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MULTI-CRITERIA DECISION METHODS IN THE EVALUATION OF SOCIAL HOUSING PROJECTS

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Abstract. The evaluation of social housing projects is a complex process that requires the consideration of multiple factors and dimensions to make informed decisions to address the emerging challenges of contemporary urbanization and achieve more resilient and sustainable communities. This study's comprehensive review of the existing literature on the use of Multi-Criteria Decision Methods (MCDM) in evaluating social housing projects was undertaken. An exhaustive analysis of a bibliographic set of 93 articles published between 1994 and March 2025 was conducted. It was noted that the articles analyzed different phases of the construction process, from planning and design to implementation and maintenance. Significant trends in the use of MCDM were identified, highlighting the prevalence of crisp number-based approaches and the emergence of modern techniques such as fuzzy logic and neutrosophic logic. Among the most widely used methods were AHP and TOPSIS, both pioneering methods. In addition, there was an increasing focus on sustainability in project evaluation, encompassing environmental, social, economic, and technical aspects. Consequently, this literature review serves as a guide for incorporating multi-criteria evaluation strategies to improve constructability, especially in social housing projects, taking sustainability into consideration.

Keywords: multi-criteria decision-making, decision making, MCDM, social housing project, social housing, constructability, sustainability.

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1. Introduction

Housing, as the physical refuge providing security and shelter to individuals and families, is pivotal in meeting the population's essential needs and shaping social cohesion, which are vital determinants of quality of life and well-being (Golubchikov & Badyina, 2012). The challenge of population growth and urbanization poses a significant dilemma for contemporary societies. This expansion of urban areas and accelerated socio-economic progress have exacerbated housing shortages in developed and developing nations (Mandala & Nayaka, 2023). With the global population rapidly increasing, cities are confronted with mounting demands for housing that is not only affordable but also environmentally and socially sustainable (John et al., 2005; Marzouk et al., 2016).

Ironically, the conventional housing construction paradigm contributes to escalating housing expenses across its life cycle, with a significant portion of these costs manifesting post-construction during the occupancy phase as detrimental health implications, besides exerting undesirable strains on environmental performance (Marzouk et al., 2016). However, haphazard urban development has fostered the proliferation of informal settlements and inadequate basic infrastructure, further widening the chasm in accessing decent housing. Within this context, social housing emerges as a pivotal solution to redress the housing needs of vulnerable populations and foster social inclusion within urban landscapes. Social housing is designed to be accessible to middle- and low-income individuals and families while ensuring minimum standards of habitability and quality of life (Cerón-Palma et al., 2013; Giannetti et al., 2018). However, the adequate conception and execution of social housing initiatives mandate a comprehensive approach encompassing myriad facets, from economic viability to environmental sustainability and social equity.

Diverse approaches exist to tackle this problem, spanning housing policies, strategic urban planning, urban vulnerability assessments (Salas & Yepes, 2018a) and zoning to construction methodologies (Brissi et al., 2021). The quest for sustainable solutions in social housing is becoming increasingly urgent in a world where unbridled urbanization jeopardizes the livelihoods of millions. Construction endeavors entail multiple participants and stakeholders, with knowledge, technologies (Rutten et al., 2009), and materials dispersed across various entities. This makes integrating new technologies or products challenging due to mutual distrust, inadequate communication, and time and budgetary constraints. Mainly, the advancement of sustainable