plants and distribution centres (Dabibi et al., 2016).

In general, the decisions involved in Facility Location are inherently strategic, and this leads to the definition of problems characterised by multiple, often conflicting, objectives. Multi-Objective approaches help balance stakeholders priorities and explore trade-offs in the design of service networks. For example, in the transport of hazardous waste, it is of paramount importance to limit the length of the journey to the final destination, given the dangerous nature of the materials and the fact that transport typically occurs on public roads, motorways and

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railways (EPA, 2022). Hence, when tackling the problem of locating waste management facilities, i.e. treatment and disposal centres, there are clearly at least two conflicting objectives to be considered: minimising the overall cost of transport, treatment and disposal operations, and reducing the transport risk, measured in terms of exposure of the population (Alumur & Kara, 2007; Zhao et al., 2016). Supply chain network design must address economic goals — such as installation, maintenance, storage and transport costs — while also considering environmental impacts. As sustainability plays a key role in industrialisation (cf. 9th Sustainable Development Goal (ONU, 2015)), Facility Location models for supply chain design must incorporate objectives related to emission reduction alongside cost minimisation (Das et al., 2021; Maliki et al., 2022).

From a theoretical point of view, when solving a Multi-Objective Optimisation problem, the aim is to optimise several objective functions simultaneously, where the concept of “optimality” must be appropriately defined, as it differs fundamentally from that in Single-Objective optimisation (Nickel et al., 2019). A solution is called *Pareto optimal* (or *efficient*) if no objective can be improved without deteriorating at least one other objective. The accurate identification and thorough analysis of Pareto optimal solutions are therefore essential for providing effective decision support (see Ehrgott (2005) for a comprehensive overview of Multi-Objective Optimisation).

The managerial relevance of Multi-Objective Facility Location Problems (MOFLP) and their methodological complexity explain the significant attention they have received in the Location literature (Daskin, 1995; Farahani et al., 2010; Nickel et al., 2019); yet there is a lack of papers that comprehensively review the current state of the art. In fact, the existing reviews either focus on a subclass of Location problems (Lopes et al., 2013; Tadaros & Migdalas, 2022) or use classification criteria based on a specific feature of the underlying problems, such as the decision space (Nickel et al., 2019) or the nature of the objectives pursued (Current et al., 1990). Therefore, in this paper, we aim to provide a comprehensive overview of the literature on MOFLP by conducting a systematic review of academic papers published in peer-reviewed international journals between 2011 and 2025. For this purpose, we have followed the four-stage scheme outlined in Maestrini et al. (2017), i.e. *source identification*, *source selection*, *source evaluation* and *data analysis*, which allows us to rigorously assess the state of the art and to identify what is still lacking. This analysis considers both the modelling techniques and algorithms used in MOFLPs, as well as the managerial drivers that necessitate multiple objectives. It should be emphasised that this review is intended to focus on the purely Mathematical Optimisation aspects of the problems; thus, for reasons of scientific interest, we considered papers on Multi-Criteria Decision Analysis (MCDA) methods as out of scope. However, we have included all papers in which MCDA methods are integrated with optimisation and are used as a tool to evaluate the efficient solutions or for pre-processing purposes.

This study identifies several research gaps in the MOFLP literature. As a result, we propose a research agenda that offers useful insights into future research directions for anyone interested in this topic, whether for theoretical or practical purposes. Indeed, this paper is also intended to provide a *vademecum* (i.e. a concise reference guide) for both academics and practitioners dealing with real-world MOFLPs. In Section 2, a brief overview of existing literature reviews on MOFLPs is provided to highlight the further and different contributions of this paper. Section 3 thoroughly describes the research methodology used to select and classify the analysed papers. Their comprehensive bibliometric analysis is presented in Section 4, together with a structured evaluation through an in-depth content analysis. Then, Section 5 discusses the main findings of this review, and presents the research agenda arising from the emerging gaps identified. Finally, concluding remarks are provided in Section 6.

2. A brief overview of previous literature reviews

Overall, no work to date has provided a comprehensive Systematic Literature Review of Multi-Objective Facility Location Problems (MOFLP). However, some studies in Location Science focus on Multi-Objective models within particular subclasses of location problems. Table 1 summarises the existing literature reviews on MOFLPs, indicating for each of them the number of papers examined, the reference period, the selection criteria and few further details on contents.

One of the first dates back to the 90s: Current et al. (1990) surveyed 45 papers on MOFLPs focusing exclusively on modelling aspects. The authors identified four macro-categories for the objective functions included in the revised papers: *cost minimisation*, *demand oriented*, *profit maximisation* and *environmental concern*. The papers were classified into the category which best represented their mathematical approach to the underlying problem. Later, Farahani et al. (2010) revised the state-of-the-art up to 2009 on Multi-Criteria Decision-Making (MCDM) approaches in Facility Location, classifying the problems into three categories: *Bi-Objective*, *Multi-Objective* and *Multi-Attribute*. Both mathematical formulations and solution approaches were detailed. The authors of Lopes et al. (2013) proposed a taxonomy of Location-Routing Problems, based on problem features and solution methods. They identified three classes of main objectives: *cost minimisation*, *environmental aspects*, *equity distribution*, and classified the reviewed papers accordingly. Specifically, in the latter category, they included all the papers in which the equity measure is related to the distribution of obnoxious facilities, vehicle load and working time balance, and the distribution of unmet demand as a way to easily meet it in the future. More recently, Tadaros and Migdalas (2022) adopted a similar perspective in reviewing Bi-Objective and Multi-Objective Location-Routing Problems, classifying the papers according to the application area in which they fitted the most. Finally, the book chapter by Nickel et al. (2019) provides a theoretical overview of major MOFLPs, classifying them according to the decision space — *continuous*, *discrete*, or *network*. The authors described the characteristics of the Pareto Sets in each setting and the algorithms used to generate them. The result is a thoroughly theoretical review of the state of the art in terms of models and methods, though not exhaustive. Similarly, Arango et al. (2022) analysed MOFLP approaches to Supply Chain Network Design, selecting contributions that incorporate sustainability and uncertainty. While not comprehensive, the review highlights recent advances in sustainable and disruption-aware approaches to Supply Chain Network Design.

Therefore, although Facility Location is a flourishing area of research in Location Science, existing literature reviews have often adopted limited perspectives. In particular, focusing on only a subset of problems and/or classifying contributions solely based on qualitative criteria (e.g. type of objective functions or decision space) provides limited support to researchers and practitioners addressing complex, real-world problems. Thus, a comprehensive literature review of MOFLPs is essential for evaluating current contributions and identify relevant research gaps.

A Multi-Objective modelling approach seeks to represent the various, and often conflicting, interests of the stakeholders involved in a given decision-making process. These interests are typically formalised through specific objective functions, whose characteristics are shaped by the managerial context in which the problem arises. In the context of Facility Location, these objectives may relate to *quality of service*, *efficiency*, *reliability*, *accessibility* among the others. Accordingly, to conduct an effective review of the existing literature, we examined not only the modelling and methodological characteristics of the contributions but also the managerial settings that underpin the problems addressed.

Table 1
Existing literature reviews on Multi-Objective Facility Location Problems.

Reference	# of papers	Time range	Selection criterion	Content analysis
Current et al. (1990)	45	1973–1987	Unknown	Papers classified in 4 macro categories based on the objectives modelled: cost minimisation, demand oriented, profit maximisation, environmental concerns.
Farahani et al. (2010)	104	1965–2009	Keyword-based	Papers classified in 3 categories: bi/multi-objective, multi-attributes.
Lopes et al. (2013)	149	up to 2013	Unknown	Papers classified by model characteristics and algorithmic approaches.
Nickel et al. (2019)	36	1973–2018	Unknown	Papers classified in 3 categories related to the decision space: continuous, discrete and network.
Tadaros and Migdalas (2022)	80	2014–2020	Keyword-based	Papers classified by the characteristics of the problems addressed, the solution approach and the application area.
Arango et al. (2022)	92	2015–2022	Keyword-based	Papers classified by location problem, decision-making and solution approach, modelling of sustainability.

3. Research methodology

Denyer and Tranfield (2009) defined the Systematic Literature Review (SLR) as a structured approach to reviewing relevant contributions on a specific topic. The review protocol was designed to ensure transparency, reproducibility and methodological rigour, in line with the established practices of systematic reviews in management and engineering research (Tranfield et al., 2003). It serves as a valuable tool for both researchers and practitioners to clearly identify existing knowledge and gaps in a given field. Given the limited scope and thematic fragmentation of existing reviews on MOFLP topic, our SLR aims to provide an integrated and analytically grounded synthesis of the field. Specifically, it seeks to:

- examine how MOFLPs are formulated and addressed from both modelling and optimisation perspectives;
- investigate the managerial and decision-making motivations underlying the adoption of Multi-Objective approaches;
- identify emerging research directions, conceptual gaps, and underlying trade-offs shaping the evolution and practical applicability of MOFLPs research.

In line with established Operational Research practices, we adopted a hybrid search procedure to define the sample of papers for the SLR. Indeed, as recently evidenced in Wohlin et al. (2022), combining different search procedures maximises the likelihood to capture all the relevant contributions to the topic of interest. Consequently, we combined a keyword-based approach using the Scopus database (Elsevier, 2004) with the *snowballing* method, consisting in *backward and forward citation chasing* (Wohlin, 2014). Scopus was selected for its broad multidisciplinary coverage, transparent and uniform indexing standards, and highly structured citation metadata, which ensure methodological coherence, replicability of the search strategy, and reliable bibliometric analysis without the inconsistencies that may arise when merging heterogeneous databases (Macrina et al., 2020; MahmoudGonbadi et al., 2021; Tadaros & Migdalas, 2022). Recently, the analysis of the backward and forward citations of key papers has become common practice for integrating the sample of papers retrieved using only the Scopus database (Sentia et al., 2023; Vitti et al., 2025; Wandelt et al., 2025).

Specifically, we adopted the four-stage framework proposed by Maestrini et al. (2017) which has been applied in related studies in the Facility Location domain (Aldrighetti et al., 2021; Carnero Quispe et al., 2025). Analogous to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Page et al., 2021), this methodology comprises the following steps: *source identification*, *source selection*, *source evaluation* and *data analysis*. These operations are described in detail below, while Fig. 1 provides a visual summary of the entire process that led to the final selection of the reviewed papers.

Since the most recent comprehensive literature review of this topic dates back to 2010 (Farahani et al., 2010), we restricted our search to papers written in English and published in international peer-reviewed

Table 2

Inclusion and exclusion criteria adopted to search the literature on MOFLPs.

Peer-reviewed papers included	Peer-reviewed papers excluded
Papers and conference proceedings published between 2011 and 2025 Written in English	Reviews, books and book chapters
Addressing MOFLPs	Adopting exclusively MCDA methods for site selection Not focusing on Location problems
Dealing with Network Design problems Addressing Logistics problems	Not including Facility Location decisions

journals from 2011 onwards. We focused on peer-reviewed journal articles and high-quality conference proceedings to ensure the methodological soundness of the retrieved contributions. Furthermore, we excluded studies focused exclusively on Multi-Criteria Decision Analysis (MCDA) methods, unless these were integrated into Mathematical Optimisation models for purposes such as solution evaluation or pre-processing. This exclusion criterion was defined a priori in order to maintain conceptual consistency with the focus of the review. Papers proposing methodological contributions that adopted MCDA techniques exclusively were excluded because they evaluated predefined alternatives rather than formulating Facility Location optimisation problems. Therefore, papers adopting MCDA methods for selecting the location of candidate facilities, as well as contributions lacking the facility location optimisation component, were considered out of scope according to the theme of this SLR. The inclusion and exclusion criteria adopted in this review are clearly defined in Table 2.

3.1. Source identification and selection

This step consists of identifying the relevant literature on Multi-Objective Facility Location Problems. To this end, an extended set of keywords was defined (reported in Table 3) and used to query the Scopus database, restricting the search to the fields “Article title, Abstract, Keywords”. In fact, we distinguished between “bi” and “multi” criteria/objective in order to increase the likelihood of capturing all relevant contributions. Additionally, the sets 5 to 9 were designed to identify hybrid approaches combining Multi-Criteria Decision Analysis Methods and Multi-Objective optimisation techniques. The search produced 1914 results, which were pre-screened in the *source selection* step to exclude papers that did not meet the non-content-based inclusion criteria. In particular, papers not written in English, as well as books, chapters and reviews were removed from the sample. Review articles were instead analysed separately to provide contextual background. The results were cross-checked in Microsoft Excel to eliminate duplicates, thus leaving 1512 papers to evaluate. It is worth mentioning that the search was conducted on May 6th, 2025, hence the number of papers recorded for 2025 may be underestimated.

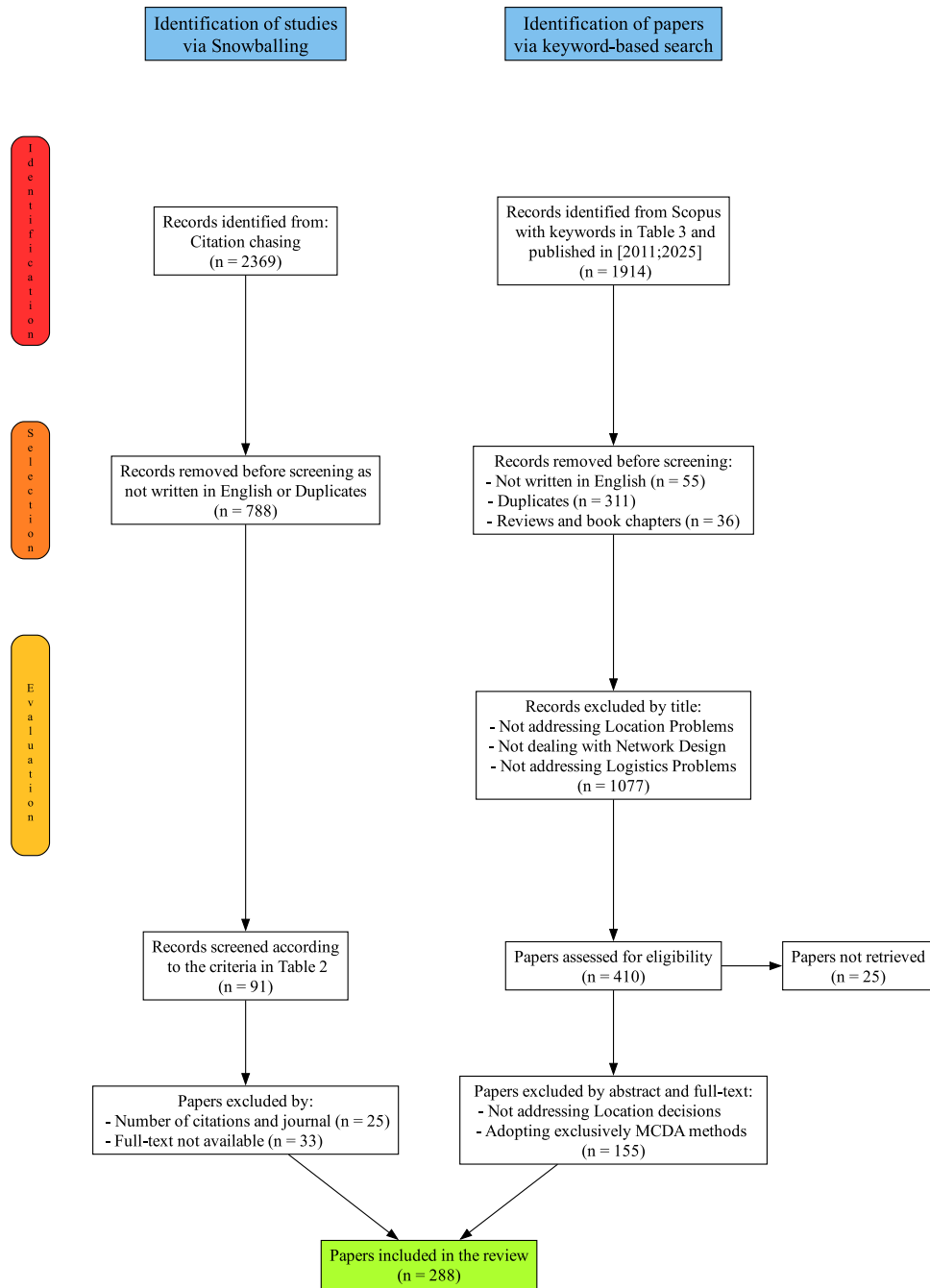


Fig. 1. Flowchart of the hybrid framework adopted to collect the sample of papers to review.

Table 3

Number of retrieved papers before and after screening by language, for each set of keywords.

Keyword set	Details	# Results	# Screened by language
1	“multi* objective” AND “location* analysis”	15	15
2	“bi* objective” AND “location* analysis”	5	5
3	“multi* objective” AND “facility location”	543	522
4	“bi* objective” AND “facility location”		183
5	“multi* criteria” AND “facility location” AND “optimi?ation”	75	73
6	“multi* criteria” AND location AND “optimi?ation”	752	735
7	“multi* criteria” AND “location” AND “* programming”	260	250
8	“bi* criteria” AND “location” AND “optimi?ation”	50	49
9	“bi* criteria” AND “location” AND “* programming”	28	27
	Total	1914	1859

3.2. Source evaluation

In order to draw the boundaries of the analysis, the source evaluation step involved screening the retrieved papers in three consecutive stages, as detailed below. After this process, we were left with 255 papers (cf. the right branch of Fig. 1).

Screening by title and full-text availability. We removed from the sample all those papers with a title not containing the terms “Location”, “Logistics” or “Network Design”. Then, we removed all papers with no full text available.

Screening by abstract. After reading the abstracts, we removed from the sample all papers that were not primarily concerned with facility location decisions, as well as those that used MCDA methods solely for site selection.

Screening by full-text. For borderline cases, i.e. papers for which screening by abstract was inconclusive, the authors independently reviewed the full texts and applied the predefined inclusion criteria. Discrepancies were resolved by discussion until consensus was reached.

3.3. Study quality assessment

To enhance methodological robustness and minimise potential selection bias, a structured *study quality assessment* was conducted in accordance with established systematic review guidelines (Page et al., 2021; Tranfield et al., 2003). Rather than relying solely on the publication venue or citation metrics, each paper in the screened sample was evaluated against the following qualitative appraisal criteria reflecting methodological soundness and relevance to the MOFLP domain. This assessment served as a consistency and robustness check, and papers lacking sufficient methodological detail to support interpretation or comparison were excluded during this phase.

Clarity and consistency of the Facility Location problem. This involves assessing whether the decision variables, objectives, constraints and modelling assumptions are clearly defined. This ensures that the optimisation problem can be interpreted and reproduced accurately.

Coherence of optimisation and solution methodologies. This evaluates the alignment between the adopted solution approach and the characteristics of the formulated MOFLP, along with the clarity with which the algorithms and implementation procedures are described, without assessing algorithmic performance or novelty.

Presence of validation through computational experiments or real-world applications.

This refers to the inclusion of computational experiments, benchmark analyses, sensitivity studies or real-world applications that demonstrate the practical performance of the proposed MOFLP model or solution method.

3.4. Snowballing

The set of papers for backward and forward citation tracking consisted of the 15 most-cited papers from the 255 papers retrieved previously, selecting one paper per year. The backward procedure involved screening the reference lists of these papers, while the forward method involved screening the citing documents retrieved from Scopus. The same inclusion and exclusion criteria adopted in the primary screening were applied (see Table 2). Additional filtering criteria were applied to ensure thematic relevance and methodological comparability with the primary sample. Citation information was used only as a supporting

relevance indicator rather than a proxy for study quality, while journal scope was considered to verify alignment with OR domain. This process identified 33 additional relevant papers, which were included in the final corpus. Consequently, the final sample consisted of 288 papers (cf. Fig. 1).

3.5. Data analysis

This stage represents the pivotal step in the SLR process (Denyer & Tranfield, 2009), where individual contributions are analysed in detail, interconnections among papers are identified and correlations across studies are detected. This process synthesises findings from the literature and identifies key research gaps that need further investigation (MahmoumGonbadi et al., 2021). The data analysis is structured into two main phases: *bibliometric analysis* and *content analysis*. The bibliometric analysis provides a first insight into the characteristics of the collected papers, focusing on the publishing journals, year of publication and the specific subject areas. Subsequently, to support the extraction of relevant information for the content analysis, we defined the following research questions (RQs):

- RQ1:** How have different classes of Facility Location Problems been addressed through Multi-Objective formulations?
- RQ2:** In which application domains do MOFLPs arise?
- RQ3:** What managerial and decision-making motivations drive the adoption of MOFLPs?
- RQ4:** What modelling features characterise MOFLPs?
- RQ5:** Which optimisation paradigms and solution strategies are employed, and how do they address the complexity of Multi-Objective formulations?
- RQ6:** How are MOFLPs models and solution methods validated, and what does this reveal about their practical applicability?
- RQ7:** What conceptual research directions emerge from the synthesis of the MOFLPs literature?

To systematically organise the information extracted during the content analysis, we relied on a set of well-established classification criteria. Building on the classification frameworks proposed by de Alcantara et al. (2025), each paper was analysed by considering both *problem characteristics* (qualitative analysis) and *solution method characteristics* (quantitative analysis), further refining this framework with insights from Carnero Quispe et al. (2025). In addition, we adopted a widely recognised taxonomy of Facility Location problems (Azarmand & Neishabouri, 2009; Daskin, 1995; Nickel et al., 2019) that delineates seven primary classes: *Center*, *Median*, *Covering*, *Anti-Covering*, *Location–Allocation*, *Location–Routing*, *General Network Design*. Accordingly, the problem characteristics considered include: the location class, the application domain and sector, the type and number of objective functions, the structure of the decision space (network, discrete or continuous), the planning horizon, the consideration of uncertainty, and the modelling approach. Regarding solution methods, we evaluated the type of optimisation approach used (exact, heuristic, or hybrid), the preference articulation method (a priori, a posteriori, interactive or no preference), the specific algorithms implemented, and the form of validation (case study or synthetic instances). The classification criteria adopted to conduct the content analysis are reported in Table 4.

Table 4
Problem and method characteristics assessed through the content analysis of the selected literature on MOFLPs.

Category	Characteristics analysed
Problem	Class of Facility Location problem
	Application area and sector
	Number and type of managerial objectives
	Stochastic or Deterministic
	Static or Dynamic
Method	Modelling approach and Decision space
	Exact, Heuristic or Hybrid
	A priori, a posteriori, interactive or no-preference
	Specific algorithms
Validation approach (case study or synthetic instances)	

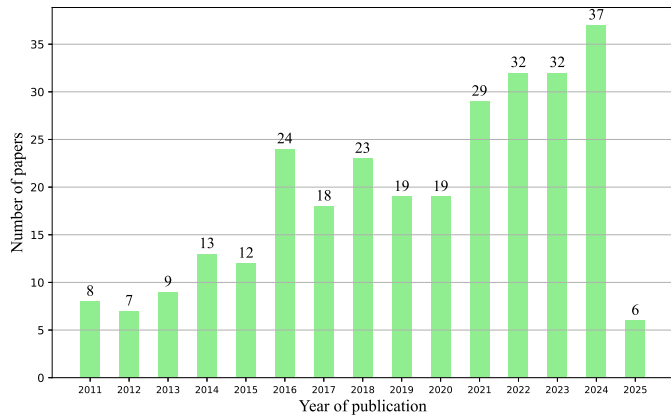


Fig. 2. Number of publications per year across the time interval [2011; 2025].

4. Results of data analysis

4.1. Bibliometric analysis

Fig. 2 shows the evolution over time of the number of papers published between 2011 and 2025.

In 2016, the number of papers doubled compared to the previous year, and the publication rate remained relatively stable thereafter until 2021, when it doubled compared to 2014. Notably, about 83% of the retrieved papers have been published since 2016, indicating a growing interest in exploring Multi-Objective approaches to Location Problems over the last decade. Using the tools provided by the Scopus database, we examined the distribution of papers across subject areas (cf. Fig. 3). Approximately 63.8% of the contributions are related to four macro-areas: *Computer Science*, *Decision Sciences*, *Engineering*, *Mathematics*. In particular, papers related to the *Energy* theme have been published from 2017 onwards. Overall, these trends highlight an increasing interest in MOFLPs by both academics and practitioners, as their versatility makes them suitable for addressing current problems in real-world contexts and arising from economic, managerial and operational needs.

The literature on MOFLPs is dispersed across 159 academic journals, of which 46 feature at least two selected papers, corresponding to 61% of the reviewed papers. The remaining 113 journals include only a single relevant paper. Table 5 shows the list of source titles with at least three selected papers. Of these, roughly 78% relate to the four macro-areas identified above, while the remainder refer to subject areas with strong socio-economic, managerial and environmental connotations. In particular, 33 journals are conference proceedings related to international conferences in Computer and Industrial Engineering, Computer Science and Operations Research, Management Sciences, Transportation.

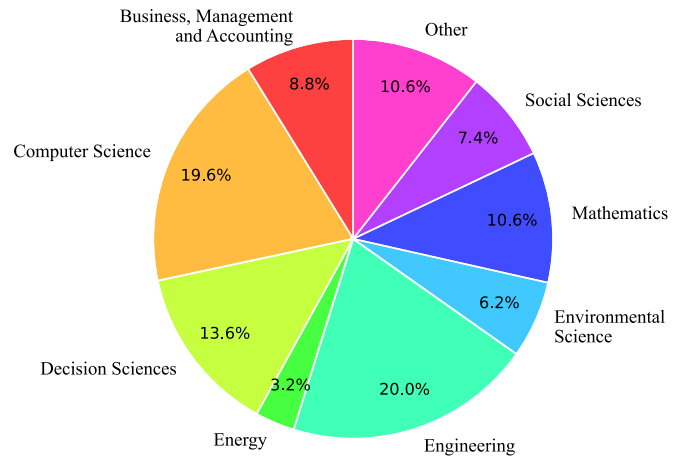


Fig. 3. Percentage of contributions per subject area. Category “Other” refers to subject areas with less than 10 papers.

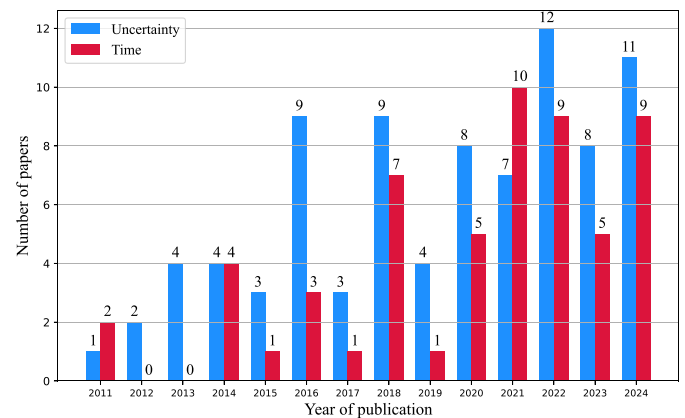


Fig. 4. Number of papers using uncertainty and/or time as modelling tools across the time interval [2011–2024].

4.2. Content analysis

The qualitative analysis of the retrieved papers focused on the number of objectives, the use of uncertainty and time as modelling tools, and the validation method for the proposed models. Firstly, we observe that approximately 60% of the collected papers address a Bi-Objective Facility Location Problem, while 33% deal with a Tri-Objective Facility Location Problem. In addition, 11 of remaining papers deal with a MOFLP with four objectives (Ahluwalia & Nema, 2011; Bashiri & Rezanezhad, 2015; Becerra et al., 2024; Jafarzadeh-Ghoushchi et al., 2023; Khalilzadeh & Bahari, 2023; Lin et al., 2018; Rahbari et al., 2023; Rico et al., 2024; Safari et al., 2024; Sirbiladze et al., 2024; Zhang et al., 2016), three papers deal with five objectives (Cai et al., 2023; Hong & Mwakalonge, 2020; Jacyna-Gołda & Izdebski, 2017), one addresses six objectives (Coutinho-Rodrigues et al., 2012b), and one considers eight objectives (Elleuch & Frikha, 2018). Finally, for six of the retrieved papers the number of objective was left generic (Hong & Jeong, 2019; Ratick et al., 2016; Rohaninejad et al., 2017; Upmanyu & Saxena, 2015a, 2015b; Zhang, 2011).

Fig. 4 shows the number of papers published between 2011 and 2024 using uncertainty and time as modelling tools: there seems to be no regular trend, and their use is not widespread.

Specifically, only 30.5% of the collected papers (namely 88 papers) deal with uncertainty. This uncertainty is addressed in relation to various factors, including: travel times (Bozorgi-Amiri & Khorsi, 2016; Fazli, 2024; Ghaffari-Nasab et al., 2013a; Kaveh et al., 2021; Khorsi

Table 5
Number of papers per journal, reporting only those with at least 3 papers. Proceedings marked with an asterisk.

Journal	# of papers	Journal	# of papers
Annals of Operations Research	14	International Journal of Advanced Manufacturing Technology	3
Applied Energy	3	International Journal of Industrial Engineering Computations	3
Applied Mathematical Modelling	3	International Journal of Services and Operations Management	3
Applied Soft Computing Journal	4	Journal of Humanitarian Logistics and Supply Chain Management	3
(*)Communications in Computer and Information Science	3	Lecture Notes in Computer Science	12
Computers and Industrial Engineering	12	Mathematical Problems in Engineering	3
Computers and Operations Research	6	OR Spectrum	3
Computers, Environment and Urban Systems	3	Socio-Economic Planning Sciences	4
Environment, Development and Sustainability	3	Soft Computing	4
Environmental Science and Pollution Research	4	Sustainability (Switzerland)	5
European Journal of Operational Research	8	Sustainable Cities and Society	3
Expert Systems with Applications	10	Transportation Research Part E: Logistics and Transportation Review	8
Geomatics, Natural Hazards and Risk	3	Uncertain Supply Chain Management 3	
IEEE Transactions on Intelligent Transportation Systems	4		

et al., 2021; Navazi et al., 2018; B. Zhang et al., 2018), facilities availability (Chanta et al., 2014; Das et al., 2024; C. Wang et al., 2022), transport costs (Jalilvand et al., 2023; Kaveh et al., 2021; Kim et al., 2024; Maharjan & Hanaoka, 2020; Shishebori et al., 2016), amount of supply (Das et al., 2024; Diglio et al., 2024; Günay et al., 2019; Jafarzadeh-Ghoushchi et al., 2023; Ransikarbun & Pitakaso, 2024; Rouhani & Amin, 2022; Shaw et al., 2022) or problem-specific parameters, such as capacity (Kaveh et al., 2021; Pishvae & Razmi, 2012; Rahbari et al., 2023; Vahdani et al., 2018a), costs (Dong et al., 2023), service and waiting times (Asadi et al., 2018; Golmohammadi et al., 2025), road reliability (Beiki et al., 2021; Mohamadi et al., 2019; P. Zhang et al., 2022), response time (Zhao et al., 2025) or recycling quantity and ratio of echelon use (Fan et al., 2023). However, for the majority of these papers (i.e. 58 out of 88) the demand is uncertain. In addition, only 20% of the collected papers, i.e. 57 papers, explicitly include time (Afshari et al., 2014a, 2016, 2014b; Ahluwalia & Nema, 2011; Amin-Tahmasbi et al., 2022; Asadi et al., 2018; Aydin, 2022; Becerra et al., 2024; Bozorgi-Amiri & Khorsi, 2016; Chen & Cheng, 2011; Das et al., 2021; Eriskin & Karatas, 2023; Eydi & Saghez, 2024; Farrokhzadeh et al., 2021; Fazli, 2024; Gital Durmaz & Bilgen, 2020; Hajipour et al., 2021; Han et al., 2022; Hu et al., 2025; Izadian et al., 2024; Jafarzadeh-Ghoushchi et al., 2023; Jalilvand et al., 2023; Jin et al., 2018; Khalili et al., 2016; Khorsi et al., 2021; Kian et al., 2022; Kim et al., 2024; Liu et al., 2019; Long et al., 2021; Maharjan & Hanaoka, 2018, 2020; Maliki et al., 2021, 2022; Martinez-Gomez et al., 2015; Mogale et al., 2018; Mohebalizadehgashti et al., 2020; Navazi et al., 2018; Nekooghadirli et al., 2014; Ouhader & El Kyal, 2023; Pourhassan et al., 2025; Rabbani et al., 2021; Rahbari et al., 2023; Rahmanifar et al., 2024; Rashvand Falari et al., 2024; Rayat et al., 2017; Rouhani & Amin, 2022; Safari et al., 2024; Savojo et al., 2022; Sepehri et al., 2024; Seydanlou et al., 2022; Sun & Liu, 2021; Tari & Alumur, 2014; Tosarkani & Amin, 2020; Turan et al., 2021; Vahdani et al., 2018a, 2018b; Xue et al., 2022; Zaeimi & Rassafi, 2021).

The analysis shows that 143 papers use a case study as the validation method for the proposed models and approaches, while the remaining papers rely on numerical examples generated randomly or adapted from existing literature. The geographical distribution of the case studies is illustrated in Fig. 5: they are mostly related to problems arising in China (22.7%), Iran (23.0%), Turkey (11.2%) and North America (9.1%), and relate to healthcare and disaster management contexts, and the installation of public service facilities.

Specifically, there are nine sectors for the case studies: *Disaster Management, Emergency Management, Energy, Healthcare, Logistics, Network Design, Services* (both private and public), *Supply Chain Management, Waste Management* (cf. Table 6), with the majority of papers referring to Disaster Management (21.7%), Healthcare (14%), Supply Chain Management (13.3%) and Waste Management (16.1%) sectors. Fig. 6 shows the number of papers proposing a case study over the considered time interval. Notably, at least half of the papers published every year from 2018 use a case study as a validation method.

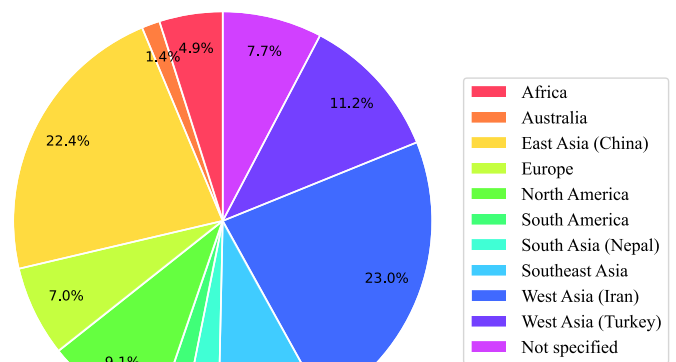


Fig. 5. Countries for the 143 case studies.

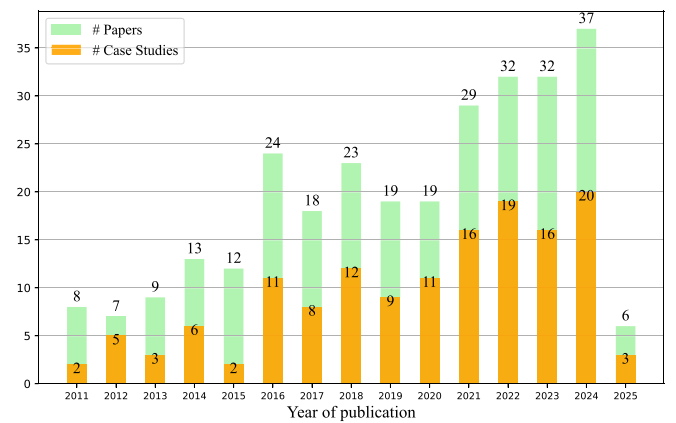


Fig. 6. Number of papers containing a case study per year across the time interval [2011; 2025].

This finding further confirms the valuable contribution that the MOFLP approach can make to public authorities and practitioners in addressing issues related to societal needs in a timely and efficient manner. References for case studies, along with the corresponding country, sector and application field are provided in Table A.1 in the Appendix.

Finally, Fig. 7 shows the class of Facility Location problem to which each MOFLP belongs, according to the well-established classification of Location Problems (cf. Section 3.5). The majority of papers fall under the class “Location–Allocation” (34.0%), followed by “Location–Routing” (16.3%), and “Covering Location” (10.4%). Additionally, the

Table 6
Number of contributions per sector for the case studies.

Sector	# of papers	Sector	# of papers	Sector	# of papers
Disaster Management	31	Healthcare	20	Services	15
Emergency Management	8	Logistics	4	Supply Chain Management	19
Energy	5	Network Design	9	Waste Management	23

Table 7

Terms used in the literature to denote the costs associated with activating a facility. The table reports the frequency of each term and its percentage out of the 143 papers that mention these costs.

Name	# of occ.	% of occ.	Name	# of occ.	% of occ.
Opening Costs	34	22.78%	Facility Costs	6	4.20%
Establishment Costs	26	18.18%	Facility Location Costs	3	2.10%
Construction Costs	24	16.78%	Activation Costs	2	1.40%
Fixed Costs	21	14.69%	Design Cost	1	0.70%
Installation Costs	13	9.09%	Deployment Costs	1	0.70%
Set-up Costs	11	7.69%	Implementation Costs	1	0.70%

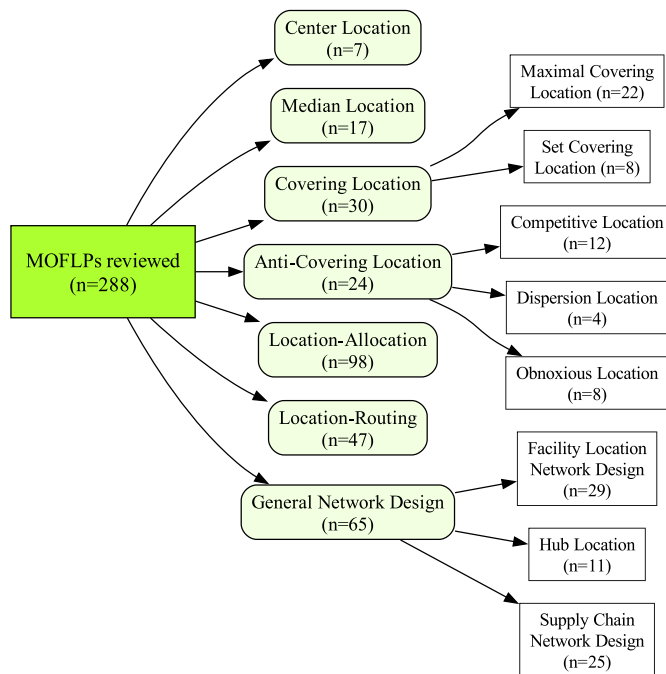


Fig. 7. The diagram shows the number of papers retrieved for each class and sub-class of Location Problems.

class “General Network Design” which contains problems combining Facility Location and Network Design (Contreras & Fernández, 2012), accounts for 22.6% of the retrieved papers.

The thorough analysis detailed in the following subsections has several aims: firstly, to identify the managerial context that gives rise to specific objectives and the application areas of the proposed problems, where available. In particular, a preliminary analysis revealed that 143 papers feature costs associated with the binary decision of activating or not a facility; however, 12 different names have been used to refer to these costs. Table 7 reports the number of occurrences for each term. Since “Opening Costs” has the highest frequency, we will refer to this class of cost uniformly as *Opening Costs* throughout the remainder of this paper.

A further objective of this in-depth analysis is to assess the *quantitative* features of the relevant literature, to visualise the main trends in terms of solution approaches. To this end, they have been characterised also according to the following classification (Mavrotas, 2009): *a priori* methods, that allow the decision-makers to express their preferences before the solution process, e.g. through weights for the objective functions; *interactive* methods, that allow decision-makers to

iteratively search for the most preferred solution; *a posteriori*, i.e. methods that provide the decision-makers with the full Pareto Set (or an approximation of it) so they can select the most preferred solution.

4.2.1. Multi-objective center location problems

The p -center Location Problem is a min-max problem defined on a network. It was first introduced by Hakimi (1964), who formulated the absolute 1-center problem of locating a police station or hospital so as to minimise the maximum distance to a set of communities connected by a road network. Since then, several variants have been proposed, depending on the number p of facilities to locate, whether they have to be located only at nodes of the network or also on its arcs, and on the topological structure of the underlying network (Daskin, 1995; Nickel et al., 2019).

From a managerial perspective, Center Location Problems are characterised by a focus on the *equity* of the service provision, which is combined with *accessibility* and *efficiency* in Delgado et al. (2022) for the location of Healthcare Centres, with *workload balance* in Davoodi (2019), and with *risk mitigation* and *opening costs* when locating facilities under disruptions as in the *r-all-neighbour p-center* problem in Medal et al. (2014b). In a similar scenario and assuming that the decision-maker is risk averse, Medal et al. (2014a) introduced a Bi-Objective Center Location Problem arising from the combination of *quality of service* and risk mitigation purposes. Similarly, equity and quality of service give rise to a Bi-Objective problem for Static and Mobile Facility Location (Gu & Wang, 2012).

It is worth noting that none of these papers deals with either time or uncertainty issues, even when considering disruptions, and all the proposed models have only been validated by numerical examples. In addition, an exact approach was used in five out of seven papers: three used an ϵ -constraint method (Delgado et al., 2022; Kazemi T. & Fathi, 2019; Medal et al., 2014a), while Medal et al. (2014b) proposed a binary search algorithm, which is also the only *a priori* method used and De Walsche et al. (2023) developed a *Radius-based Incremental Algorithm*. The heuristics proposed are search-based: Gu and Wang (2012) combined a clustering-based heuristic with a greedy approach, Davoodi (2019) developed an iterative algorithm based on the Voronoi diagram, and Kazemi T. and Fathi (2019) an *Incremental Algorithm* exploiting the relationship between the p -dispersion problem and an associated node packing problem. In particular, the prevalence of a posteriori approaches shows that when the focus is on equity, a comprehensive view of the set of alternatives is crucial for a well-informed decision-making process.

Discussion and outlook. In summary, the existing literature on Multi-Objective Center Location Problems demonstrates a strong emphasis on equity-oriented objectives. However, there is a lack of attention to temporal dynamics and uncertainty, even in scenarios related to disruption. These gaps highlight promising avenues for future research, particularly in dynamic and stochastic settings that are relevant to critical applications, such as those in the healthcare sector.

4.2.2. Multi-objective median location problems

The p -median Location Problem was originally introduced by Hakimi (1964, 1965); it deals with the selection of a fixed number of p locations (the *medians*) among a set of candidate facilities in order to minimise the *allocation costs* for potential users of the provided service. These costs generally depend equally on the distance between users and the nearest facilities, thus representing the cost of satisfying their demand, typically expressed as the average or total cost associated with users. Therefore, the managerial rationale behind Median Location problems is economic. Different Multi-Objective Median Location problems can arise when the decision-making process is also guided by service-related factors, such as: the *opening costs*, the *service quality* or *efficiency*.

Allocation costs are combined with system *efficiency* in the location of vaccination centres (Cabanilla et al., 2022), blood-mobiles (Maliki et al., 2021) and emergency resource distribution centres (Peng et al., 2022), as well as in the location and protection of facilities from intentional attack (C. Zhang et al., 2018). The economic concerns are addressed from the perspective of both users and service providers, by including the minimisation of opening, operating and maintenance costs (Chen & Cheng, 2011; Hu et al., 2022; Huang & Shi, 2021). Finally, the combination of allocation costs and equity is applied to the location of municipal centres (Tüzün Aksu & Oca, 2012). Moreover, *workload balance* has been adopted as a metric to assess the efficiency of service provision. L. Wang et al. (2023) combined it with risk mitigation when locating distribution centres, while Davoodi and Calabrese (2024) combine workload balance and travel distances when locating test centres. Indeed, the case studies are related to the installation of healthcare or public service facilities (Cabanilla et al., 2022; Hu et al., 2022; Huang & Shi, 2021; Maliki et al., 2021; Tüzün Aksu & Oca, 2012; L. Wang et al., 2023).

Four papers proposed a mathematical exploration of Multi-Objective Median Location Problems: the median and center objectives are addressed together considering a *probabilistic line barrier* (Amiri-Aref et al., 2011), a class of discrete cost bottleneck location problems (Gadegaard et al., 2018) or in one and two dimensions under the Manhattan metric (Roostapour et al., 2016). Also, Sayyady et al. (2015) defined the p -median p -dispersion problem for traffic sensor location; Karatas and Yakıcı (2018) combined covered demand with allocation costs to locate public emergency service stations and explore the scalability of an original Branch&Bound algorithm; Sánchez-Oro et al. (2022) designed an algorithm for the *obnoxious p -median problem*.

Regarding the solution methods, the *a posteriori* approaches are strongly preferred, as only two out of 17 papers proposed *Goal Programming* procedures to address the corresponding problem, either fuzzy (Amiri-Aref et al., 2011) or iterative and combined with Branch & Bound (Karatas & Yakıcı, 2018). An exact approach was used in almost half of the papers, being primarily the ϵ -constraints method (Gadegaard et al., 2018; Sayyady et al., 2015; Ushakov et al., 2018) (Davoodi & Calabrese, 2024). In Ushakov et al. (2018) the authors also developed a hybrid Branch&Cut algorithm combined with Simulated Annealing, while Cabanilla et al. (2022) used a bubble sort approach. The most widely used heuristics are population-based (Chen & Cheng, 2011; Hu et al., 2022; Huang & Shi, 2021; Maliki et al., 2021; L. Wang et al., 2023; C. Zhang et al., 2018) but Sánchez-Oro et al. (2022) developed a Parallel Variable Neighbourhood Search, Davoodi and Calabrese (2024) proposed a Hill Climbing local search procedure, and Peng et al. (2022) designed an improved Particle Swarm Optimisation method.

Discussion and outlook. The review of the existing literature indicates that Multi-Objective Median Location Problems have been predominantly applied to public and healthcare service planning, addressing allocation costs minimisation alongside considerations of equity, efficiency, and risk mitigation. However, current models largely rely on deterministic, single-period formulations. To enhance both the theoretical depth and the practical relevance of this class of MOFLPs, future research should focus on developing dynamic models that incorporate uncertainty in demand, service disruptions, and user behaviour.

4.2.3. Multi-objective covering location problems

Covering problems focus on locating facilities that serve only users within a specified distance from the nearest facility (Nickel et al., 2019), who are therefore considered “covered”. Two main variants exist: the *Set Covering Location Problem* (Toregas et al., 1971), which minimises the number of facilities needed to cover all demand, and the *Maximal Covering Location Problem* (Church & ReVelle, 1974), which maximises covered demand given a fixed number of facilities. Service is deemed inadequate when users lie beyond a critical distance from the nearest facility (Daskin, 1995). Consequently, coverage provides an important managerial indicator of service distribution adequacy.

Multi-objective maximal covering location problem. Maximising coverage often conflicts with the financial costs of establishing and operating the service; as a result, focusing on coverage and opening costs led to a Bi-Objective Maximal Covering Location Problem in Şen et al. (2011), to locate fire stations, and in the design of a cloud seeding network in Sadeghi and Yaghoubi (2024). Also, Mendoza-Gómez and Ríos-Mercado (2022) considered the location of primary healthcare centres, taking into account budget and distance constraints, whose trade-offs were then explored through two different Bi-Objective coverage models. Other managerial considerations include *quality of service* — measured in terms of response or delay time — and *fairness*. For instance, Schmidt-Dumont and Van Vuuren (2016) examined coverage and average signal strength in a mobile telecommunications network. Besides, Olivos and Caceres (2022) addressed the *ambulance location problem*, considering both coverage and service effectiveness, measured in terms of response time. In addition, Yue et al. (2024) considered coverage when locating electric scooter deployment stations. They used the maximum tolerable distance from stations as a proxy for service quality. Zhao et al. (2017) combined coverage, allocation costs, and equity for the location of temporary emergency rescue facilities, while Khalilzadeh and Bahari (2023) addressed equity, opening costs, and service costs for the location of emergency medical services.

The concept *user satisfaction*, closely related to equity, often depends on the distance from facilities. For example, Eskandari and Nookabadi (2018) examined this in the context of off-street parking location, where they also considered the environmental impact of the system. Similarly, Yang et al. (2024) considered user satisfaction in locating *senior-friendly* restaurants. Instead, Atta et al. (2021) incorporated user preferences into the Maximal Covering Location Problem to explore whether the location meets these preferences while ensuring coverage. Similarly, Mohammadi et al. (2016) focused on equity in relief distribution to ensure user satisfaction when modelling the pre-positioning of emergency earthquake response supplies, assuming that demand for supply and transport costs are stochastic.

Uncertainty is a common modelling approach in Multi-Objective Maximal Covering Location Problems, particularly due to variability in demand. For instance, Berman et al. (2018) addressed uncertainty about travel time and demand in a Facility Location–Network Design problem (FLND), aiming to determine an optimal reconfiguration of the network in terms of coverage and opening costs. Parragh et al. (2022) considered uncertain demand with a known probability distribution while focusing on coverage and the economic aspects of service installation. Similarly, Shishebori et al. (2016) considered system uncertainty in a FLND and used coverage as a measure of system efficiency, while addressing economic concerns related to opening and operating costs. The authors of Chanta et al. (2014) considered stochastic facility availability when addressing the ambulance location problem. They adopted *expected coverage* as a measure of system efficiency and introduced three different measures of *fairness* related to the maximum distance between an uncovered area and the nearest facility, the number of uncovered rural areas, and the amount of uncovered demand. Finally, Ratick et al. (2016) studied the Maximal Covering Location Model with Hedging, which treats user coverage as separate objectives ranked Lexicographically, reflecting uncertainty in

the spatial distribution of demand. In Han et al. (2022), the authors addressed the problem of locating maintenance stations and mobile service fleets over multiple periods of a harvest season by combining coverage with measures of (re-)location plan efficiency. Finally, two papers include the combination of Maximal Covering, p -median, and p -center Location Problems for algorithmic exploration purposes (Karatas & Yakıcı, 2018; López-Sánchez et al., 2021). Gradual and cooperative coverage are combined for mathematical purposes in Karatas (2017), while Maliszewski et al. (2012) performed a mathematical exploration of the trade-off between the p -dispersion and other location objectives, including coverage, for managing critical assets in urban areas.

It is worth noting that most of the Multi-Objective Maximal Covering Location Problems addressed in the retrieved papers are related to the installation of facilities for emergency or healthcare services. This is consistent with the fact that coverage is a crucial aspect when installing a predefined number of facilities to provide such essential services. This result is also evident from the areas of application of the 13 case studies considered.

The quantitative analysis shows that 10 out of 22 reviewed papers used exact approaches, six of which are a posteriori. Specifically, the ϵ -constraint method (Chanta et al., 2014; Eskandari & Nookabadi, 2018; Olivos & Caceres, 2022) and its *augmented* versions (Han et al., 2022; Mendoza-Gómez & Ríos-Mercado, 2022) are widely used, given their suitability for generating the full Pareto Set for Mixed-Integer MOFLPs. Parragh et al. (2022) embedded Benders decomposition in a Branch&Bound framework to address a Bi-Objective stochastic FLP. The a priori exact methods used include: Compromise Programming (Sadeghi & Yaghoubi, 2024), Lexicographic optimisation (Ratick et al., 2016), Goal Programming combined with Branch & Bound (Karatas & Yakıcı, 2018), the weighting method (Maliszewski et al., 2012; Yang et al., 2024), and Lagrangean relaxations (Shishebori et al., 2016). The heuristics proposed are mainly search-based or meta-heuristic algorithms: Atta et al. (2021) developed a Multi-Objective version of the *Harmony Search* algorithm; Berman et al. (2018) combined *Tabu Search* and *Greedy Search* algorithms, and López-Sánchez et al. (2021) adapted the *Scatter Search* algorithm. Instead, Mohammadi et al. (2016) used the Particle Swarm Optimisation framework, while Khalilzadeh and Bahari (2023) and Schmidt-Dumont and Van Vuren (2016) adapted the Simulated Annealing scheme, and Zhao et al. (2017) used the Non-dominated Sorting Genetic Algorithm II (NSGA-II). Finally, Karatas (2017) developed a matheuristic that solves the non-linear programming formulation to obtain a “good” starting point, which was then used to solve the linearised formulation. Lastly, Yue et al. (2024) adopted a deep learning procedure to solve the single-objective model associated with their MOFLP, obtained via a Weighted Sum approach.

Multi-objective set covering location problem. The related literature is rather scarce, consisting of only eight papers, three of which describe problems that were addressed for purely theoretical or algorithmic purposes. The assumption that the decision-makers are unable to provide precise information led to the Multi-Objective problems addressed in Upmanyu and Saxena (2015a, 2015b), while the Bi-Objective problem in Parragh and Tricoire (2019) is instrumental in validating their novel Bi-Objective Branch&Bound algorithm.

The authors of Dabibi et al. (2016) combined coverage with the economic perspective when installing service centres across different levels of a supply chain; Wichapa and Khokhajaikiat (2017a) determined the best location for infectious waste disposal centres according to geological, social and environmental factors. Then, Yao et al. (2019) considered coverage and *accessibility* when locating urban fire stations, while Blesa et al. (2016) evaluated the robustness of a sensor placement methodology aimed at providing the best diagnosis in leak detection while minimising the number of installed sensors. Finally, Camara et al. (2024) propose a Bi-Objective Set Covering Location Problem to optimise the design a roadside traffic survey system, assessing its

efficiency in terms of number of support units and travel costs incurred to install them.

The quantitative analysis highlights that five out of eight papers use an exact method: the linearisation technique in Upmanyu and Saxena (2015a, 2015b) is based on the subsequent application of the cutting plane method, Parragh and Tricoire (2019) developed a generic Bi-Objective Branch&Bound algorithm, and Yao et al. (2019) used the *constraint method* to solve the urban fire station location problem. Wichapa and Khokhajaikiat (2017a) use the Analytic Hierarchy Process to determine the weights to be assigned to several different qualitative criteria, before using Goal Programming. In terms of heuristics, Blesa et al. (2016) used a clustering technique to reduce the number of candidates before performing an *exhaustive search* of the Pareto Set, while Dabibi et al. (2016) solved the Single-Objective problem in the ϵ -constraint framework through a genetic algorithm and Camara et al. (2024) adapted the NSGA-II framework to address their problem.

Discussion and outlook. Multi-Objective Covering Location Problems mainly arise in relation to emergency and healthcare service planning, where coverage is a critical metric alongside equity and quality of service. Although various exact and heuristic methods have been used to solve these problems in deterministic and stochastic scenarios, most models have limitations in terms of their temporal and behavioural assumptions. Future research could explore equity-driven fairness metrics to improve the accuracy and applicability of these models.

4.2.4. Multi-objective anti-covering location problem

In this subsection we collected considerations for three classes of problems: *Competitive Facility Location*, *p-Dispersion Location* and *Obnoxious Facility Location* problems. In fact, they have in common that the facilities to locate are “repulsive” either to users (in the Obnoxious Facility Location problem) or to other facilities (in the Competitive Facility Location and the p -Dispersion Location problems). A brief description of these problems is provided in the following, in the respective section.

Multi-objective competitive facility location. The managerial imperative behind the Competitive Facility Location Problem is related to *competitiveness*. The problem was first introduced by Hotelling (1929), who modelled a scenario where customers are uniformly distributed along a line segment — such as a main street — and competing retailers independently choose their locations and prices to maximise profit. The total cost to the customer includes both the selling price and transport costs. Competitiveness is seldom integrated with other concrete managerial considerations in the Multi-Objective literature. Of the 12 selected papers, seven address Multi-Objective Competitive Location Problems from a purely mathematical or algorithmic perspective. The authors of Beresnev and Melnikov (2020) modelled the problem as a Stackelberg game with uncertain demand. These assumptions lead to a Bi-Objective *Leader* problem where both the probability of receiving a *guaranteed profit* and the profit itself are maximised. The game-theoretic approach is also used in Rohaninejad et al. (2017) who exploited the competitiveness problem as the maximisation of utility for multiple competitors. In the Bilevel model proposed by Camacho-Vallejo and Corpus (2024), the follower’s managerial perspective entails competitiveness and profit maximisation, while Konak et al. (2017) considered the demand covered by each facility. Similarly, the covered demand is combined with construction and operating costs for the location of recycling facilities in Ma et al. (2024). If one of the two firms wants to expand, the *cannibalisation* effect becomes a relevant managerial issue that, if addressed with competitiveness, gives rise to a particular Bi-Objective Competitive Location Problem (Lancinskas et al., 2014, 2015; Lancinskas & Žilinskas, 2013, 2014). In fact, some of the new facilities could attract customers from the company’s existing facilities. This Bi-Objective perspective is adopted in Roudsari and Wong (2014) when identifying

the location for a new supermarket in the only case study found, and to locate grocery stores in urban areas in Cebi and Goularas (2021). Finally, Levanova et al. (2023) combined competitiveness and robustness to tackle demand uncertainty for company expansion. All these problems have been addressed mainly through a posteriori heuristics, including evolutionary (Camacho-Vallejo & Corpus, 2024; Lančinskas & Žilinskas, 2013, 2014; Ma et al., 2024), genetic (Cebi & Goularas, 2021; Konak et al., 2017), search-based (Lančinskas et al., 2014, 2015) or approximation (Rohaninejad et al., 2017) algorithms. This choice may reflect the fact that, given the inherent complexity of these problems, an approximation of the Pareto Sets is preferred to an exact computation. Furthermore, the predominant use of a posteriori approaches suggests that for these problems, decision-makers are interested in knowing the trade-offs between different objectives before expressing a preference.

Multi-objective p -dispersion facility location. In the p -Dispersion Facility Location Problem the aim is to locate a fixed number p of facilities so as to maximise the minimum distance between any pair of facilities (Daskin, 1995). From a managerial point of view, the separation between facilities may be required for safety or competitiveness reasons. In fact, Karbasian and Dashti (2011) combined competitiveness with measures of efficiency and quality of the service provided by the located facilities. Similarly, Lozano-Osorio et al. (2023) dealt with the Bi-Objective p -median and p -dispersion problem (Sayyady et al., 2015). Conversely, the dispersion approach aims to ensure safety when designing a plant layout, thus combining this managerial need with the economic concerns related to opening costs in the multi-annual framework proposed in Martinez-Gomez et al. (2015). Similarly, Salinas et al. (2023) considered the location of vaccination centres from the perspective of safety and equity. Regarding the solution approaches, two of four papers used an a priori exact method (Karbasian & Dashti, 2011; Martinez-Gomez et al., 2015), thus requiring the knowledge of the preferences for the decision-makers; the remaining two used a posteriori tailored heuristic approaches (Lozano-Osorio et al., 2023; Salinas et al., 2023). However, given the reduced number of papers, we could not draw further conclusions about the correlation between the features of these problems and most used/indicated solution methods.

Multi-objective obnoxious facility location. The facilities to be located may be undesirable or obnoxious if they threaten the lives of users located near them; they may therefore need to be located so as to maximise a function of the distance between the users and the nearest facility (Daskin, 1995). From a managerial perspective, the repulsion for these facilities translates into safety or environmental impact objectives which are combined with efficiency and economic issues in the six retrieved Multi-Objective contributions. In Hammad et al. (2017b) the authors considered the location of noise-sensitive and noise-generating facilities in urban environments by considering the environmental impact associated with their location and the transport costs in the underlying road network. Similarly, economic managerial concerns were combined with those related to obnoxiousness in Hammad et al. (2017a) when locating airports. Also, Teran-Somohano and Smith (2019) defined the Bi-Objective problem of locating semi-obnoxious facilities (e.g. solid waste transfer stations) in the Euclidean Plane while accounting for environmental impact, transport costs and system operating costs. A similar approach was adopted to design a biomass to biofuel supply chain in Turkey in Yunusoglu et al. (2024). The location of fuel storage tanks in Istanbul led to the definition of a Bi-Objective Semi-Obnoxious Facilities Location Problem in Eriskin and Karatas (2023). In fact, the authors considered pull and push objectives arising from managerial concerns related to transport costs and safety. The same rationale was followed in Coutinho-Rodrigues et al. (2012a) for the location of Solid Waste Containers in Coimbra, Portugal. Men et al. (2020) addressed the location of emergency rescue facilities in chemical parks by combining the economic perspective with the ones of safety and efficiency. Finally, Kaveh and Mahdavi (2024) addressed a classic Obnoxious MOFLP with a novel Multi-Objective evolutionary algorithm. It

is worth noting that six of eight papers validate the proposed problem through a case study, proving that the combination of the obnoxiousness with different managerial perspectives is instrumental at providing the chance to address specific real-world problems.

The quantitative analysis shows that, in certain contexts, an a priori knowledge of the decision-makers preferences might be required. For example, the airport location problem is addressed using the Weighted Sum method (Hammad et al., 2017a), while while Goal Programming is applied to the location of fuel storage areas (Eriskin & Karatas, 2023) and the design of a biomass to biofuel supply chain (Yunusoglu et al., 2024). However, three of the remaining problems are solved with a posteriori evolutionary algorithms (Men et al., 2020; Teran-Somohano & Smith, 2019) which efficiently approximate the Pareto Sets. Finally, the AUGMECON method, which belongs to the class of the ϵ -constraint algorithms, is used to tackle the Bi-level Mixed Integer Non-Linear problem in Hammad et al. (2017b). The constraint method is used in Coutinho-Rodrigues et al. (2012a) to address their Bi-Objective FLIP.

Discussion and outlook. Overall, the analysis of Multi-Objective Anti-Covering Location Problems reveals how different managerial imperatives, such as competitiveness, safety, equity, and environmental impact, shape the formulation and solution of these complex models. While Competitive Facility Location problems have largely been approached from a mathematical perspective, Dispersion and Obnoxious Facility Location Problems more clearly integrate safety and social considerations, particularly in contexts such as plant layout design, healthcare provision, or the location of hazardous facilities. The predominance of a posteriori heuristics, particularly evolutionary algorithms, as a method of solving these problems highlights their complexity and suggests that a possible area of future research could be exploring the balance between more tailored, sophisticated solutions and practical relevance in order to provide valuable support in complex decision-making contexts.

4.2.5. Multi-objective location-allocation problems

Location-Allocation Problems involve a finite set of users who demand a service, and a set of potential facility locations that provide it. These problems require two key decisions related to the location of facilities, and the assignment of users to the located facilities in order to satisfy their demand (Azarmand & Neishabouri, 2009). Additionally, as reported in the seminal paper by Cooper (1963), there are generally assignment costs which are a function of demand and facility-user distance (Azarmand & Neishabouri, 2009).

Different variants of Location-Allocation Problems have emerged, depending on factors such as the integration of constraints on the service capacity of the facilities (capacitated vs. uncapacitated) and/or on the user assignment modes (single assignment vs. multiple assignment), and the presence of opening costs for the facilities (Nickel et al., 2019). Problems involving fixed charge costs for locating facilities are usually referred to as Fixed Charge Facility Location; the related Multi-Objective literature is analysed in a separate paragraph in this section. Capacities are typically treated as exogenous parameters that define limits on the maximum demand that can be served from any located facility, providing a particular type of service, such as schools and hospitals (Daskin, 1995; Fernández & Landete, 2019). From a managerial perspective, Location-Allocation Problems arise when the decision-making process focuses on service provision, and its quality or economic aspects (e.g. transport costs from facilities to users). These problems have received significant attention in the Location literature and their relevance is clear even when multiple objectives are considered, accounting for 34% of the retrieved papers.

The managerial concern related to the quality of service has been formalised in several ways: service delay (Hussain et al., 2023), travel times to incidents when locating maritime search and rescue vessels (Akbari et al., 2018), evacuation time when locating shelters (Zhong et al., 2023), travel distances when locating emergency stations

in underground mine networks (Lotfian & Najafi, 2019) and primary healthcare facilities (Wang et al., 2024), total conveyance time when considering the sustainability of logistics networks (Das et al., 2024). Indeed, this aspect is usually combined with the *efficiency* of the service provided alone (Akbari et al., 2018) or along with *equity*. Similarly, in Jalali et al. (2018) travel distances between users and facilities and between different types of facilities are indicators for the quality of service, and this managerial perspective is combined with *equity* of service provision and *accessibility* to the service. In addition, Avramescu et al. (2023) used this definition of quality along with construction and operation costs and coverage for the design of a personalised medicine supply chain. Service quality and efficiency were combined with the *user satisfaction* in Zhou et al. (2021) when locating city air terminals. Then, in Baik and Murray (2022) and Cho et al. (2023), the quality of service is expressed in terms of demand coverage while the assignment costs measured service *accessibility*. The same managerial purposes led to the definition of the Multi-Objective Problems in Elkady and Abdelsalam (2016), who expressed the assignment cost as the travelled distance of the uncovered demand in their healthcare facility planning problem. The authors in Günay et al. (2019) modelled the selection of facilities providing assistance to refugees and de Campos et al. (2024) addressed the location of mammography units. Still in humanitarian logistics, Xue et al. (2022) coupled service quality and efficiency with *system productivity*, while Mishra et al. (2022) combined coverage with transport costs to represent those managerial objectives related to service quality and service provision costs when designing a relief distribution network. Instead, Dogan et al. (2020) assumed that there was a limited budget available for the installation of preventive healthcare facilities, and combined the economic perspective with the quality of service, measured by defining an acceptable waiting time, and public engagement, thus defining a Tri-Objective problem. In Fazli (2024), the economic perspective relating to establishment and procurement costs is combined with qualitative criteria to represent social utility when addressing an Inventory–Location–Routing in the context of disaster management operations. The focus is on quality of service, *safety* and *environmental impact* when locating rental stations and bike paths for a public bike system and emergency shelters in Lin et al. (2018) and Ma et al. (2019) respectively.

When addressing Facility Location Problems with Queuing, service requests have a probabilistic behaviour and thus the quality of service is usually expressed in terms of travel and waiting times for users, and combined with *system productivity*, measured by the average idle probability (Chambari et al., 2011; Eshaghi Chaleshtori et al., 2020; Hajipour & Pasandideh, 2012), or eventually with *profit* (Tavakkoli-Moghaddam et al., 2017) in the Multi-Objective literature.

The assignment costs are generally expressed as transport costs when modelling location problems defined on specific network types. For instance, Akgün and Erdal (2019) modelled the design of an ammunition distribution network and combined the economic perspective with *system reliability*, Kaveh et al. (2024) for the design of a humanitarian logistics network, and Mohamadi et al. (2019) for a telecommunication network. For the reorganisation of a blood supply chain, Diglio et al. (2021) jointly considered transport costs, *efficiency* and *effectiveness* as done later by Oksuz and Satoglu (2024) for post-disaster operations. Then, the location of vehicle inspection stations is addressed by pursuing both transport costs and travel time objectives (Tian & Zhou, 2015; Tian et al., 2016). Additionally, both the Location–Allocation problems in Jacyna-Golda and Izdebski (2017) and Li et al. (2022) were addressed with a focus on managerial perspectives related to the costs of operating the logistics network underlying the respective systems, i.e. transport, operating and supply costs. Specifically, Li et al. (2022) also took into account the environmental concerns by focusing on CO₂ emissions. Instead, *safety* is explicitly considered among the managerial concerns in three papers, along with economic aspects in the design of an Electric Waste Management system (Ahluwalia & Nema, 2011), with efficiency in the location of

earthquake emergency shelters (Ma et al., 2022), and with accessibility and coverage in evacuation planning (Rico et al., 2024). Finally, three papers dealt with purely algorithmic explorations (Hong & Jeong, 2019; Lai et al., 2019; Rudziński, 2017); specifically Lai et al. (2019) considered financial and qualitative factors in modelling and solving a Supply Chain Network Design problem, while Rudziński (2017) focused on maintenance costs, CO₂ emissions and customer service reliability when planning a distribution network.

The qualitative analysis showed that 17 revised papers use numerical examples to validate the proposed models/methods and 22 describe a real case study, confirming the theoretical and practical relevance of Multi-Objective Location–Allocation problems. Moreover, the 58% of the retrieved papers considered a capacitated problem, with service capacities not included in the modelling phase when the focus is on economic aspects related to transport (Tian & Zhou, 2015; Tian et al., 2016), or it is primarily on quality of service (Baik & Murray, 2022; Dogan et al., 2020; Hussain et al., 2023), eventually combined with: productivity (Eshaghi Chaleshtori et al., 2020; Tavakkoli-Moghaddam et al., 2017), safety (Lin et al., 2018) or efficiency (Avramescu et al., 2023; Lotfian & Najafi, 2019). Also, only four of 39 described the underlying problems through multi-period models (Ahluwalia & Nema, 2011; Dogan et al., 2020; Xue et al., 2022); such an outcome may depend on the strong strategic connotation of the Location–Allocation problems. Finally, 15 out of 39 papers explicitly dealt with uncertainty, of which only eight addressing a case study. Since the managerial focus of Location–Allocation problems is on service provision, the uncertainty is mainly related to demand (Ahluwalia & Nema, 2011; Akbari et al., 2018; Fazli, 2024; Ma et al., 2019) and Mohamadi et al. (2019) which was supposed to follow a Poisson distribution in most of the cases (Chambari et al., 2011; Dogan et al., 2020; Eshaghi Chaleshtori et al., 2020; Hajipour & Pasandideh, 2012; Tavakkoli-Moghaddam et al., 2017); however, Günay et al. (2019) considered the uncertain amount of supply, while Tian and Zhou (2015) and Tian et al. (2016) assumed stochastic demand and vehicle velocities and Oksuz and Satoglu (2024) considered uncertainties on the health conditions of casualties.

In terms of solution approaches, we found that an exact approach is used in 17 papers, while 20 proposed a heuristics, either adapted from the literature or tailored to the problem under investigation. Only Eshaghi Chaleshtori et al. (2020) adopted both ϵ -constraint and the NSGA-II genetic algorithm. In general, the a posteriori methods seem to be preferred to address these problems, as they can provide decision-makers with a comprehensive view of the efficient alternatives when it comes to the economic and delivery aspects of the service. However, among the exact approaches, seven are a posteriori (Ahluwalia & Nema, 2011; Baik & Murray, 2022; Das et al., 2024; Eshaghi Chaleshtori et al., 2020; Kaveh et al., 2024; Lin et al., 2018; Oksuz & Satoglu, 2024), two are *no preference* methods (i.e. a global criterion method (Lotfian & Najafi, 2019) and Lp-metric (Mohamadi et al., 2019)), and the remaining are a priori (Akbari et al., 2018; Akgün & Erdal, 2019; Diglio et al., 2021; Dogan et al., 2020; Fazli, 2024; Günay et al., 2019; Jalali et al., 2018; Li et al., 2022; Rico et al., 2024), with Goal Programming (Akbari et al., 2018; Dogan et al., 2020; Fazli, 2024; Li et al., 2022; Rico et al., 2024) and Weighted Sum (Akgün & Erdal, 2019; Günay et al., 2019) being the most used. Indeed, except for one, the other a priori approaches are relative to problems arising from real case studies meaning that the decision-makers preferences are part of the modelling process. As for the others, Ahluwalia and Nema (2011), Diglio et al. (2021), Kaveh et al. (2024) used a solver, Jalali et al. (2018) the Lexicographic method, Das et al. (2024), Lin et al. (2018) the ϵ -constraint method and Oksuz and Satoglu (2024) the AUGMECON2 variant, Li et al. (2022) a goal attainment procedure, and Baik and Murray (2022) a GIS-based strategic partitioning procedure. The most widely used heuristic methods are Genetic Algorithms (Cho et al., 2023; Jacyna-Golda & Izdebski, 2017; Tian & Zhou, 2015; Wang et al., 2024; Zhong et al., 2023; Zhou et al., 2021), mainly NSGA-II (Avramescu

et al., 2023; Chambari et al., 2011; de Campos et al., 2024; Eshaghi Chaleshtori et al., 2020; Xue et al., 2022), and Particle Swarm Optimisation (PSO) (Elkady & Abdelsalam, 2016; Hajipour & Pasandideh, 2012; Hussain et al., 2023; Lai et al., 2019; Ma et al., 2022, 2019). Specifically, the hybrid approach in Hussain et al. (2023) combines NSGA-II and PSO, while the one in Ma et al. (2022) combines Genetic Algorithm, PSO and Simulated Annealing. In addition, the two-phase local search in Mishra et al. (2022) is characterised by *exploration* and *exploitation*, where the former identifies a near optimal solution, while the latter improves the quality of the solution. Also, Tian et al. (2016) proposed a hybrid intelligent algorithm integrating stochastic simulation and Multi-Objective Teaching-learning-based optimisation. Finally, Rudziński (2017) used the generalised strength Pareto evolutionary, and Tavakkoli-Moghaddam et al. (2017) the Vibration Damping Optimisation.

Multi-objective fixed charge facility location problems. In these problems also the location decisions incur in fixed costs, and, from a managerial perspective, they describe those private sector scenarios where a single actor is responsible for the installation of the service and realises the benefits from its provision, and both costs and benefits are monetary (Daskin, 1995). The literature search yielded 59 results on Multi-Objective Fixed Cost Facility Location Problems, of which approximately 67.8% involve capacity constraints. In the following, we first analyse the 19 uncapacitated problems.

Given the managerial perspective that gives rise to the classic Fixed Charge Facility Location Problems, it was not surprising that the *opening costs* were present in the managerial context of all the papers retrieved. In fact, they were combined with other aspects of the service provision, such as *efficiency*, *quality* or *reliability*. In this respect, Alves de Queiroz et al. (2021) considered efficiency and opening costs in their Bi-Objective sensor allocation problem, Barzinpour and Esmaili (2014) for the design of a relief distribution network in Iran, Jalilvand et al. (2023) for an organ transplant network design problem, and Arabahmadi et al. (2023) for the location of technical inspection centres in Iran. C. Wang et al. (2022) also included *reliability* in their Tri-Objective Location problem by accounting for possible facility disruptions. Both the efficiency and the quality of service delivered through personal medicine were considered in Avramescu et al. (2021); similarly, efficiency and equity were pursued in the design of an organ transplant network in Rouhani and Amin (2022). In Zhang et al. (2016) the authors addressed the problem of locating healthcare facilities in extended urban areas by considering economic aspects along with accessibility, equity and quality of service. Finally, the quality of service emerged as a managerial imperative in disaster relief logistics (Bozorgi-Amiri et al., 2013; Maharjan & Hanaoka, 2020; Shaw et al., 2022) and for systems with queuing (Hajipour et al., 2016). Several papers jointly addressed the economic concerns related to the installation and the operation of the service. For instance, Atta et al. (2019) considered service costs and user preferences when locating facilities and assigning users to them according to their specific preferences. In Liu et al. (2023), the focus is also on system reliability, which appeared among the managerial perspectives adopted by Xifeng et al. (2013), along with environmental considerations for a sustainable Facility Location problem. Economic and environmental concerns were combined for the location of municipal waste in Darmian et al. (2020). Finally, Vargas-Santiago et al. (2025) addressed an uncapacitated Fixed Charge Facility Location problem under failure scenarios from a purely algorithmic perspective.

The proposed models were validated by synthetic instances in nine papers (Alves de Queiroz et al., 2021; Atta et al., 2019; Hajipour et al., 2016; Jahantigh & Malmir, 2016; Liu et al., 2023; Shaw et al., 2022; Vargas-Santiago et al., 2025, 2021; Xifeng et al., 2013), while the remaining 10 proposed case studies, mainly related to humanitarian logistics (Barzinpour & Esmaili, 2014; Bozorgi-Amiri et al., 2013; Maharjan & Hanaoka, 2020), healthcare management (Avramescu et al.,

2021; Jalilvand et al., 2023; Zhang et al., 2016) and waste management (Darmian et al., 2020). Seven papers also included uncertainty, with reference to demand (Arabahmadi et al., 2023; Bozorgi-Amiri et al., 2013; Shaw et al., 2022), transport costs (Jalilvand et al., 2023; Maharjan & Hanaoka, 2020), supply amount (Rouhani & Amin, 2022) and facility availability (C. Wang et al., 2022). Except for Atta et al. (2019), Barzinpour and Esmaili (2014), Bozorgi-Amiri et al. (2013) and Jalilvand et al. (2023), all the solution methods are a posteriori approaches. In addition, an exact approach was used in seven papers: LP-metric in Bozorgi-Amiri et al. (2013), AUGMECON in Rouhani and Amin (2022), ϵ -constraint in Arabahmadi et al. (2023), Goal Programming in Barzinpour and Esmaili (2014), Weighted Sum method in Atta et al. (2019) and Jalilvand et al. (2023). Concerning the heuristics, half of the papers used a genetic algorithm (see e.g. Atta et al. (2019), Jalilvand et al. (2023) and Zhang et al. (2016)); Avramescu et al. (2021) used both NSGA-II and a random search approach, while Hajipour et al. (2016) NSGA-II with Tabu Search. In particular, Vargas-Santiago et al. (2025) proposed a novel version of NSGA, namely NSGA-III. Then, C. Wang et al. (2022) devised an evolutionary approach for their stochastic model while Darmian et al. (2020) designed a population-based local search; similarly, Jahantigh and Malmir (2016) combined Multi-Objective Vibration Damping Optimisation with Multi-Objective Harmony Search. Alves de Queiroz et al. (2021) proposed a tailored *Variable Neighbourhood Search* procedure, Xifeng et al. (2013) a greedy heuristics and Liu et al. (2023) a learning-based method, Shaw et al. (2022) a Neutrosophic Compromise Programming. Finally, Vargas-Santiago et al. (2021) introduced the concept of *Adaptable Pareto Set*, capable of increasing the flexibility of the decision-making process, and designed the *incremental* and *decremental* Pareto heuristics to compute this set.

In Capacitated Multi-Objective Fixed Charge Facility Location Problems, the managerial context typically combines economic considerations with aspects of service operation or quality, depending on the application domain. For example, in humanitarian logistics, the focus is primarily on the cost of the logistical network—namely transport, operational, and supply costs. In contrast, when designing networks of public sector facilities, the quality of service becomes the dominant managerial concern. These perspectives were combined in Gutjahr and Dzubur (2016) and Paldrak et al. (2023) for emergency relief distribution, in Boonmee and Kasemset (2020) for the effective location of warehouses for the province of Pichit in Thailand and in Rodríguez-Espindola et al. (2023) for the design of relief supply networks in Mexico. In these two case studies, the quality of service is assessed by considering the response time to satisfy the demand of the relief logistics system and the amount of unmet demand, respectively. The authors of Navazi et al. (2018) considered the design of an efficient Emergency Medical Services network, consisting of ambulances and helicopter ambulances, and measured the quality of service by the average time to cover demand. Finally, the logistics network costs and the quality of service were jointly addressed with the *accessibility* concern in H. Zhang et al. (2022), to design a two-level medical facility network for the implementation of a hierarchical diagnosis and treatment system for a district in Shanghai. In the context of humanitarian logistics, the cost of the logistical network is combined with *effectiveness* and *efficiency* in Praneetpholkrang et al. (2021) for determining the shelters Location–Allocation in the event of flooding, by focusing on evacuation time. Similarly, Geng et al. (2022) considered the evacuation time as a measure of efficiency, along with the associated logistics costs, in designing a humanitarian relief network for an earthquake. Addressing a similar problem, Jafarzadeh-Ghoushchi et al. (2023) combined these perspectives with coverage and fairness. Liu et al. (2019) focused on the number of expected survivals saved as a measure of effectiveness when planning for post-disaster humanitarian medical service. When locating relief facilities in crisis conditions, Khalili et al. (2016) also focused on reducing shortages, while the underlying network's reliability was assessed in Al Ayub Ahmed et al. (2021).

The quality of service was one of the most widely adopted managerial perspectives when stating Multi-Objective Uncapacitated Fixed Charge Facility Location Problems. In fact, it was jointly pursued with: *productivity* in location problems with queuing (Pasandideh et al., 2013; Rahmati et al., 2013), *reliability* in broadcasting systems (Chantre & Da Fonseca, 2018), coverage in a hierarchical facility network (Tadros et al., 2018), equity in reverse logistics (Tari & Alumur, 2014). Moreover, it appeared as a key perspective to consider when installing public services, i.e. facilities for waste management (Rossit et al., 2017) or medical services (Song et al., 2021; Wang et al., 2016, 2018), and it was expressed in terms of demand coverage (Izco et al., 2023; Song et al., 2021) or proximity to demand (Wang et al., 2016, 2018).

Another relevant imperative is the *sustainability* of the service network designed. Indeed, Habibi et al. (2017) considered the greenhouse gas *emissions* of municipal solid waste facilities, presenting a case study in Tehran and taking into account the *environmental impact*, in terms of visual pollution. The authors in Aydin (2022) jointly addressed sustainability, quality and operating costs of the service in the location of parking lots. Indeed, the managerial concern for sustainability is exploited by including the reduction of CO_2 *emissions* among the objectives in several papers addressing location problems related to green logistics (Harris et al., 2014; Karimi et al., 2023; Mohammadi et al., 2023; Tang et al., 2020; Tang & Zhang, 2015; Zhu et al., 2015).

Seven out of 39 papers focus on the costs for service provision, related to different application areas, such as waste management (Herrera-Granda et al., 2019), strategic location of military facilities (Turan et al., 2021), humanitarian logistics (Nazemi et al., 2022) or supply chain management (Arabzad et al., 2015; Mogale et al., 2018). In most cases it has been combined with efficiency (Arabzad et al., 2015; Nazemi et al., 2022), effectiveness (Mogale et al., 2018; Turan et al., 2021) and user satisfaction (Filippi et al., 2021; Herrera-Granda et al., 2019), measured with *conditional β -mean* in Filippi et al. (2021). Three out of 39 contributions aimed to carry out a mathematical exploration (cf. Arana-Jiménez and Blanco (2019)). Carrizosa et al. (2015) considered providing service over a long period of time without probabilistic information on demand distribution and evolution. Instead, Jamalain and Salahi (2020) aimed at measuring the efficiency and the reliability of Fixed Charge Models through DEA algorithms.

The analysis showed that half of the papers addressed real-world case studies, mainly in the fields of disaster management (Boonmee & Kasemset, 2020; Geng et al., 2022; Khalili et al., 2016; Navazi et al., 2018; Nazemi et al., 2022; Praneetpholkrang et al., 2021; Rodríguez-Espíndola et al., 2023), healthcare management (Song et al., 2021; Wang et al., 2016, 2018; H. Zhang et al., 2022), and waste management (Habibi et al., 2017; Herrera-Granda et al., 2019; Mohammadi et al., 2023; Rossit et al., 2017; Tari & Alumur, 2014). In terms of modelling tools, we found that time was explicitly considered in eight papers (Aydin, 2022; Jafarzadeh-Ghoushchi et al., 2023; Khalili et al., 2016; Liu et al., 2019; Mogale et al., 2018; Navazi et al., 2018; Tari & Alumur, 2014; Turan et al., 2021). Uncertainty was included in 16 papers and mainly related to demand which either was assumed to follow a specific distribution, such as Poisson (Pasandideh et al., 2013; Rahmati et al., 2013) or Bernoulli (Shiripour & Mahdavi-Amiri, 2019), or its uncertainty was treated with robust approaches (Carrizosa et al., 2015; Liu et al., 2019; Nazemi et al., 2022). Also the cost parameters were uncertain in Arabzad et al. (2015) and Wang et al. (2018); in Boonmee and Kasemset (2020) all input parameters are uncertain and managed using fuzzy programming. In Navazi et al. (2018), both the number of required facilities and the travel times were uncertain, while Habibi et al. (2017) related this feature to the amount of recyclable and non-recyclable waste. Finally, Chantre and Da Fonseca (2018) addressed uncertainty by modelling the probability of link failure, while the availability of routes was stochastic in Al Ayub Ahmed et al. (2021).

In contrast to the Uncapacitated problems, the use of exact methods was predominant for these problems, with 23 papers proposing an exact method and 14 using a heuristics; both types of approach were chosen

in Nazemi et al. (2022) and Shiripour and Mahdavi-Amiri (2019). Additionally, 10 solution approaches belong to the class of a priori methods (Aydin, 2022; Filippi et al., 2021; Geng et al., 2022; Herrera-Granda et al., 2019; Jafarzadeh-Ghoushchi et al., 2023; Khalili et al., 2016; Paldrak et al., 2023; Praneetpholkrang et al., 2021; Tadros et al., 2018; Tari & Alumur, 2014), three are no preference methods (Arabzad et al., 2015; Habibi et al., 2017; Jamalain & Salahi, 2020), and the remaining are a posteriori methods. This latter trend is aligned with the one observed for the Multi-Objective Location–Allocation Problems. The most common exact methods are: ϵ -constraint (Boonmee & Kasemset, 2020; Carrizosa et al., 2015; Gutjahr & Dzubur, 2016; Izco et al., 2023; Mohammadi et al., 2023; Nazemi et al., 2022; Praneetpholkrang et al., 2021; Rodríguez-Espíndola et al., 2023; Wang et al., 2018; Zhu et al., 2015) and its extended variants, AUGMECON (Shiripour & Mahdavi-Amiri, 2019) and AUGMECON2 (Navazi et al., 2018; Rossit et al., 2017), then Weighted Sum (Aydin, 2022; Filippi et al., 2021; Herrera-Granda et al., 2019), LP-Metric Methods (Arabzad et al., 2015; Habibi et al., 2017; Jamalain & Salahi, 2020) and Goal Programming (Geng et al., 2022; Jafarzadeh-Ghoushchi et al., 2023; Paldrak et al., 2023; Praneetpholkrang et al., 2021). In particular, Filippi et al. (2021) also developed a Benders decomposition to tackle large instances; in addition, Liu et al. (2019) devised an iterative method based on the ϵ -constraint, while the Lexicographic approach is used in Tari and Alumur (2014).

In terms of heuristics, almost half of the papers used both a Genetic Algorithm, mainly NSGA-II (Karimi et al., 2023), and another approach, such as Particle Swarm Optimisation (Chantre & Da Fonseca, 2018), Controlled NSGA-II (Shiripour & Mahdavi-Amiri, 2019), Simulated Annealing (Pasandideh et al., 2013), the Evolutionary Algorithm SEAMO2 (Tang & Zhang, 2015). The latter method is also used by Harris et al. (2014), who also devised a Lagrangean relaxation procedure for the assignment of customers to depots. In addition, Turan et al. (2021) developed a simulation-based procedure using NSGA-II, and Tang et al. (2020) proposed a hybrid Evolutionary Algorithm combining NSGA-II and a greedy procedure. Both an Evolutionary Algorithm and the Multi-Objective Harmony Search approach were used in Rahmati et al. (2013). Afterwards, Mogale et al. (2018) used Non-dominated Chemical Reaction Optimisation. In terms of search-based heuristics, H. Zhang et al. (2022) adopted the Tabu Search algorithm and Song et al. (2021) the *Hill climbing* heuristics. Other heuristic methods adapted in the solution process are the *Dragonfly algorithm* (Al Ayub Ahmed et al., 2021), the Reservation level controlled Tchebycheff procedure (Khalili et al., 2016), and the Particle Swarm Optimisation (Wang et al., 2016).

Discussion and outlook. In conclusion, the extensive body of literature on Multi-Objective Location–Allocation Problems, particularly those involving Fixed Charge Facility Location Problems, highlights their critical role in strategic decision-making across a wide range of domains, including public service provision to humanitarian logistics and private sector operations. A recurring theme in both uncapacitated and capacitated models is the integration of economic objectives with managerial concerns such as service quality, sustainability, accessibility, and operational reliability. While uncapacitated models tend to prioritise quality and equity in service delivery, capacitated models more frequently incorporate detailed logistical cost structures. The adoption of both exact and heuristic solution methods reflects the methodological diversity and complexity of these problems. In particular, a posteriori approaches are valued for their ability to support informed decision-making; furthermore, the prevalence of real-world case studies in this branch of literature emphasises the practical relevance of Multi-Objective Location–Allocation Problems. However, the limited attention given to multi-period and uncertainty in the modelling phase suggests promising avenues for future research.

4.2.6. Multi-objective location–routing problems

Location–Routing Problems (LRPs) are characterised by finite sets of users demanding a service and of facilities providing that service; however, the Location–Allocation decisions do not affect the routing decisions, namely, it is deemed necessary to design the paths of a fleet of vehicles to route users demands to or from the facilities they are assigned. Therefore, for each user, the assignment cost also depends on the route taken by the vehicle serving it. Three decisions have to be made in LRPs which concern the location of facilities, the assignment of users, and the design of vehicle routes (Lopes et al., 2013).

From a managerial perspective, these problems arise when the focus is on minimising service costs, including opening and distribution (i.e. travel) costs. However, both practitioners and researchers often overlook the interrelation between location and routing due to the more complex nature of routing problems and/or the fact that location is a strategic decision while routing occurs at the operational level (Lopes et al., 2013). This trend is also evident in the Multi-Objective Location literature, as only 16.3% of the retrieved papers addressed a Multi-Objective Location–Routing problem.

In addition to the economic aspects related to the installation and distribution of services, the main managerial concerns addressed in this branch of literature are related to *quality of service* and *sustainability*. The authors in Rashvand Falari et al. (2024) focused on delivery time as a measure of the quality of a perishable goods distribution system, while Rahmanifar et al. (2024) aimed at minimising *tardiness* for delivery in a cold chain logistics network. Sustainability and quality of service are jointly addressed in Ghasemi et al. (2021) and in B. Zhang et al. (2018). The former studied the location of launching facilities and charging stations for drone batteries, using covered demand as a measure of service quality. The latter considered the LRP connected to emergency facilities, including CO₂ emissions and route travel times. Similarly, Alamatsaz et al. (2022) and Li et al. (2023) focused on CO₂ emissions due to vehicles stuck in traffic congestion; in general, CO₂ emissions were considered alongside transport costs (Asadi et al., 2018; Aydemir-Karadag & Akdere, 2023; Heidari et al., 2023; Niu et al., 2024) and exploring the benefits of horizontal cooperation in delivery along traffic roads (Ouhader & El Kyal, 2017, 2020, 2023). The quality of service was measured in terms of delivery time to customers (Ghaffari-Nasab et al., 2013a, 2013b; Nekooghadirli et al., 2014), number of customers receiving orders on time (Dharmika et al., 2020), timeliness (Adarang et al., 2020; Bai, 2016; Bozorgi-Amiri & Khorsi, 2016; Hu et al., 2025), demand covered (Cai et al., 2023; Kian et al., 2022). Also, when addressing problems in disaster management, the economic aspects related to service provision were usually combined with the perspective of efficiency, equity or quality of service. For instance, Vahdani et al. (2018a, 2018b) (resp. Long et al. (2021)) considered roads reliability (resp. fairness) when locating distribution centres, Padasht and Razmi (2016) considered demand coverage and *efficiency* in the LRP associated with relief distribution centres, while Coutinho-Rodrigues et al. (2012b) and Sirbiladze et al. (2024) explicitly took into account the issues related to evacuation time and safety of the planned routes. However, other perspectives that were addressed together with the economic one are: profit (Misni et al., 2024; Rabbani et al., 2021), risk mitigation (Rayat et al., 2017; Samanlioglu, 2013; Yu & Solvang, 2016; Zhao et al., 2025; Zhao & Verter, 2015), system reliability (Beiki et al., 2021; Khorsi et al., 2021; Zhang, 2011), completion times (Ghezavati & Beigi, 2016), user satisfaction (Davoodi & Rezaei, 2023; Golmohammadi et al., 2025) and workload balance (Pourhassan et al., 2025). Finally, Multi-Criteria Decision Analysis methods can be used to incorporate multiple qualitative factors into managerial decision-making, alongside their relevance to decision-makers. For this purpose, in Wichapa and Khokhajaikiat (2017b, 2018) infrastructural, geological, social and environmental factors are used to weight the facility sites for the installation of infectious waste disposal centres.

Our analysis confirmed that LRPs have received little attention from practitioners, with less than half of the papers proposing a real-world case study as a validation method. In particular, these case studies are related to waste management (Niu et al., 2024; Rabbani et al., 2021; Samanlioglu, 2013; Wichapa & Khokhajaikiat, 2017b, 2018; Zhao et al., 2025; Zhao & Verter, 2015), green logistics (Alamatsaz et al., 2022; Asadi et al., 2018; Ouhader & El Kyal, 2023), emergency logistics (Bai, 2016; Hu et al., 2025; Long et al., 2021), humanitarian and relief logistics (Bozorgi-Amiri & Khorsi, 2016; Khorsi et al., 2021; Kian et al., 2022; Padasht & Razmi, 2016), shelter location (Coutinho-Rodrigues et al., 2012b) and launch distribution network design (Aydemir-Karadag & Akdere, 2023). Only 19 papers dealt with uncertainty; though mainly related to demand (Adarang et al., 2020; Alamatsaz et al., 2022; Asadi et al., 2018; Hu et al., 2025; Long et al., 2021; Niu et al., 2024; Padasht & Razmi, 2016; Rashvand Falari et al., 2024; Rayat et al., 2017) or travel time alone (Ghaffari-Nasab et al., 2013a), it was also considered for both (Khorsi et al., 2021; Nekooghadirli et al., 2014) and along with costs (Bozorgi-Amiri & Khorsi, 2016; B. Zhang et al., 2018), supply and path availability (Bai, 2016), response time (Zhao et al., 2016), storage capacity (Vahdani et al., 2018a), and service time (Golmohammadi et al., 2025).

Although generally difficult to solve, like classical LRP, almost half of the proposed problems were mainly solved using the ϵ -constraint method (Adarang et al., 2020; Beiki et al., 2021; Bozorgi-Amiri & Khorsi, 2016; Ghasemi et al., 2021; Heidari et al., 2023; Ouhader & El Kyal, 2017, 2020, 2023; Pourhassan et al., 2025; Rahmanifar et al., 2024; Sirbiladze et al., 2024; Zhao et al., 2025). In addition, AUGMECON and AUGMECON2 were adopted in Yu and Solvang (2016) and Rabbani et al. (2021), respectively while the latter implemented also the Lexicographic approach. Goal Programming was used in Bai (2016), Dharmika et al. (2020), Wichapa and Khokhajaikiat (2017b, 2018), Zhao and Verter (2015). In fact, the latter is combined with *Fuzzy AHP* in Wichapa and Khokhajaikiat (2017b, 2018), where this method was used to evaluate several criteria before solving the proposed problem with the a priori Goal Programming approach. Other a priori methods used are the Weighting method (Aydemir-Karadag & Akdere, 2023; Coutinho-Rodrigues et al., 2012b; Samanlioglu, 2013) and the LP metric (Padasht & Razmi, 2016). All the proposed heuristics are a posteriori, with Genetic Algorithms being the most widely used (Alamatsaz et al., 2022; Cai et al., 2023; Ghezavati & Beigi, 2016; Wichapa & Khokhajaikiat, 2017b; Zhang, 2011; B. Zhang et al., 2018). Specifically, Wichapa and Khokhajaikiat (2017b) hybridised genetic algorithm and local search, Li et al. (2023) combined genetic algorithm and Ant Colony, while Alamatsaz et al. (2022) combined *Progressive Hedging Algorithm* with genetic approach and Asadi et al. (2018), Ghezavati and Beigi (2016), Heidari et al. (2023), Pourhassan et al. (2025), Rahmanifar et al. (2024), Vahdani et al. (2018a, 2018b), Zhao et al. (2025) chose NSGA-II. Other heuristics used for this class of problems include the Grey Wolf algorithm (Hu et al., 2025) and different Evolutionary Algorithms (Long et al., 2021; Niu et al., 2024), such as Simulated Annealing (Ghaffari-Nasab et al., 2013b; Rashvand Falari et al., 2024; Rayat et al., 2017), *Shuffled Frog Leaping algorithm* (Adarang et al., 2020), *Find–Fix–Finish–Exploit–Analyse* procedure (Khorsi et al., 2021), and the Multi-Objective variant of the *Imperialist Competitive Algorithm* (Golmohammadi et al., 2025; Hadian et al., 2019; Nekooghadirli et al., 2014). A Particle Swarm Optimisation approach was used in Asadi et al. (2018) and Vahdani et al. (2018a, 2018b). Among the search based procedures: Ghaffari-Nasab et al. (2013a) used the Variable Neighbourhood Descent heuristic, Misni et al. (2024) the Harmony Search, and Kian et al. (2022) designed a *hierarchical metaheuristic* that computes an initial solution by solving the underlying location problem first and then the routing problem, before improving the quality of the solution with a local search. Also, Davoodi and Rezaei (2023) used a local search and C. Wang et al. (2023) proposed a Learning-based search strategy, while Sirbiladze et al. (2024) devised a Machine Learning procedure.

Discussion and outlook. In conclusion, this literature review reveals that, although Multi-Objective Location–Routing Problems offer a more realistic and holistic framework for modelling logistics networks, they have received comparatively less attention than their single-objective counterparts. In particular, real-world applications remain under-represented, with fewer than half of the reviewed studies employing empirical validation through case studies. However, the analysis highlights a growing interest in incorporating quality of service, sustainability, and risk mitigation into Location–Routing problems. Additionally, efficient methods for handling uncertainty relating to demand, travel times, or service conditions appear to offer fertile ground for further exploration.

4.2.7. Multi-objective general network design problems

General Network Design Problems (GNDPs) involve two main types of decisions: *design decisions*, concerning the location of facilities and the activation of links, and *operational decisions*, related to user allocation and the routing of requests (Contreras & Fernández, 2012). The nature of routing decisions depends on the role of facilities which is itself determined by the type of service demand. If the service is provided at/from the facilities, the focus is on connecting users to their assigned facilities; if, on the other hand, the service demand is between users and the facilities are intermediate locations, the design and routing decisions aim to establish connections between users and facilities, and among the facilities themselves. Both *Facility Location–Network Design* (FLND) and Location–Routing problems belong to the former typology, while *Hub Location* problems belong to the latter.

Multi-objective facility location–network design problems. One of the main differences between these problems and those of Location–Routing (cf. Section 4.2.6) lies in the characteristics of the routes, which for the former are simple paths and for the latter are circuits rooted in the located facilities (Contreras & Fernández, 2012). Clearly, the managerial context in which FLND problems arise relates to the costs of installing and operating the service, which include: the costs of setting up the facilities and the links, and the operational costs associated with user assignment and transport. Thus, Supply Chain Network Design problems are FLNDs with additional constraints.

In the Multi-Objective literature, FLND received a great deal of attention, accounting for 22.6% of the retrieved papers: 54 papers addressed one of these problems in the reference period, 25 of which dealt with supply chain design (Amin-Tahmasbi et al., 2022; Anvari & Turkay, 2017; Becerra et al., 2024; Brahami et al., 2022; Caramia & Pizzari, 2023; Das et al., 2021; Farrokhzadeh et al., 2021; Gital Durmaz & Bilgen, 2020; Hajipour et al., 2021; Izadian et al., 2024; Jaigirdar et al., 2023; Jain et al., 2022; Kim et al., 2024; Maliki et al., 2022; Mohammed et al., 2017; Mohebalizadehgashti et al., 2020; Nguyen et al., 2023; Pishvae & Razmi, 2012; Rahbari et al., 2023; Ransikarbum & Pitakaso, 2024; Sæterbø et al., 2023; Safari et al., 2024; Savoji et al., 2022; Sepehri et al., 2024; Seydanlou et al., 2022).

The opening costs of facilities and/or connections were considered in most Multi-Objective FLND papers together with (part of) the logistics costs (e.g. inventory, maintenance, service operation or transport costs); this is consistent with the managerial context giving rise to FLND problems. In particular, these concerns are combined with those related to the *environmental impact* or the *quality* of the service provided by the designed network, or its *sustainability*. More specifically, the environmental impact associated with a supply chain network is measured by a score assigned to suppliers in Amin-Tahmasbi et al. (2022) and Safari et al. (2024), while Anvari and Turkay (2017) considered resource consumption, air pollution from transport, water and soil pollution. In addition, the former evaluated the *efficiency* of the designed supply chain as done in Pishvae and Razmi (2012), while the latter measure its *social benefit*, related to employment opportunities, regional development and security levels as in Seydanlou et al. (2022). The environmental impact is related to the obnoxiousness of the waste

transfer stations located in the FLND addressed in Chen et al. (2021) and Ratković et al. (2022), and those of the municipal solid waste facilities in Duan et al. (2024) and Olapiriyakul (2017), where also CO₂ emissions from waste transport activities were considered. Finally, this impact is related to the pollution for people living around the bio-refineries in Hong and Mwakalonge (2020), and is accounted along with the resilience and productivity of the network. Indeed, sustainability is a very important issue in the implementation of a logistics network; in this respect, several contributions considered the minimisation of CO₂ emissions (Becerra et al., 2024; Brahami et al., 2022; Caramia & Pizzari, 2023; Das et al., 2021; Fan et al., 2023; Kim et al., 2024; Lin et al., 2020; Maliki et al., 2022; Mohebalizadehgashti et al., 2020; Mohsenizadeh et al., 2020; Nguyen et al., 2023; Olapiriyakul, 2017; Ransikarbum & Pitakaso, 2024; Sæterbø et al., 2023; Savoji et al., 2022; Sepehri et al., 2024; Tosarkani & Amin, 2020; Vansia & Dhodiya, 2021) or greenhouse gas emissions (Zaeimi & Rassafi, 2021) due to transport activities. The other major concern in the design of a service network, i.e. the *quality of service* provided, was expressed in terms of the (percentage of) demand met (Afshari et al., 2014a, 2016, 2014b; Chen & Lai, 2022; Mohammed et al., 2017; Shishebori et al., 2016), the worst case service level (Hong & Mwakalonge, 2020), or the amount of undamaged supply sent (Hajipour et al., 2021). Additionally, different aspects of the provided service were considered in the Multi-Objective FLND literature, such as: reliability (Izadian et al., 2024; Tarôco et al., 2016), efficiency (Diglio et al., 2024; Farrokhzadeh et al., 2021; Rahbari et al., 2023) and timeliness (Jaigirdar et al., 2023; Jia et al., 2023; Sun & Liu, 2021) or a combination of the latter two (P. Zhang et al., 2022). Finally, a few contributions addressed the economic concern in terms of *profit* related to the provision of the service by eventually combining it with: sustainability (Chang et al., 2021; Xu et al., 2022), quality of service as travel costs/distances (Gital Durmaz & Bilgen, 2020; Xu et al., 2022), social benefit (Bal & Badurdeen, 2020; Becerra et al., 2024; Dong et al., 2023; Jin et al., 2018; Kim et al., 2024) or system-related qualitative criteria (Raad & Rajendran, 2024).

This analysis showed that the Multi-Objective FLND problems mostly arose from real-world contexts; in fact, 24 out of 54 papers used a case study as a validation method. These problems were related to: disaster management (Chen & Lai, 2022; Sun & Liu, 2021; P. Zhang et al., 2022), distribution network design (Afshari et al., 2014a; Izadian et al., 2024; Jain et al., 2022; Jia et al., 2023; Shishebori et al., 2016), reverse logistics and circular economy (Afshari et al., 2016, 2014b; Bal & Badurdeen, 2020; Chang et al., 2021), supply chain network design (Anvari & Turkay, 2017; Diglio et al., 2024; Farrokhzadeh et al., 2021; Gital Durmaz & Bilgen, 2020; Jaigirdar et al., 2023; Mohammed et al., 2017; Mohebalizadehgashti et al., 2020; Nguyen et al., 2023; Pishvae & Razmi, 2012; Rahbari et al., 2023; Ransikarbum & Pitakaso, 2024; Sæterbø et al., 2023), and waste management (Chen et al., 2021; Dong et al., 2023; Duan et al., 2024; Mohsenizadeh et al., 2020; Olapiriyakul, 2017; Ratković et al., 2022; Tosarkani & Amin, 2020; Zaeimi & Rassafi, 2021).

Regarding the modelling tools, 22 papers included the time component, mainly when designing supply chain networks (Amin-Tahmasbi et al., 2022; Becerra et al., 2024; Das et al., 2021; Farrokhzadeh et al., 2021; Gital Durmaz & Bilgen, 2020; Hajipour et al., 2021; Kim et al., 2024; Maliki et al., 2022; Mohebalizadehgashti et al., 2020; Rahbari et al., 2023; Safari et al., 2024; Savoji et al., 2022; Sepehri et al., 2024; Seydanlou et al., 2022) and specific logistics networks (Afshari et al., 2014a, 2016, 2014b; Izadian et al., 2024; Jin et al., 2018; Sun & Liu, 2021; Tosarkani & Amin, 2020; Zaeimi & Rassafi, 2021). However, only 17 papers dealt with uncertainty: apart from time-varying demand (Afshari et al., 2016, 2014b; Farrokhzadeh et al., 2021; Izadian et al., 2024; Kim et al., 2024; Maliki et al., 2022; Pishvae & Razmi, 2012; Raad & Rajendran, 2024; Rahbari et al., 2023; Ransikarbum & Pitakaso, 2024; Savoji et al., 2022), supply availability (Diglio et al., 2024; Ransikarbum & Pitakaso, 2024) uncertainty of variable costs (Kim et al., 2024), also alongside capacities of resources appeared in Pishvae and

Razmi (2012), Rahbari et al. (2023) and Tosarkani and Amin (2020), while several forms of environmental uncertainties were addressed in Lin et al. (2020), of recycling quantity and ratio of echelon use in Fan et al. (2023) and of disaster consequences on road availability and conditions in P. Zhang et al. (2022). Finally, it is worth noting that all papers dealing with Supply Chain Network Design have been published since 2017, which shows how recent the use of this modelling scheme is in the field and suggests a possible upward trend.

Although NP-hard as their single objective counterpart, the Multi-Objective FLND Problems were solved mainly with an exact method: ϵ -constraint (Caramia & Pizzari, 2023; Dong et al., 2023; Mohammed et al., 2017; Mohsenizadeh et al., 2020; Raad & Rajendran, 2024; Sepehri et al., 2024; Zaeimi & Rassafi, 2021) and its augmented (Anvari & Turkay, 2017; Bal & Badurdeen, 2020; Farrokhezadeh et al., 2021; Gital Durmaz & Bilgen, 2020; Izadian et al., 2024; Mohebalizadehgashiti et al., 2020; Savoji et al., 2022) and interactive fuzzy version (Pishvae & Razmi, 2012). Indeed, the ϵ -constraint scheme is used a framework for an iterative heuristics in Tosarkani and Amin (2020); in addition, we found that seven case studies were approached with a priori methods, namely Weighting method (Afshari et al., 2014a; Jaigirdar et al., 2023; Ransikarbum & Pitakaso, 2024), Lexicographic optimisation (Ratković et al., 2022) and Goal Programming (Hong & Mwakalonge, 2020; Jain et al., 2022; P. Zhang et al., 2022), most likely because it was necessary to consider the preferences of the decision-makers in solving the underlying problems. *Compromise Programming* was used both as a solution method (Mohammed et al., 2017; Olapiriyakul, 2017; Safari et al., 2024) and as a basis for a heuristic approach (Das & Roy, 2019). It is worth mentioning that in Olapiriyakul (2017) three well-known DEA methods were adopted to evaluate the network design obtained, and that Fan et al. (2023) proposed an exact interactive method based on fuzzy planning with priority control. Finally, a commercial solver was used in three papers (Diglio et al., 2024; Kim et al., 2024; Nguyen et al., 2023).

Genetic Algorithms are widely used to solve the Multi-Objective FLNDs (Afshari et al., 2016, 2014b; Jin et al., 2018), mainly NSGA-II (Brahami et al., 2022; Duan et al., 2024; Maliki et al., 2022; Sæterbø et al., 2023; Tarôco et al., 2016; Vansia & Dhodiya, 2021; Xu et al., 2022). Other well-known heuristics adapted are: Artificial Bee Colony (Sun & Liu, 2021), Evolutionary Algorithm (Jia et al., 2023), Particle Swarm Optimisation (Amin-Tahmasbi et al., 2022; Chang et al., 2021), Simulated Annealing (Chen & Lai, 2022; Chen et al., 2021; JabalAmeli & Mortezaei, 2011; Seydanlou et al., 2022), and Vibration Damping Optimisation (Amin-Tahmasbi et al., 2022; Hajipour et al., 2021). In particular, the hybrid approach in JabalAmeli and Mortezaei (2011) consisted of two stages: the first one dealing with the location and network design decisions, taken with a Simulated Annealing approach, and the second with the allocation ones taken by solving a transportation problem. Instead, the hybrid algorithm in Chang et al. (2021) combined Particle Swarm Optimisation with a *gravitation* approach. Furthermore, the *locate-allocate* heuristics was combined with fuzzy programming in Das et al. (2021) and with *Compromise Programming* in Das and Roy (2019). Finally, Seydanlou et al. (2022) devised a hybrid approach combining Electromagnetism-like Algorithm and Genetic Algorithm.

Multi-objective hub location problems. These problems mainly arise in telecommunication or transportation contexts, where the hub facilities are intermediate locations that aim to efficiently route flows between origins and destinations (Contreras & Fernández, 2012). In fact, the hubs can act as *transshipment* points if they allow flows to be processed and sent to destinations with fewer links, and as *consolidation* points if they allow the aggregation/disaggregation of flows, thus leading to economies of scale (Nickel et al., 2019). Once the hub locations are known, the routing decisions lead to the definition of the shortest paths between origins and destinations. This may result in a *multiple allocation* scheme of users to hubs. Therefore, when explicitly stated, the *single*

allocation hypothesis requires that all demands from the same origin or to the same destination are routed through the same hub (Nickel et al., 2019). The managerial rationale behind Hub Location problems is clearly economic; though in practice, it has rarely been combined with different perspectives, as evidenced by the fact that only 11 of 288 analysed papers addressed a Multi-Objective Hub Location Problem. All but Babaei et al. (2025) and Bashiri and Rezaeezad (2015) combined the managerial economic perspective with exactly one other, related to *resilience* (Bi et al., 2016; Parvaresh et al., 2014; Ramamoorthy et al., 2024), *quality of service* (Kaveh et al., 2021; Maharjan & Hanaoka, 2018; Masoumzadeh et al., 2016), *accessibility* (Eydi & Saghez, 2024) or *sustainability* (Kanzian et al., 2013).

Specifically, in Bashiri and Rezaeezad (2015), the Multi-Objective p-Hub Covering Location Problem combines opening and transport costs with system reliability and travel time. Instead, Bhattacharjee and Mukhopadhyay (2021) considered a Hierarchical Hub Facility Location Problem, assuming the presence of central and transshipment hubs, and focusing on maintenance and communication costs between these different types of facilities. Bi et al. (2016) defined a Bi-Objective Hub Location Problem to design a *power projection network* in which the troops are first consolidated at transportation hubs and shipped between them, then they are deployed to dispersed areas as needed. In this case, the transport costs under worst case conditions measures the resilience of the designed network. Similarly, in the multiple allocation scheme, Parvaresh et al. (2014) included *risk mitigation* aiming to identify the hubs that, if intentionally disrupted, would be most likely to increase the transport costs. Similarly, Ramamoorthy et al. (2024) addressed the strategic design of a hub network to mitigate disruption risks through hub dispersion. Mobile hubs were considered in the Bi-Objective problem detailed in Eydi and Saghez (2024) to improve quality and level of response to demands. The analysis also revealed that the single allocation hypothesis was adopted in three papers (Bashiri & Rezaeezad, 2015; Bhattacharjee & Mukhopadhyay, 2021; Bi et al., 2016), while the rest opted for more flexible network structures. Masoumzadeh et al. (2016) proposed a p-hub location and protection model with backup hubs to design a network protection scheme, and measured the quality of service by considering the minimum potential flows between all origin-destination pairs. Instead, in Maharjan and Hanaoka (2018), the quality of service was measured by considering the uncovered demand when locating temporary logistics hubs during disaster response. Finally, for the design of a sustainable forest energy supply network, profit and sustainability were combined in Kanzian et al. (2013), while Kaveh et al. (2021) addressed the design of a public transport network in Iran.

In terms of solution methods: Bashiri and Rezaeezad (2015) used the a posteriori ϵ -constraint algorithm, Ramamoorthy et al. (2024) proposed cutting plane and accelerated Benders decomposition procedures, and the remaining four exact methods are a priori: Weighting method (Kanzian et al., 2013; Maharjan & Hanaoka, 2018), Goal Attainment (Eydi & Saghez, 2024) and Fuzzy Goal Programming (Masoumzadeh et al., 2016). In particular, to determine the weights of the objective functions, Maharjan and Hanaoka (2018) proposed a fuzzy factor rating system under the group decision-making condition. Among the heuristics, Babaei et al. (2025), Bhattacharjee and Mukhopadhyay (2021), Bi et al. (2016) and Eydi and Saghez (2024) used the NSGA-II algorithm, while Parvaresh et al. (2014) proposed Multi-Objective version of Simulated Annealing and Tabu Search heuristics and Babaei et al. (2025), Eydi and Saghez (2024) and Kaveh et al. (2021) adapted the Particle Swarm Optimisation scheme.

Discussion and outlook. Multi-Objective FLND is a research field with significant real-world applications. Indeed, these problems build upon traditional Location-Routing models by incorporating installation, operational and assignment costs alongside additional sustainability, environmental impact and service quality objectives. The literature shows an increasing focus on environmental and social considerations, particularly in the context of supply chains and waste management. Notably,

Table 8

Number of occurrences of the managerial objectives identified in the papers reviewed and their relative percentage of occurrence in the sample of papers.

Managerial objective	# occ.	% occ.	Managerial objective	# occ.	% occ.	Managerial objective	# occ.	% occ.
Opening Costs	96	33.3%	User Satisfaction	14	4.9%	Maintenance Costs	4	1.4%
Quality of Service	65	22.6%	Profit	13	4.5%	Resilience	4	1.4%
Logistics Network costs	59	20.5%	Safety	11	3.8%	Evacuation Time	3	1.0%
Efficiency	49	17.0%	Social Utility	11	3.8%	Fairness	3	1.0%
CO ₂ emissions	41	14.2%	Travel Time	11	3.8%	Lead Time	3	1.0%
Transport Costs	35	12.2%	Accessibility	10	3.5%	Cannibalisation	2	0.7%
Coverage	34	11.8%	System Productivity	10	3.5%	Energy Consumption	2	0.7%
Operating Costs	34	11.8%	Allocation Costs	9	3.1%	Gas emissions	2	0.7%
Supply Chain Costs	29	10.1%	Risk Mitigation	9	3.1%	Quality of products	2	0.7%
Environmental Impact	25	8.7%	Travel Distance	8	2.8%	Robustness	2	0.7%
Equity	20	6.9%	Qualitative Criteria	7	2.4%	Data Analysis	1	0.3%
System Reliability	18	6.3%	Competitiveness	5	1.7%	Makespan	1	0.3%
Effectiveness	14	4.9%	Workload Balance	5	1.7%	Public Engagement	1	0.3%

the percentage of contributions related to case studies reflects an attempt to link theoretical modelling with practical relevance. Similarly, within the more specific field of Multi-Objective Hub Location Problems, economic concerns remain central, but objectives such as resilience, accessibility, and sustainability are also being integrated, albeit to a lesser extent. The growing interest in these problems, as evidenced by recent publications and methodological diversification, suggests fertile ground for future research, particularly given the increasing systemic uncertainties and demand for sustainable logistics solutions.

5. Discussion

Although the MOFLPs have received a great deal of attention due to their usefulness in decision-making processes and their theoretical relevance, there is still a lack of contributions that comprehensively illustrate the state of the art. In fact, the existing reviews on this topic (cf. Section 2) are characterised by a limited perspective and fail to capture all the characteristics that have not yet been, or have not been sufficiently, considered. They also provide little information about the managerial context in which the conflicting objectives arise and give rise to the Multi-Objective nature of the resulting problems. Therefore, this systematic review aims to fill these gaps, by assessing the state of the art of MOFLPs in terms of modelling and solution approaches, as well as in terms of managerial concerns underlying the corresponding problems.

The review showed a growing interest in Multi-Objective approaches to Facility Location problems since 2016. In addition, the majority of contributions are related to four macro areas, namely *Computer Science*, *Decision Sciences*, *Engineering*, *Mathematics*, and scientific interest in MOFLPs, particularly in the areas of *Energy* and *Decision Sciences*, has increased since 2017. This finding suggests a growing awareness of the suitability of this class of approaches to support current real-world decision processes involved in the provision of specific services by taking into account the interests of the various stakeholders.

In fact, in the majority of the 288 papers analysed, the managerial context giving rise to the Multi-Objective problems involves the combination of an economic perspective, related to the installation of the service, with another one related to its provision, e.g. *accessibility*, *equity*, *quality*, *reliability*, *user satisfaction*; this emerges from Table B.1 that shows the managerial context of the revised papers, excluding those related to mathematical or algorithmic exploration. In addition, Table 8 shows the number of occurrences of the managerial objectives addressed: it is not surprising that the *opening*, *operating* and *transport costs*, as well as the *quality of the service* are the most frequent. There is also a strong emphasis on sustainability concerns such as *CO₂ emissions* and *environmental impact*, but also *energy consumption* and *gas emissions*. Indeed, the MOFLP literature also focuses on these aspects since they represent extremely urgent issues. On the other hand, these data suggest that objectives related to uncertainty and fairness have received little attention possibly because of computational scalability issues and constraints on data availability.

5.1. Modelling and solution strategies

The qualitative analysis revealed that MOFLPs are mainly discrete problems or problems defined on a network; in fact, 52.1% of the papers addressed a Multi-Objective version of a network-based Location problem, while 6.6% of them addressed a continuous MOFLP. In addition, 83.5% of problems on discrete space (resp. 64.2% of problems on network) rely on linear mathematical programming formulations.

The analysis of the solution methods used to obtain full or even approximate Pareto Sets for the resulting problems showed that almost 49% of the papers used a heuristic approach, while exact methods were preferred in 44.1% of them, mainly to solve Center and Covering problems. Indeed, an approximation of the Pareto Set through heuristic methods was strongly preferred if tackling General Network Design, Location–Allocation, and Location–Routing problems, due to their inherent complexity. Additionally, heuristic approaches were adopted in 53.7% of papers published between 2021 and 2025. This suggests a growing tendency to address larger and more complex MOFLP instances, for which exact methods become computationally impractical.

Exact algorithms predominantly feature in papers that address MOFLPs defined in discrete spaces or networks and described through linear formulations. This suggests a relatively well-established methodological approach. Conversely, the growing complexity of nonlinear formulations corresponds with an increased reliance on heuristic solution approaches, reflecting the scalability challenges associated with more complex representations of real-world systems.

The structure of the resulting Pareto sets is influenced by modelling assumptions. Problems characterised by strongly conflicting objectives, such as economic and environmental objectives, or economic and efficiency objectives, frequently employ evolutionary heuristics to approximate diverse efficient solutions. In contrast, formulations with weakly conflicting objectives often rely on ϵ -constraint and scalarisation techniques. These patterns indicate that the selection of algorithms in MOFLPs is largely shaped by the complexity of the decision space and the intensity of objectives conflict, rather than methodological preference alone.

Finally, 73.3% of the solution methods belong to the class of *a posteriori* approaches, indicating that in several contexts decision-makers prefer to use the knowledge of the full set of alternatives to make more informed decisions. However, in some specific managerial contexts, an a priori knowledge of the decision-maker's preferences may be necessary to obtain the set of efficient alternatives. In fact, the *a priori* approaches seem to be useful when dealing with Anti-Covering and Covering Location problems, as well as with Location–Routing problems.

5.2. Case studies, policy-making perspectives and implementation challenges

The review shows that nearly half of the selected papers validate their models through real-world case studies. As well as serving as illustrative applications, these case studies provide insight into the

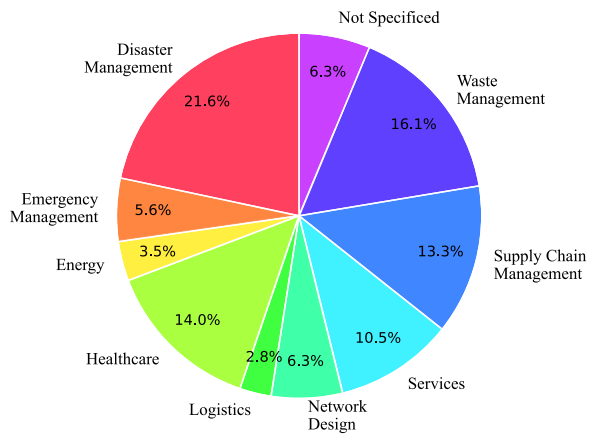


Fig. 8. Sectors for the 143 case studies.

contexts in which MOFLPs are intended for use by managers or policymakers. This section therefore examines their geographical distribution and areas of application, critically analysing the extent to which policy-making perspectives are embedded and implemented within the modelling frameworks.

The application-oriented MOFLPs are predominantly investigated through case studies located in China, Iran, and Turkey, and mainly focus on Disaster Management, Healthcare, and Waste Management applications (cf. Fig. 8).

One possible explanation for the strong presence of contributions related to disaster management operations is the high exposure of certain countries to natural hazards. For instance, China recorded the highest global *exposure score* in both 2022 and 2023 (Hilft & IFHV, 2022, 2023). Such exposure has encouraged significant attention to disaster preparedness and emergency planning, which is reflected in the number of papers proposing Facility Location models for disaster response and relief logistics. Similarly, countries such as Iran and Turkey face substantial seismic risk, which are coupled with infrastructural fragility, limited institutional capacity, and socio-economic vulnerabilities which can amplify the impact of natural disasters, particularly earthquakes (Ghasemi et al., 2020; Seddighi & Salmani, 2019). In response to these challenges, researchers in these countries have devoted considerable effort to developing strategies to advance disaster response, resource allocation, and overall system resilience. A comparable pattern emerges in the area of Waste Management. Most case studies related to Waste Management infrastructure are conducted in Iran. This may be explained by the increasing pressure on national Waste Management systems: Iran is the 17th largest producer of waste worldwide, yet less than 20% of this waste is currently recycled (Bakhtiari, 2021). These conditions make the optimisation of waste collection and treatment infrastructure a particularly relevant research topic.

From a methodological perspective, most case studies are used as validation tools to illustrate model behaviour under realistic data, rather than as instruments supporting actual implementation. Regarding decision-making perspectives, the majority of case studies (48%) implicitly target system and infrastructure planners or operational decision makers, with the remaining contributions evenly split between network designers and supply chain planners. Only a limited subset of case studies explicitly adopts a policy-making perspective. Overall, 51 papers out of 143 incorporate policy-related elements, of which 28 include *explicit* policy mechanisms, such as regulatory constraints, public mandates, or normative allocation rules, while the remaining 23 embed socially or environmentally oriented objectives without linking them to specific policy instruments. Explicit policy-making perspectives emerge predominantly in case studies related to Disaster

Management and Healthcare infrastructure planning. However, even in these contexts, policy considerations are mostly embedded as general normative objectives, such as equity and timeliness (Bozorgi-Amiri & Khorsi, 2016; Coutinho-Rodrigues et al., 2012b; Fazli, 2024; Geng et al., 2022; Maharjan & Hanaoka, 2018, 2020; Mohammadi et al., 2016; Praneetpholkraeng et al., 2021; Rico et al., 2024; Xue et al., 2022), or accessibility (de Campos et al., 2024; Mendoza-Gómez & Ríos-Mercado, 2022; Song et al., 2021; Wang et al., 2016; Zhang et al., 2016; H. Zhang et al., 2022) rather than being expressed through explicit regulatory constraints. Analogously, the case studies related to the installation of Waste Management infrastructures (Duan et al., 2024; Olapiriyakul, 2017; Pasandideh et al., 2013; Rossit et al., 2017) and the design of Supply Chain networks implicitly encompass policy-making elements concerned with environmental impact and sustainability.

These findings suggest that, while MOFLP models are frequently tested using realistic data, they are primarily employed for illustrative purposes rather than for practical applications. The limited incorporation of explicit policy instruments and the lack of documented adoption strategies highlights significant implementation barriers. They may originate from the computational complexity of large-scale Multi-Objective formulations, which may conflict with the time constraints and administrative requirements of public decision-making processes. In addition, in politically sensitive domains, such as healthcare or waste management where decisions directly affect communities, the availability of large sets of alternative configurations may even exacerbate decision complexity. Indeed, these real-world decision contexts involve multiple stakeholders whose preferences are difficult to identify and formalise. These observations suggest that the gap between modelling and actual implementation is a key area for future research in the field of MOFLPs, as it will be thoroughly discussed in Section 5.3.

5.3. Gaps and research agenda

The content analysis of the 288 selected papers identified several research gaps related to modelling and methodological aspects as well as management objectives addressed so far. Addressing these gaps could lead to more effective Multi-Objective methodologies. Practitioners could also benefit by developing service systems that are better equipped to handle diverse needs and unexpected disruptions. We next discuss these gaps and provide research guidelines, separating the considerations that apply to Multi-Objective Facility Location Problems in general (Section 5.3.1) from the observations and suggestions related to application-oriented MOFLP (Section 5.3.2). The research gaps identified in this review, together with suggestions for future lines of investigation, are summarised in Table 9.

5.3.1. Theoretical level

An apparent shortcoming of the MOFLP literature is the limited development of tailored solution methods. Indeed, the vast majority of both exact and heuristic approaches used to obtain (an approximation of) the Pareto Sets of the corresponding problems are adaptations of well-established frameworks. Among the exact ones, the most used are *Goal Programming* and *Weighted Sum* for the a priori class, and *Lexicographic* and (*augmented*) ϵ -constraints for the a posteriori class. Also, more than 90% of the proposed heuristics are actually meta-heuristics, either *evolutionary-based* and *nature-inspired* (Particle Swarm, Simulated Annealing), or *trajectory-based* (Iterated Local Search, Tabu Search, Variable Neighbourhood Search) (Blum & Roli, 2003). While these methods are sound, relying on them exclusively is restrictive. They often overlook those specific mathematical properties of problems that could lead to more efficient solution approaches. Therefore, the design of tailored methods is crucial to extend the knowledge of Multi-Objective approaches and to improve the scalability of the solution processes. A first promising way to fill this gap is to develop exact methods based on *search region decomposition*, that are more output-aware. In fact, they identify and efficiently update the part of the objective space

Table 9
Summary of research gaps and related research directions.

Gap	Suggested line of research
Limited proposal of tailored solution methods [Theoretical Level]	Development of tailored exact and heuristic procedures that follow promising trends
Limited explicit integration of uncertainty in MOFLP [Theoretical Level]	Identification of appropriate uncertainty representations and development of quantitative methods
Limited attention to fairness concerns [Theoretical Level]	Development of metrics to quantify fairness and better integration of fairness into the managerial context and models
Lack of post-optimisation analysis of Pareto Sets [Theoretical/Practical Level]	Application and further development of techniques to determine representative sets of efficient solutions
Limited integration of Multi-Criteria Decision Analysis methods for pre- and post-processing aims [Theoretical/Practical Level]	Better integration of tools to display the relevance levels of qualitative factors for decision-makers and evaluate efficient solutions
Lack of considerations of behavioural Operational Research aspects [Theoretical/Practical Level]	Exploration of aspects related to <i>behaviour in models</i> and <i>behaviour with models</i> in MOFLPs models
Lack of considerations of resilience aspects [Practical Level]	Exploration of the effective integration of more uncertainty-aware and adaptive strategies
Lack of Multi-Objective approaches to Supply Chain Network Design problems [Practical Level]	Development of models and methods to accurately address the inherent challenges of efficient supply chain design
Lack of extensive industrial applications in key sectors [Practical Level]	Development of Multi-Objective models and methods to address facility location planning for Public Services and Economics
Fragmented exploration of emerging paradigms [Practical Level]	Formulation of Multi-Objective Facility Location Problems integrating economic, service, and sustainability objectives

in which the efficient solutions not yet obtained could lie (Dächert et al., 2017; Klamroth et al., 2015). In addition, it has recently been observed that a tailored matheuristic procedure can overcome the performance of the exact approaches while providing a high-quality approximation of the relevant Pareto Sets for large instances (Fugaro & Sgalambro, 2023; Nazemi et al., 2022). Consequently, we believe that tailored matheuristics should also be considered as a means of addressing this gap.

In the modelling field, we observed a limited consideration of *uncertainty* that can affect different aspects of service provision. In fact, only 30.5% of the collected papers explicitly addressed uncertainty, typically using it as a modelling tool, which mainly results in *robust* or *expected value* models. Moreover, uncertainty is generally only considered for parameters subject to unpredictable variation, such as demand. However, little attention has been paid to the uncertainty arising from disruptions or predictable events with unpredictable effects (e.g. natural disasters and man-made disruptions). Ignoring uncertainty inevitably leads to service delivery configurations which lack both efficiency and effectiveness and are therefore unrealistic and of limited practical use. This represents a significant gap in the current MOFLP literature due to the lack of models that appropriately represent different types of uncertainty, such as probability distributions, uncertainty sets, or scenarios with no prior information.

In the managerial context, this review highlights a gap concerning the integration of fairness, also referred to as *equity*, into service delivery models. In fact, equity or fairness appears as a managerial objective in fewer than 8% of the papers (cf. Table 8). Nevertheless, as the recent focus in Decision Sciences indicates, it is a crucial aspect to consider when making strategic decisions about service provision, especially in cases where resources are limited, such as monetary budget or physical materials, which must be allocated to entities with different characteristics. One commonly adopted approach is the *Rawlsian model*: it prioritises the well-being of the worst-off entities, in line with Rawls' theory (Rawls, 1971), by maximising the amount of resources they receive or ensuring a minimum threshold is met (Dönmez et al., 2022). In particular, fairness is a key factor when planning humanitarian logistics operations, providing healthcare services to rural and urban populations (Chanta et al., 2014), dealing with ambulance planning for emergency medical services (Abreu et al., 2025), or analysing the complexities of supply chain design (Choi & Messinger, 2016). In these contexts, it is essential to establish measures that assess whether decisions are made fairly for all stakeholders, and to incorporate these

either as constraints or as objectives within the corresponding optimisation models, depending on the decision-making contexts. In general, MOFLP models for Disaster, Emergency, Healthcare and Supply Chain Management would benefit from a more holistic approach that considers equity alongside efficiency and quality of service delivery. Developing specific metrics to quantify fairness would not only enhance the accuracy of modelling in these domains, but also offer a broader contribution to the literature on equity concerns.

Finally, this review highlights that behavioural aspects of Operational Research (OR) remain largely absent from MOFLP formulations, with limited integration of considerations related to both *behaviour in models* and *behaviour with models* (cf. Kunc et al. (2020)) in the analysed literature. Specifically, the analysis reveals a marginal treatment of behavioural aspects in MOFLPs applied to Disaster Management, Waste Management, and Service Provision System Planning, both in terms of how human behaviour is represented within optimisation models and how decision makers and users may respond to model-supported decisions. Only 12.1% of the collected papers introduce modelling tools that account for customer preferences, behaviours, or satisfaction levels. This lack of behavioural considerations represents a notable theoretical gap, rooted in the modelling assumptions underlying MOFLPs, which in turn constrains their practical applicability and policy relevance. However, recent studies extend Facility Location formulations by integrating customer behavioural preferences to better capture demand choice mechanisms, service attractiveness, and user-driven allocation processes (Guerrero-Lorente et al., 2020; Kang et al., 2023), thereby moving beyond traditional distance-based assumptions and opening new directions for behaviour-aware MOFLP modelling. Therefore, addressing both dimensions of behavioural OR within MOFLPs appears essential to enhance the contribution of Multi-Objective approaches to real-world decision-making and human-centred problem solving (Franco & Hämäläinen, 2016).

5.3.2. Practical level

Despite the significant number of case studies identified in the MOFLP literature analysed, we feel that in most situations the proposed contributions do not provide effective support to the relevant decision-makers. Multi-Objective tools often generate large sets of alternatives that are difficult for practitioners to interpret, especially when analysing complex trade-offs (Antipova et al., 2015). However, the MOFLP literature lacks the application of techniques capable of reducing the cardinality of the Pareto Sets obtained and/or supporting the

evaluation of the set of alternatives. Therefore, we believe that the academics interested in the topic should devote effort to the adaptation of existing techniques, e.g. *clustering* (Kahagalage et al., 2023; Seyedashraf et al., 2023) and *ranking* (Brownlee & Wright, 2012) methods, as well as the development of novel approaches to identify the similarities between solutions and thus select a set of alternatives capable of representing the entire Pareto Set. Additionally, the evaluation of efficient solutions could benefit from the application of Multi-Criteria Decision Analysis (MCDA) methods (Erdogan et al., 2021; Jing et al., 2018; Z. Wang et al., 2022). Indeed, the post-optimisation analysis could improve the applicability and effectiveness of the academic results in the field of MOFLP.

Another relevant methodological gap is the limited integration of MCDA methods in Multi-Objective approaches, particularly at the pre-processing stage. Indeed, the use of these methods could be instrumental in representing various levels of relevance of qualitative factors from the perspective of decision-makers. However, we found only five papers in the reference period that employed MCDA as a pre-processing technique to evaluate the weights applied in the selected a priori approach. A major criticism of a priori methods is the difficulty in quantifying stakeholder preferences, especially when objectives conflict (Mavrotas, 2009). Therefore, traditional Multi-Objective Optimisation tools should be combined with methods from the Multi-Criteria Decision Analysis literature in order to improve, for example, the evaluation process of candidate locations based on qualitative criteria, thus incorporating the information about the stakeholders' preferences into the solution process. Such integration could enable the systematic inclusion of both subjective and objective factors in the decision process (Sanchis et al., 2008).

Furthermore, the MOFLP models proposed in the literature fail to adequately address the need to consider *resilience* in the planning of service provision. Indeed, together with equity, these are key factors for the efficient and effective design of new infrastructure, as evidenced by the strong emphasis on these issues in the 9th and 11th Sustainable Development Goals (ONU, 2015), which call for action to "build resilient infrastructure" and "make cities and human settlements inclusive, safe, resilient and sustainable" respectively. In addition, following the outbreak of the Covid-19 pandemic, the robustness of a supply chain has become crucial to ensuring its survival against unexpected disruptions, as evidenced by the high percentage of companies investing in strategies to strengthen theirs (WTO & Bank, 2021). This seems to suggest the need for a more comprehensive approach to assess the effectiveness of service delivery in a wide range of contexts, from humanitarian aid operations (Akbari & Shiri, 2022; Farahi & Salimifard, 2021; Shiri et al., 2023) to supply chain management (Simchi-Levi et al., 2014, 2018). As highlighted in Section 5.3.1, it is important to explore the effective integration of more uncertainty-aware and adaptive strategies to bridge this gap and improve overall resilience.

Another gap is the limited use of Multi-Objective tools in Supply Chain Network Design. In fact, 8.7% of the reviewed papers considered a MOFLP in this context, half of them in relation to a real case study. This is also a rather recent trend, as these papers cover the period from 2017 to 2024. However, advanced MOFLP models could provide valuable support in accurately modelling the different aspects involved in the efficient design of such infrastructures. Notably, multiple stakeholders are involved in the activities of designing, planning and operating a supply chain; moreover, various factors such as efficiency, resilience, sustainability, and workload balance have to be taken into account when making the relevant decisions (Khalili-Fard et al., 2024; Saeedi et al., 2024). Therefore, the managerial context underlying a Supply Chain Network Design problem is inevitably characterised by multiple conflicting objectives (Jayarathna et al., 2021). Consequently, the development of Multi-Objective mathematical models could offer a more holistic view of these network design problems while enabling efficient management of their inherent challenges. In addition, advanced solution techniques may be required as incorporating these

critical factors into the modelling framework may result in increasingly complex mathematical models.

The analysis of case studies shows that the existing MOFLP literature covers nine major application sectors (see Fig. 8). At the same time, the review highlights that several relevant domains remain comparatively under-explored, particularly *Public Services* and *Economics and Finance*. While Location Science has addressed Facility Location problems in areas such as transport and education (Haase et al., 2019) and in the banking sector (Celik Turkoglu & Erol Genevois, 2020), these studies often involve inherently Multi-Objective decision contexts, characterised by the simultaneous consideration of accessibility, equity, and efficiency. The limited presence of explicit MOFLP formulations in these fields therefore represents an important gap identified through our synthesis. Consequently, we believe that the adoption of Multi-Objective Optimisation frameworks in these contexts could provide a more comprehensive and realistic representation of complex decision scenarios.

Finally, the review reveals a fragmented integration of emerging paradigms such as *Digital Economy*, *Circular Economy* and *Low-carbon Transition* within the MOFLP literature. In the *Digital Economy* era, the planning of activities enabled by digital and IoT technologies increasingly requires the simultaneous consideration of sustainability and resilience objectives. From a Location Analysis perspective, recent contributions have addressed problems such as parcel locker location (Dayal et al., 2025) and cloud computing network design (Larumbe & Sansò, 2012). Moreover, Cao et al. (2023) addressed the location of temporary disposal centres through a novel digital twin-driven conceptual framework. Despite these advances, our analysis shows that, due to the complexity of jointly quantifying the diverse managerial objectives involved, these studies predominantly adopt single-objective formulations typically prioritising economic performance or service coverage. Our review makes explicit that such modelling choices, while understandable, limit the ability to capture the full range of strategic trade-offs. Similarly, a Multi-Objective perspective appears particularly relevant and advantageous in the transition to a *Circular Economy* at the supply chain level (MahmoumGonbadi et al., 2021), where economic, environmental, and social objectives must be balanced simultaneously as evidenced by recent contributions on Supply Chain Network Design problems (Govindan et al., 2017; MahmoumGonbadi et al., 2023). With respect to the *Low-carbon Transition*, the integration with MOFLPs emerges as still limited. As reported in Table 8, CO₂ emissions reduction is considered as an objective in around 14.2% of the reviewed papers, whereas broader environmental impact objectives appear in only 8.7% of the studies, and explicit objectives related to energy consumption or gas emissions are present in approximately 1% of the sample. This quantitative evidence suggests that, although decarbonisation concerns are gaining attention, they are still addressed in a simplified manner, mainly through single carbon-based indicators. The results reveal a substantial research gap and underline the need for future MOFLP models that incorporate richer energy- and climate-related objectives. Such developments would be fully aligned with the objectives of sustainable industrialisation and responsible consumption and production patterns outlined in the 9th and 12th Sustainable Development Goals (ONU, 2015).

5.3.3. Conceptual synthesis and future research directions in MOFLPs

While the above research gaps concern different modelling and application-oriented aspects, collectively they reflect a broader transition in MOFLPs research towards more realistic, socially aware, and decision-oriented optimisation frameworks. The synthesis of the reviewed literature highlights three key research priorities.

- **Increasing modelling realism.** Advances in uncertainty modelling, behavioural considerations, fairness objectives, and resilience requirements improve modelling accuracy but introduce a fundamental trade-off with computational tractability. This emphasises the need for tailored exact algorithms and matheuristic approaches capable of scaling the solution methods.

- **Balancing economic efficiency and societal objectives.** As sustainability, equity and the low-carbon transition are key priorities in designing real-world systems, conflicts arise between efficiency-oriented objectives and broader societal performance criteria. Tackling this issue requires innovative Multi-Objective formulations that can integrate economic, environmental, and social goals simultaneously.
- **Bridging optimisation and decision support.** The practical adoption of MOFLP models depends on the integration of optimisation with decision support processes. The large sets of efficient solutions that are potentially generated by Multi-Objective methods require stronger integration with MCDA techniques and behavioural OR approaches in order to improve the interpretability of solutions and engage policymakers.

These priorities are inherently interconnected; progress in one area often intensifies trade-offs in the others. Consequently, future research on MOFLPs should move beyond isolated methodological improvements towards integrated frameworks that explicitly address these priorities.

6. Conclusions

Multi-Objective Facility Location is a flourishing area of research within the broader field of Location Science. Accordingly, this paper provides a Systematic Literature Review of the relevant contributions to this topic in order to properly assess the current state of the art and highlight research aspects requiring further investigation. For this purpose, we analysed 288 peer-reviewed papers published between 2011 and 2025.

Our analysis reveals a growing interest in MOFLPs, an increasing number of real-world applications, and a focus on current emerging managerial challenges. However, the review also highlights several significant research gaps, at the modelling and methodological levels, as well as in terms of relevant issues not addressed yet from a managerial perspective. In particular, the literature reflects a number of key challenges, including the trade-off between modelling realism and computational tractability, balancing economic efficiency with societal objectives such as equity and sustainability, and integrating optimisation techniques with decision-support processes.

These findings have not been highlighted in previous literature reviews. Most importantly, they suggest several promising directions for future research. From a methodological perspective, further progress is needed in developing tailored solution methods capable of handling

richer modelling frameworks incorporating uncertainty, time dynamics, and fairness considerations. Concurrently, stronger integration between optimisation models and Multi-Criteria Decision Analysis could enhance the interpretability and practical relevance of MOFLP solutions. From a managerial perspective, future research should address the practical barriers limiting the real-world implementation of MOFLP models. This includes the institutional constraints shaping policy and infrastructure planning decisions, and identifying and formalising stakeholders' preferences. Addressing these issues would help to bridge the gap between theoretical MOFLPs modelling and their actual implementation in public service systems, supply chains, and infrastructure planning.

Nevertheless, this study has certain limitations that could be addressed in future research. One such limitation stems from the focus on papers proposing purely Mathematical Optimisation approaches to MOFLPs. As a result, a substantial body of literature employing Multi-Criteria Decision Analysis methods has been excluded. These methods enable qualitative and quantitative criteria to be incorporated into models of complex, real-world decision-making scenarios, and allow alternatives to be evaluated according to stakeholders' preferences. Conducting a Systematic Literature Review specifically focused on MCDA-based approaches to MOFLPs would provide valuable insights into their contributions decision-making.

In parallel, recent years have seen a growing number of studies addressing Facility Location problems through learning-based and data-driven techniques (Guo et al., 2025). Interest in these methodologies has increased due to their capacity to efficiently solve complex combinatorial optimisation problems and support decision-making in dynamic environments. Therefore, establishing the current state of the art in relation to these approaches is essential to identify promising avenues for future research in the field of Facility Location.

CRedit authorship contribution statement

Serena Fugaro: Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Antonino Sgalambro:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization.

Appendix A. Case studies

See [Table A.1](#).

Table A.1

Full list of case study references with country and application area, where provided (DM = Disaster Management; EM = Emergency Management; H = Healthcare; L = Logistics; ND = Network Design; S = Services; SCM = Supply Chain Management; WM = Waste Management).

Ref.	Country	Sector	Application Field(s)
Afshari et al. (2014a), Izadian et al. (2024)	Europe; Iran	SCM	Green Distribution ND
Afshari et al. (2016, 2014b), Chang et al. (2021)	-; China	SCM	Reverse Logistics
Akbari et al. (2018)	North America	DM	Search&Rescue Vessels
Akgün and Erdal (2019)	Turkey	L	Ammunition Distribution
Alamatsaz et al. (2022)	Iran	L	Green Logistics
Anvari and Turkay (2017)	Turkey	SCM	-
Arabahmadi et al. (2023)	Iran	S	Inspection Centres Location
Asadi et al. (2018), Hong and Mwakalonge (2020)	Iran; North America	Energy	Bio-fuel Logistics ND
Avramescu et al. (2021, 2023)	-	H	Personalised Medicine
Aydemir-Karadag and Akdere (2023)	Turkey	S	Lunch Distribution ND
Aydin (2022)	Turkey	S	Parking Lot Location
Babaei et al. (2025)	-	S	Telecommunication ND
Baik and Murray (2022), Hong and Jeong (2019), Maliszewski et al. (2012)	North America	-	-
Bal and Badurdeen (2020)	Turkey	SCM	Circular Economy
Barzinpour and Esmaili (2014), Fazli (2024), Khalili et al. (2016), Mohammadi et al. (2016), P. Zhang et al. (2022)	Iran; Indonesia	DM	Relief Logistics

(continued on next page)

Table A.1 (continued).

Ref.	Country	Sector	Application Field(s)
Boonmee and Kasemset (2020), Bozorgi-Amiri et al. (2013), Bozorgi-Amiri and Khorsi (2016), Geng et al. (2022), Günay et al. (2019), Jalali et al. (2018), Kaveh et al. (2024), Kian et al. (2022), Nazemi et al. (2022), Praneetpholkrang et al. (2021), Rodríguez-Espíndola et al. (2023)	Thailand; North America; West Africa; Iran; China; Turkey	DM	Humanitarian Logistics
Cabanilla et al. (2022)	Philippines	H	Vaccination Centres Location
Chanta et al. (2014), Chen and Lai (2022), Navazi et al. (2018), Oksuz and Satoglu (2024)	North America; China; Iran; Turkey	EM	Emergency Facility Location
Chen et al. (2021), Duan et al. (2024), Teran-Somohano and Smith (2019)	China; North America	WM	Waste Transfer Stations Loc
Coutinho-Rodrigues et al. (2012a)	Europe	WM	Sorted Waste Containers Loc.
Coutinho-Rodrigues et al. (2012b) ; Rico et al. (2024), Zhong et al. (2023)	Europe; Philippines; China	DM	Evacuation Planning; Shelters Location
Şen et al. (2011), Teran-Somohano and Smith (2019), Yao et al. (2019)	Turkey; China; North America	EM	Fire Stations Location
Darman et al. (2020), Niu et al. (2024), Rabbani et al. (2021)	Iran; China	WM	Waste Collection Centres Loc.
de Campos et al. (2024)	South America	H	Mammography Unit Location
Diglio et al. (2021, 2024), Farrokhzadeh et al. (2021)	Europe; Turkey	H	Blood SCM
Dogan et al. (2020)	Turkey	H	Preventive Healthcare
Dong et al. (2023), Habibi et al. (2017), Herrera-Grandia et al. (2019), Mohammadi et al. (2023), Mohsenizadeh et al. (2020), Olapiriyakul (2017), Ratković et al. (2022), Rossit et al. (2017), Zaeimi and Rassafi (2021)	China; Europe; Iran; South America; Turkey; Thailand	WM	Municipal Solid WM
Elleuch and Frikha (2018)	Africa	SCM	Manufacturing Plants Location
Eriskin and Karatas (2023)	Turkey	Energy	Hydrogen Storage Areas Loc
Eskandari and Nookabadi (2018), Kaveh et al. (2021)	Iran	S	Urban Transport ND
Gital Durmaz and Bilgen (2020), Nguyen et al. (2023), Ransikarbum and Pitakaso (2024), Yunusoglu et al. (2024)	Turkey; Vietnam; Thailand	SCM	Biomass Supply Chain ND
Hammad et al. (2017a)	Australia	S	Airport Location
Han et al. (2022)	China	S	Maintenance Facilities Location
Hu et al. (2025), Sun and Liu (2021)	China ;-	DM	Emergency Logistics
Hu et al. (2022)	China	S	General Service Infrastructures
Hussain et al. (2023)	Europe	S	Vehicular Fog Computing
Izco et al. (2023)	Europe	ND	Parcel lockers ND
Huang and Shi (2021), Jaigirdar et al. (2023), Shishebori et al. (2016), L. Wang et al. (2023)	;- China; Iran	SCM	Distribution Systems Planning
Jain et al. (2022)	India	SCM	Omni-Channel Retail Chain
Jalilvand et al. (2023), Rouhani and Amin (2022)	Iran	H	Organ Transplant ND
Jia et al. (2023)	China	ND	Fresh Food Transport ND
Kanzian et al. (2013)	Europe	Energy	Wood Energy Supply ND
Khorsi et al. (2021), Long et al. (2021)	Iran; China	DM; EM	Temporary Relief DC Location
Lin et al. (2018)	Taiwan	S	ND for Public Bike System
Lotfian and Najafi (2019)	Iran	EM	Emergency Stations Location
Ma et al. (2022, 2019)	China	DM	Earthquake Shelters Loc
Maharjan and Hanaoka (2018, 2020)	Nepal	DM	Temporary Hub Location
Maliki et al. (2021)	North Africa	H	Blood-mobiles Location
Martinez-Gomez et al. (2015)	-	-	Plant Layout
Men et al. (2020)	China	EM	Rescue Facilities Location
Mendoza-Gómez and Ríos-Mercado (2022), Wang et al. (2024)	North America; Singapore	H	Primary Health. Centres Loc
Mogale et al. (2018)	India	SCM	Food Grain SCM
Mohamadi et al. (2019)	Iran	DM	Telecom. Tower Loc
Mohammed et al. (2017), Mohebalzadehgashti et al. (2020)	Europe; Iran	SCM	Meat SCM
Ouhader and El Kyal (2023)	North Africa	SCM	Sustainable SCM
Olivos and Caceres (2022)	South America	H	Ambulance Location
Padasht and Razmi (2016)	Iran	DM	Relief Distribution Systems
Pishvae and Razmi (2012)	Iran	SCM	Medical SCM
Raad and Rajendran (2024)	Iran	L	Dry port Network Design
Rahbari et al. (2023)	Iran	SCM	Canned Food SCM
Ratick et al. (2016)	North America	H	Screening Facilities Location
Roudsari and Wong (2014)	Iran	S	Supermarket Location
Sadeghi and Yaghoubi (2024)	Iran	ND	Cloud Seeding ND
Sæterbø et al. (2023)	Europe	SCM	Additive Manufacturing SCM
Samanlioglu (2013), Wichapa and Khokhajaikiat (2017a, 2017b, 2018)	Iran; Thailand	WM	Infectious Waste Disposal Centres Location
Schmidt-Dumont and Van Vuuren (2016)	South Africa	ND	Radio Transmitter Location
Song et al. (2021)	China	H	-
Tadros et al. (2018)	North Africa	-	-

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Table A.1 (continued).

Ref.	Country	Sector	Application Field(s)
Tari and Alumur (2014)	Turkey	WM	WEEE Centres Loc
Tian et al. (2016)	China	S	Automotive Service Location
Tosarkani and Amin (2020)	North America	WM	Wastewater Treatment ND
Turan et al. (2021)	Australia	Military	Military Facility Location
Tüzün Aksu and Ocak (2012)	Turkey	S	Municipal Centres Location
C. Wang et al. (2022), Zhang (2011)	China	–	–
Wang et al. (2016)	China	H	Nursing Home Location
Wang et al. (2018), Zhang et al. (2016), H. Zhang et al. (2022)	China	H	Medical Facilities Location
Xue et al. (2022)	Africa	DM	Refugees Camp Location
Yang et al. (2024)	China	S	Senior-friendly Restaurant Loc
Yue et al. (2024)	North America	S	E-Scooter Deployment Stations
Zhao et al. (2025)	China	WM	Urban medical WM Facilities
Zhao and Verter (2015)	China	WM	Used Oil Disposal Centres Loc
Zhou et al. (2021)	China	S	Air Transport

Appendix B. Managerial objectives

See Table B.1.

Table B.1

Managerial context for the revised papers and related class of location problem (FC = Fixed Charge; LA = Location-Allocation; LR = Location-Routing; MC = Maximal Covering; ND = General Network Design; SC = Set Covering; SCM = Supply Chain ND || QoS = Quality of service).

Reference(s)	Managerial context	Macro class
Blesa et al. (2016)	Robustness	SC
Jacyna-Golda and Izdebski (2017)	LogNet costs	LA
Ratick et al. (2016)	Coverage	MC
Ushakov et al. (2018)	Data Analysis	Median
Cho et al. (2023), Yao et al. (2019)	Accessibility; Coverage	LA, SC
Eydi and Saghez (2024)	Accessibility; LogNet costs	HubLoc
Baik and Murray (2022)	Accessibility; Quality of service	LA
Cabanilla et al. (2022)	Allocation costs; Efficiency	Median
Tüzün Aksu and Ocak (2012)	Allocation costs; Equity	Median
Huang and Shi (2021)	Allocation costs; Opening costs	Median
Cebi and Goularas (2021), Roudsari and Wong (2014)	Cannibalisation; Competitiveness	Competitive
Mohammadi et al. (2023), Asadi et al. (2018), Fan et al. (2023), Heidari et al. (2023), Mohsenizadeh et al. (2020), Tosarkani and Amin (2020)	CO ₂ emissions; LogNet costs	LA, LR, ND
Ouhader and El Kyal (2017)	CO ₂ emissions; Operating costs	LR
Caramia and Pizzari (2023), Chang et al. (2021), Kanzian et al. (2013)	CO ₂ emissions; Profit	HubLoc, ND, SCM
Karimi et al. (2023), Maliki et al. (2022), Nguyen et al. (2023), Ouhader and El Kyal (2023), Savoji et al. (2022)	CO ₂ emissions; Supply chain costs	LA, LR, SCM
Ouhader and El Kyal (2020)	CO ₂ emissions; Transport costs	LR
Levanova et al. (2023)	Competitiveness; Robustness	Competitive
Camacho-Vallejo and Corpus (2024)	Competitiveness; Profit	Competitive
Berman et al. (2018), Dabibi et al. (2016), Gutjahr and Dzubur (2016), Izco et al. (2023), Mendoza-Gómez and Ríos-Mercado (2022), Sadeghi and Yaghoubi (2024)	Coverage; Opening costs	LA, MC, SC
Elkady and Abdelsalam (2016), Schmidt-Dumont and Van Vuuren (2016), Yue et al. (2024)	Coverage; Quality of service	LA, MC
Yang et al. (2024)	Coverage; Social utility	MC
Atta et al. (2021)	Coverage; User satisfaction	MC
Han et al. (2022), Olivos and Caceres (2022)	Effectiveness; Efficiency	MC
Chanta et al. (2014)	Efficiency; Equity	MC
Adarang et al. (2020), Barzinpour and Esmaeili (2014), Jalilvand et al. (2023), Maliki et al. (2021)	Efficiency; LogNet costs	LA, LR, Median
Alves de Queiroz et al. (2021), Nazemi et al. (2022), Parragh et al. (2022)	Efficiency; Opening costs	FC, MC
Akbari et al. (2018), Günay et al. (2019)	Efficiency; Quality of service	LA
Ma et al. (2022)	Efficiency; Safety	LA
Peng et al. (2022)	Efficiency; Social utility	Median
Arabzad et al. (2015), Farrokhzadeh et al. (2021)	Efficiency; Supply chain costs	FC, SCM
Khorsi et al. (2021)	Efficiency; System reliability	LR
Camara et al. (2024)	Efficiency; Transport costs	SC
Hussain et al. (2023)	Energy consumption; QoS	LA
Teran-Somohano and Smith (2019)	Environmental impact; LogNet costs	Obnoxious
Hammad et al. (2017b)	Environ. impact; Quality of service	Obnoxious
Yunusoglu et al. (2024)	Environmental impact; Profit	Obnoxious
Pishvae and Razmi (2012)	Environ. impact; Supply chain costs	SCM
Ma et al. (2019)	Environ. impact; Travel distance	LA
Gu and Wang (2012)	Equity; Quality of service	Center
Salinas et al. (2023)	Equity; Safety	Dispersion

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Table B.1 (continued).

Reference(s)	Managerial context	Macro class
Davoodi (2019)	Equity; Work-balance	Center
Filippi et al. (2021)	Fairness; Opening costs	FC
Jaigirdar et al. (2023), Mogale et al. (2018), Sæterbo et al. (2023)	Lead time; Supply chain costs	FC, SCM
Boonmee and Kasemset (2020), Maharjan and Hanaoka (2018), Rahmanifar et al. (2024), Rashvand Falari et al. (2024), Rodríguez-Espíndola et al. (2023)	LogNet costs; Quality of service	FC, HubLoc, LR
Misni et al. (2024)	LogNet costs; Profit	LR
Samanlioglu (2013), Yu and Solvang (2016), Zhao et al. (2025), Zhao and Verter (2015)	LogNet costs; Risk mitigation	LR
Kaveh et al. (2021)	LogNet costs; Travel time	HubLoc
Sun and Liu (2021)	LogNet costs; User satisfaction	ND
Bhattacharjee and Mukhopadhyay (2021)	Maintenance costs; Transport costs	HubLoc
Masoumzadeh et al. (2016), Rossit et al. (2017), Wang et al. (2016)	Opening costs; Quality of service	FC, HubLoc
JabalAmeli and Mortezaei (2011)	Opening costs; Transport costs	ND
Paldrak et al. (2023)	Opening costs; Travel distance	LA
Herrera-Granda et al. (2019), Coutinho-Rodrigues et al. (2012a)	Opening costs; User satisfaction	FC, Obnoxious
Mishra et al. (2022)	Operating costs; Quality of service	LA
Ahluwalia and Nema (2011)	Operating costs; Safety	LA
Dong et al. (2023)	Operating costs; Social Utility	ND
Zhang (2011)	Operating costs; System Reliability	LR
Davoodi and Rezaei (2023)	Operating costs; User satisfaction	LR
Gital Durmaz and Bilgen (2020)	Profit; Quality of service	SCM
Raad and Rajendran (2024)	Profit; Qualitative criteria	ND
Jain et al. (2022)	Qualitat. criteria; Supply chain costs	SCM
Medal et al. (2014a)	Quality of service; Risk mitigation	Center
Hajipour et al. (2021), Tadros et al. (2018)	Quality of service; Supply chain costs	FC, SCM
Chambari et al. (2011), Eshaghi Chaleshtori et al. (2020), Hajipour and Pasandideh (2012)	Quality of service; System productivity	FC, LA
Bi et al. (2016), Ramamoorthy et al. (2024)	Resilience; Transport costs	HubLoc
Parvaresh et al. (2014)	Risk mitigation; Transport costs	HubLoc
Rayat et al. (2017)	Risk mitigation; Supply chain costs	LR
L. Wang et al. (2023)	Risk mitigation; Workload balance	Median
Eriskin and Karatas (2023)	Safety; Transport costs	Obnoxious
Izadian et al. (2024)	Supply chain costs; System reliability	SCM
Pourhassan et al. (2025)	Supply chain costs; Workload balance	LR
Akgün and Erdal (2019)	System reliability; Transport costs	LA
Tian and Zhou (2015), Tian et al. (2016)	Transport costs; Travel time	LA
Davoodi and Calabrese (2024)	Travel time; Workload balance	MC
Rico et al. (2024)	Accessibility; Coverage; Safety	LA
Delgado et al. (2022)	Accessibility; Efficiency; Equity	Center
Wang et al. (2024)	Accessibility; Equity; Opening costs	LA
Jalali et al. (2018)	Accessibility; Equity; QoS	LA
Tang et al. (2020)	Alloc. costs; CO ₂ emiss.; Open. costs	FC
Zhao et al. (2017)	Allocation costs; Coverage; Equity	MC
C. Zhang et al. (2018)	Alloc. costs; Efficiency; Open. costs	Median
Chen and Cheng (2011)	Alloc. costs; Open. costs; Main. costs	Median
Martinez-Gomez et al. (2015)	Alloc. costs; Open. costs; Safety	Dispersion
Ransikarbum and Pitakaso (2024)	CO ₂ emissions; Coverage; Supply chain costs	SCM
Li et al. (2022)	CO ₂ emis.; Efficiency; LogNet costs	LA
Mohebalizadehgashti et al. (2020)	CO ₂ emissions; Efficiency; Supply chain costs	SCM
Li et al. (2023), Niu et al. (2024)	CO ₂ emis.; Env. impact; LogNet costs	LR
Aydemir-Karadag and Akdere (2023)	CO ₂ emissions; LogNet costs; Quality of products	LR
Lin et al. (2020)	CO ₂ emis.; LogNet costs; Social utility	ND
Das et al. (2021)	CO ₂ emis.; LogNet costs; Travel time	SCM
Alamatsaz et al. (2022), Harris et al. (2014)	CO ₂ emis; Open. costs; Operat. costs	FC, LR
Brahmi et al. (2022), Zhu et al. (2015)	CO ₂ emis.; Open. costs; Transp. costs	FC, SCM
Xu et al. (2022)	CO ₂ emissions; Profit; QoS	ND
Kim et al. (2024), Seydanlou et al. (2022)	CO ₂ emissions; Social utility; Supply chain costs	SCM
Sepehri et al. (2024)	CO ₂ emissions; Supply chain costs; System reliability	SCM
Das and Roy (2019), Vansia and Dhodiya (2021)	CO ₂ emis.; Travel time; Transp. costs	ND
Karbasian and Dashti (2011)	Competitiveness; Coverage; Efficiency	Dispersion
Avramescu et al. (2023), Shaw et al. (2022)	Coverage; Effic.; Supply Chain costs	LA
Babaei et al. (2025)	Coverage; Energy consumption; Operating costs	HubLoc
Eskandari and Nookabadi (2018)	Coverage; Env. impact; User sat.	MC
de Campos et al. (2024)	Coverage; Equity; Travel Distance	LA

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Table B.1 (continued).

Reference(s)	Managerial context	Macro class
Ma et al. (2024), Şen et al. (2011), Shishebori et al. (2018, 2016)	Coverage; Opening costs; Operating costs	MC, ND, Comp
Arabahmadi et al. (2023)	Coverage; Open. costs; Transp. costs	LA
Mohamadi et al. (2019)	Coverage; System reliab.; Travel dist.	LA
Diglio et al. (2021, 2024), Hu et al. (2025)	Effectiv.; Efficiency; Transp. costs	LA, LR
Oksuz and Satoglu (2024)	Effectiveness; Efficiency; Travel dist.	ND
Long et al. (2021)	Effectiveness; Fairness; LogNet costs	LR
Liu et al. (2019)	Effectiv.; LogNet costs; Open. costs	FC
Kaveh et al. (2024), Beiki et al. (2021), Vahdani et al. (2018b)	Effectiveness; LogNet costs; System Reliability	LA, LR
Lotfian and Najafi (2019)	Efficiency; Equity; Quality of service	LA
Rabbani et al. (2021)	Efficiency; Environ. impact; Profit	LR
Amin-Tahmasbi et al. (2022)	Efficiency; Environmental impact; Supply chain costs	SCM
P. Zhang et al. (2022)	Efficiency; Fairness; LogNet costs	SCM
Golmohammadi et al. (2025)	Efficiency; LogNet costs; User satisf.	LR
Hadian et al. (2019)	Efficiency; Open. costs; Operat. costs	LR
Men et al. (2020)	Efficiency; Opening costs; Safety	Obnoxious
C. Wang et al. (2022)	Efficiency; Open. costs; System reliab.	FC
Bal and Badurdeen (2020)	Efficiency; Profit; Social utility	ND
Avramescu et al. (2021)	Efficiency; QoS; Supply chain costs	FC
Xue et al. (2022)	Efficiency; QoS; System prod.	LA
Zhou et al. (2021)	Efficiency; QoS; User satisfaction	LA
Das et al. (2024)	Environ. Impact; LogNet costs; QoS	LA
Duan et al. (2024)	Environ. Impact; LogNet costs; Safety	ND
Chen et al. (2021), Ratković et al. (2022)	Environmental impact; Opening costs; Transport costs	ND
Darmian et al. (2020)	Environmental impact; Opening costs; User satisfaction	LA
Jin et al. (2018)	Environ. impact; Profit; Social utility	ND
Hammad et al. (2017a)	Environ. impact; QoS; Resilience	Obnoxious
Lin et al. (2018)	Environ. impact; QoS; Safety	LA
Zhong et al. (2023)	Equity; Evacuation time; Opening costs	LA
Khalilzadeh and Bahari (2023)	Equity; Open. costs; Operat. costs	MC
Medal et al. (2014b)	Equity; Open. costs; Risk mitigation	Center
Coutinho-Rodrigues et al. (2012b)	Evacuation time; Safety; Travel dist.	LR
Zaeimi and Rassafi (2021)	Gas emis.; LogNet costs; Open. costs	ND
Afshari et al. (2014a, 2016, 2014b), Navazi et al. (2018), Nekooghadirli et al. (2014)	LogNet costs; Opening costs; Quality of service	FC, LR, ND
Khalili et al. (2016)	LogNet costs; Open. costs; User satisf.	FC
Jia et al. (2023)	LogNet costs; Transport costs; Workload Balance	ND
Tarôco et al. (2016)	Opening costs; Maintenance costs; System reliability	ND
Atta et al. (2019)	Open. costs; Operat. costs; User satisf.	FC
Shiripour and Mahdavi-Amiri (2019)	Opening costs; Operating costs; Workload balance	FC
Dogan et al. (2020)	Open. costs; Public engagement; QoS	LA
Pasandideh et al. (2013), Rahmati et al. (2013)	Open. costs; QoS; System prod.	FC
Chantre and Da Fonseca (2018)	Open. costs; QoS; System reliability	FC
Bozorgi-Amiri et al. (2013), Maharjan and Hanaoka (2020), Song et al. (2021)	Opening costs; Quality of service; Transport costs	FC
Chen and Lai (2022)	Opening costs; QoS; Travel time	ND
Al Ayub Ahmed et al. (2021)	Opening costs; System reliability; Transport costs	FC
Liu et al. (2023)	Opening costs; Operating costs; System reliability	FC
Ghezavati and Beigi (2016)	Makespan; Open. costs; Operat. costs	LR
Wichapa and Khokhajaikiat (2017b, 2018)	Opening costs; Operating costs; Qualitative criteria	LR
Dharmika et al. (2020), Ghaffari-Nasab et al. (2013a, 2013b), Kian et al. (2022)	Opening costs; Operating costs; Quality of service	LR
Tavakkoli-Moghaddam et al. (2017)	Profit; QoS; System productivity	LA
Vahdani et al. (2018a)	System reliability; Transport costs; Travel time	LR
Zhang et al. (2016)	Access.; Equity; Open. costs; QoS	FC
H. Zhang et al. (2022)	Accessibility; Opening costs; QoS; Transport costs	FC
Hu et al. (2022)	Allocation costs; Environmental impact; Open. costs; Transport costs	Median
Olapiriyakul (2017)	CO ₂ emissions; Environ. impact; Opening costs; Transport costs	ND
Aydin (2022), B. Zhang et al. (2018)	CO ₂ emissions; Opening costs; Operating costs; QoS	FC, LR

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Table B.1 (continued).

Reference(s)	Managerial context	Macro class
Tang and Zhang (2015), Xifeng et al. (2013)	CO ₂ emissions; Opening costs; Operating costs; System reliability	FC
Becerra et al. (2024)	CO ₂ emissions; Supply chain costs; Social utility	SCM
Jafarzadeh-Ghoushchi et al. (2023)	Coverage; Efficiency; Fairness; LogNet costs	LA
Padasht and Razmi (2016)	Coverage; Efficiency; Opening costs; Operating costs	LR
Mohammed et al. (2017)	Coverage; Opening costs; Quality of products; Transport costs	SCM
Mohammadi et al. (2016)	Coverage; Opening costs; Transport costs; User satisfaction	MC
Sirbiladze et al. (2024)	Effectiveness; Efficiency; Evacuation time; LogNet costs	LR
Praneetpholkrang et al. (2021)	Effectiveness; Efficiency; LogNet costs; Opening costs	FC
Turan et al. (2021)	Effectiveness; Maintenance costs; Opening costs; Operating costs	FC
Rouhani and Amin (2022)	Efficiency; Equity; LogNet costs; Opening costs	FC
Geng et al. (2022)	Efficiency; LogNet costs; Opening costs; User satisfaction	FC
Habibi et al. (2017)	Environmental impact; Gas emissions; LogNet costs; Opening costs	FC
Anvari and Turkay (2017)	Environmental impact; LogNet costs; Open. costs; Social utility	SCM
Ghasemi et al. (2021)	Environmental impact; Opening costs; Operating costs; Quality of service	LR
Safari et al. (2024)	Environmental impact; Qualitative criteria; QoS; Supply chain costs	SCM
Bozorgi-Amiri and Khorsi (2016)	Equity; LogNet costs; Opening costs; Quality of service	LR
Fazli (2024)	Equity; LogNet costs; Qualitative criteria; Quality of service	LA
Bai (2016)	Equity; Opening costs; Operating costs; Quality of service	LR
Tari and Alumur (2014)	Equity; Opening costs; Quality of service; Transport costs	FC
Wang et al. (2018)	Opening costs; Operating costs; Quality of service; Travel distance	FC
Wichapa and Khokhajaikiat (2017a)	Opening costs; Operating costs; Qualitative criteria; Transport costs	SC
Hajipour et al. (2016)	Opening costs; Quality of service; System productivity; Transport costs	FC
Bashiri and Rezanezhad (2015)	Opening costs; System reliability; Transport costs; Travel time	HubLoc
Rahbari et al. (2023)	Social utility; Supply chain costs; System productivity; User satisfaction	SCM
Cai et al. (2023)	Coverage; Efficiency; LogNet costs; Travel distance; Travel time	LR
Hong and Mwakalonge (2020)	Environ. impact; LogNet costs; Open. costs; QoS; Resilience; System prod.	ND

Appendix C. Solution methods

Data availability

See Tables C.1 and C.2.

Data will be made available on request.

Table C.1

List of references proposing an exact approach to the addressed MOFLP and related class of location problem (C = Competitive; D = Dispersion; FC = Fixed Charge; LA = Location–Allocation; LR = Location–Routing; MC = Maximal Covering; ND = General Network Design; O = Obnoxious; SC = Set Covering; SCM = Supply Chain ND).

Reference(s)	Solution method	Class	Location macro-class
Farrokhzadeh et al. (2021), Gital Durmaz and Bilgen (2020), Hammad et al. (2017b), Han et al. (2022), Mohebalizadehgashti et al. (2020), Rouhani and Amin (2022), Shiripour and Mahdavi-Amiri (2019), Yu and Solvang (2016)	AUGMECON	POST	FC, LR, MC, O, SCM
Anvari and Turkay (2017), Bal and Badurdeen (2020), Izadian et al. (2024), Mendoza-Gómez and Ríos-Mercado (2022), Navazi et al. (2018), Oksuz and Satoglu (2024), Rabbani et al. (2021), Rossit et al. (2017)	AUGMECON2	POST	FC, MC, ND, SCM, LA, LR
Savoji et al. (2022)	SAUGMECON	POST	SCM
Karatas and Yakıcı (2018), Parragh and Tricoire (2019), Parragh et al. (2022)	Branch&Bound	POST	MC, Median, SC
Cabanilla et al. (2022)	Bubble Sort	POST	Median
Coutinho-Rodrigues et al. (2012a), Martinez-Gomez et al. (2015), Yao et al. (2019)	Constraint Method	POST	D, O, SC

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Table C.1 (continued).

Reference(s)	Solution method	Class	Location macro-class
Adarang et al. (2020), Arabahmadi et al. (2023), Bashiri and Rezaezhad (2015), Beiki et al. (2021), Beresnev and Melnikov (2020), Boonmee and Kasemset (2020), Bozorgi-Amiri and Khorsi (2016), Caramia and Pizzari (2023), Carrizosa et al. (2015), Chanta et al. (2014), Das et al. (2024), Davoodi and Calabrese (2024), Delgado et al. (2022), Dong et al. (2023), Eshaghi Chaleshtori et al. (2020), Eskandari and Nookabadi (2018), Gadegaard et al. (2018), Ghasemi et al. (2021), Gutjahr and Dzubur (2016), Heidari et al. (2023), Izco et al. (2023), Kazemi T. and Fathi (2019), Lin et al. (2018), Medal et al. (2014a), Mohammadi et al. (2023), Mohsenizadeh et al. (2020), Nazemi et al. (2022), Olivos and Caceres (2022), Ouhader and El Kyal (2017, 2020, 2023), Pourhassan et al. (2025), Praneetpholkrang et al. (2021), Raad and Rajendran (2024), Rahmanifar et al. (2024), Rodríguez-Espindola et al. (2023), Sayyady et al. (2015), Sirbiladze et al. (2024), Ushakov et al. (2018), Wang et al. (2018), Zaeimi and Rassafi (2021), Zhao et al. (2025), Zhu et al. (2015)	ϵ -constraint	POST	C, Center, FC, HubLoc, LA, LR, MC, Median, ND, SCM
Sepehri et al. (2024)	Adaptive ϵ -constraint	POST	SCM
Liu et al. (2019)	Iteration Method	POST	FC
Farrokhizadeh et al. (2021), Shishebori et al. (2018)	Lagrangian Relaxation	POST	MC, SCM
Parragh et al. (2022)	L-shaped	POST	MC
Baik and Murray (2022)	Decomposition Meth.	POST	LA
De Walsche et al. (2023)	Partitioning Method	POST	Centre
Lin et al. (2020), Nguyen et al. (2023), Tüzün Aksu and Ocak (2012)	Radius-based	POST	
Ahluwalia and Nema (2011), Kim et al. (2024), Maharjan and Hanaoka (2020), Tadros et al. (2018)	Incremental algorithm	POST	Median, ND, SCM
Kaveh et al. (2024)	Solver (CPLEX)	POST	FC, LA, SCM
	Solver (LINGO)	POST	
	Solver (Baron)	POST	LA
Filippi et al. (2021)	Benders Decomposition	PRI	FC
Ramamoorthy et al. (2024)	Benders Decomposition;	PRI	HubLoc
	Cutting plane		
Medal et al. (2014b)	Binary Search	PRI	Center
Upmanyu and Saxena (2015a, 2015b)	Cutting plane; Dantzig cuts	PRI	SC
Wichapa and Khokhajaikiat (2017a, 2017b, 2018)	Fuzzy AHP with Goal Program.	PRI	LR, SC
Amiri-Aref et al. (2011), Karbasian and Dashti (2011), Masoumzadeh et al. (2016), Paldrak et al. (2023)	Fuzzy Goal Programming	PRI	D, FC, HubLoc, Median
Bai (2016), Barzinpour and Esmaeili (2014), Dharmika et al. (2020), Dogan et al. (2020), Eriskin and Karatas (2023), Fazli (2024), Geng et al. (2022), Hong and Mwakalonge (2020), Jafarzadeh-Ghoushchi et al. (2023), Li et al. (2022), Praneetpholkrang et al. (2021), Rico et al. (2024), Sirbiladze et al. (2024), Zhao and Verter (2015)	Goal Programming	PRI	FC, LA, LR, ND, O
Yunusoglu et al. (2024)	Goal Programming with k-means	PRI	SCM
Karatas and Yakıcı (2018)	Iterative Goal Programming	PRI	Median
P. Zhang et al. (2022)	Revised Multichoice Goal Programming	PRI	ND
Jain et al. (2022)	Weighted Goal Programming	PRI	SCM
Eydi and Saghez (2024)	Goal attainment	PRI	HubLoc
Aydemir-Karadag and Akdere (2023)	K-means with Weighted Sum	PRI	LR
Becerra et al. (2024), Jalali et al. (2018), Rabbani et al. (2021), Ratick et al. (2016), Ratković et al. (2022), Tari and Alumur (2014)	Lexicographic	PRI	FC, LA, LR, MC, ND, SCM
Diglio et al. (2021, 2024)	Solver (Gurobi)	PRI	LA, ND
Mohammed et al. (2017), Samanlioglu (2013)	Tchebycheff Weighted	PRI	LR, SCM
Afshari et al. (2014a), Akgün and Erdal (2019), Atta et al. (2019), Aydin (2022), Coutinho-Rodrigues et al. (2012b), Filippi et al. (2021), Günay et al. (2019), Hammad et al. (2017a), Herrera-Granda et al. (2019), Jaigirdar et al. (2023), Jalilvand et al. (2023), Kanzian et al. (2013), Maharjan and Hanaoka (2018), Maliszewski et al. (2012), Ransikarbum and Pitakaso (2024), Roudsari and Wong (2014), Yang et al. (2024)	Weighted Sum	PRI	C, FC, HubLoc, LA, LR, MC, ND, O, SCM
Fan et al. (2023)	Interactive Fuzzy Planning with Priority Control	interactive	ND
Pishvae and Razmi (2012)	Interactive Fuzzy ϵ -constraint	interact.	SCM
Rahbari et al. (2023)	Interactive Possibilistic	interact.	SCM
Huang and Shi (2021), Mohammed et al. (2017), Olapiriyakul (2017), Sadeghi and Yaghoubi (2024), Safari et al. (2024)	Compromise Programming	no pref.	MC, Median, ND, SCM
Lotfian and Najafi (2019)	Global Criterion	no pref.	LA
Arabzad et al. (2015), Bozorgi-Amiri et al. (2013), Habibi et al. (2017), Jamalalian and Salahi (2020), Mohamadi et al. (2019), Padasht and Razmi (2016)	LP-metric Method	no pref.	FC, LA, LR

Table C.2

List of references proposing a heuristic approach to the MOFLP tackled and related class of location problem (C = Competitive; D = Dispersion; FC = Fixed Charge; LA = Location–Allocation; LR = Location–Routing; MC = Maximal Covering; ND = General Network Design; O = Obnoxious; SC = Set Covering; SCM = Supply Chain ND).

Reference(s)	Solution method	Class	Location class
Evolutionary-based			
Camacho-Vallejo and Corpus (2024), Cho et al. (2023), Harris et al. (2014), Jia et al. (2023), Lancinskas and Žilinskas (2013), Long et al. (2021), Men et al. (2020), Niu et al. (2024), Rudziński (2017), Tang et al. (2020), Tang and Zhang (2015), Teran-Somohano and Smith (2019), C. Wang et al. (2022), C. Zhang et al. (2018)	Evolutionary Algorithm	POST	C, FC, LA, LR, Median, ND, O
L. Wang et al. (2023)	Sparse Evolutionary Algorithm	POST	Median
Khorsi et al. (2021)	Find–Fix–Finish–Exploit–Analyse	POST	LR
Afshari et al. (2016, 2014b), Cebi and Goularas (2021), Chen and Cheng (2011), Jacyna-Golda and Izdebski (2017), Jin et al. (2018), Khalilzadeh and Bahari (2023), Konak et al. (2017), Tian and Zhou (2015), Vansia and Dhodiya (2021), Wang et al. (2024), Wichapa and Khokhajaikiat (2017b), Zhang (2011), Zhang et al. (2016), B. Zhang et al. (2018), Zhong et al. (2023), Zhou et al. (2021)	Genetic Algorithm	POST	C, FC, LA, LR, MC, Median, ND
Seydanlou et al. (2022)	Genetic Algorithm with Electro-magnetism-like Algorithm	POST	SCM
Chambari et al. (2011)	NRGA	POST	LA
Li et al. (2023)	Ant Colony with Gen. Alg.	POST	LR
Kaveh and Mahdavi (2024)	Colliding Bodies Opt. Alg.	POST	O
Lancinskas and Žilinskas (2014)	NSGA-II comb. with Multi-Objective	POST	C
Eydi and Saghez (2024), Hussain et al. (2023)	Single Agent Stochastic Search	POST	HubLoc, LA
Jahantigh and Malmir (2016)	NSGA-II with Particle Swarm Optimisation	POST	FC
Shiripour and Mahdavi-Amiri (2019)	NSGA-II with Tabu Search	POST	FC
Avramescu et al. (2023)	CNSGA-II	POST	LA
Vargas-Santiago et al. (2025)	R-NSGA-II	POST	FC
Lai et al. (2019)	NSGA-III	POST	LA
Alamatsaz et al. (2022)	Non-dominated Sorting Simplified Swarm Optimisation	POST	LR
Dabibi et al. (2016)	Progressive Hedging with Gen. Alg.	POST	SC
Golmohammadi et al. (2025), Hadian et al. (2019), Nekooghadirli et al. (2014)	ϵ -constraint with Genetic Alg.	POST	LR
López-Sánchez et al. (2021)	Imperialist Competitive Algorithm	POST	LR
Adarang et al. (2020)	Scatter Search	POST	MC
Rahmanifar et al. (2024)	Shuffled Frog Leaping Algorithm	POST	LR
Arabahmadi et al. (2023), Asadi et al. (2018), Atta et al. (2019), Avramescu et al. (2021), Babaei et al. (2025), Bashiri and Rezaezhad (2015), Bhattacharjee and Mukhopadhyay (2021), Brahami et al. (2022), Camara et al. (2024), Chambari et al. (2011), Chantre and Da Fonseca (2018), Duan et al. (2024), Eshaghi Chaleshtori et al. (2020), Ghezavati and Beigi (2016), Heidari et al. (2023), Karimi et al. (2023), Ma et al. (2024), Maliki et al. (2022), Pourhassan et al. (2025), Rahmanifar et al. (2024), Sæterbø et al. (2023), Shiripour and Mahdavi-Amiri (2019), Tang et al. (2020), Tang and Zhang (2015), Taróco et al. (2016), Turan et al. (2021), Vahdani et al. (2018a, 2018b), Vansia and Dhodiya (2021), L. Wang et al. (2023), Xu et al. (2022), Xue et al. (2022), Zhao et al. (2025, 2017)	Social Engineering Optimiser	POST	LR
	NSGA-II	POST	C, FC, HubLoc, LA, LR, MC, Median, ND, SC, SCM
Trajectory-based			
Blesa et al. (2016)	Exhaustive Search	POST	SC
Berman et al. (2018)	Greedy Search	POST	MC
Davoodi and Calabrese (2024), Song et al. (2021)	Hill Climbing	POST	FC, Median
Liu et al. (2023), C. Wang et al. (2023)	Learning-based Search Strategy	POST	FC, LR
Davoodi and Rezaei (2023), Kian et al. (2022), Lozano-Osorio et al. (2023), Mishra et al. (2022)	Local Search	POST	D, LA, LR
Lancinskas et al. (2014, 2015)	Parallel Stochastic Search	POST	C
Darmian et al. (2020)	Population-based Local Search	POST	LA
Avramescu et al. (2021)	Random Search	POST	FC
Gu and Wang (2012)	Static and Mobile Search	POST	Centre
Berman et al. (2018), Bi et al. (2016), Parvaresh et al. (2014), H. Zhang et al. (2022)	Tabu Search	POST	FC, HubLoc, MC
Alves de Queiroz et al. (2021), Ghaffari-Nasab et al. (2013a), Sánchez-Oro et al. (2022)	Variable Neighbourhood Search (VNS)	POST	FC, LR, Median
Levanova et al. (2023)	Reduced VNS with Simple Evolutionary Multi-obj Optimisation	POST	C

(continued on next page)

Table C.2 (continued).

Reference(s)	Solution method	Class	Location class
Nature-inspired			
Sun and Liu (2021)	Artificial Bee Colony	POST	ND
Cai et al. (2023)	Artificial Physarum Polycephalum Colony	POST	LR
Al Ayub Ahmed et al. (2021)	Dragonfly Algorithm	POST	FC
Hu et al. (2025)	Grey Wolf Optimiser	POST	LR
Atta et al. (2021), Hajipour et al. (2016), Mismi et al. (2024), Rahmati et al. (2013)	Harmony Search Meta-heuristic	POST	FC, LR, MC
Rashvand Falari et al. (2024)	Keshtel Algorithm	POST	LR
Mogale et al. (2018)	Non-dom Chemical Reaction	POST	FC
Amin-Tahmasbi et al. (2022), Asadi et al. (2018), Babaei et al. (2025), Chantre and Da Fonseca (2018), Elkady and Abdelsalam (2016), Hu et al. (2022), Kaveh et al. (2021), Ma et al. (2019), Mohammadi et al. (2016), Peng et al. (2022), Vahdani et al. (2018a, 2018b), Wang et al. (2016)	Particle Swarm Optimisation	POST	FC, HubLoc, LA, LR, MC, Median, SCM
Hajipour and Pasandideh (2012)	Adaptive Particle Swarm Opt.	POST	LA
Chang et al. (2021)	Particle Swarm Optimisation with Gravitation Algorithm	POST	ND
Ma et al. (2022)	Particle Swarm Opt. with Simulated Annealing and Genetic Algorithm	POST	LA
Rahmanifar et al. (2024)	Hybrid Red Deer Algorithm	POST	LR
Vansia and Dhodiya (2021)	Self-Adaptive Multi-Population Elitism Jaya	POST	ND
Chen and Lai (2022), Chen et al. (2021), Ghaffari-Nasab et al. (2013b), Huang and Shi (2021), JabalAmeli and Mortezaei (2011), Khalilzadeh and Bahari (2023), Maliki et al. (2021), Parvaresh et al. (2014), Pasandideh et al. (2013), Rashvand Falari et al. (2024), Schmidt-Dumont and Van Vuuren (2016)	Simulated Annealing	POST	FC, HubLoc, LR, MC, Median, ND
Rayat et al. (2017)	Archived Multi-Obj Simulated Annealing	POST	LR
Ushakov et al. (2018)	Branch&Cut with Simulated Annealing	POST	Median
Tian et al. (2016)	Stochastic Simul. with Teaching-learning Based Algorithm	interactive	LA
Amin-Tahmasbi et al. (2022), Hajipour et al. (2016, 2021), Tavakkoli-Moghaddam et al. (2017)	Vibration Damping Optimisation	POST	FC, LA, SCM
Pourhassan et al. (2025)	Whale Optimisation	POST	LR
Defined ad-hoc			
Das and Roy (2019), Shaw et al. (2022)	Alternating locate-allocate Heuristic with Neutrosophic Compromise Programming	POST	LA, ND
Das et al. (2021)	Alternating locate-allocate Heuristic with Intuitionistic Fuzzy Programming	POST	SCM
Rohaninejad et al. (2017)	Approximation Algorithm	POST	C
Xifeng et al. (2013)	Greedy Heuristic	POST	FC
Kazemi T. and Fathi (2019), Sayyady et al. (2015)	Incremental Algorithm	POST	Center, Median
Vargas-Santiago et al. (2021)	Incremental/Decremental Pareto	POST	FC
Davoodi (2019)	Iter. Alg. (Voronoi diagram)	POST	Center
Tosarkani and Amin (2020)	Iterative Alg. (ϵ -constraint)	POST	ND
Sayyady et al. (2015)	Lagrangean Relaxation	POST	Median
Shishebori et al. (2016)	LP-metric Relaxation	no pref.	ND
Karatas (2017), Nazemi et al. (2022)	Model-based Matheuristic	POST	FC, MC
Salinas et al. (2023)	Cross-entropy based	POST	D
Khalili et al. (2016)	Reservation Level-driven Tchebycheff	interactive	FC
Sirbiladze et al. (2024)	Machine Learning procedure	POST	LR
Yue et al. (2024)	Deep Reinforcement Learning	PRI	MC

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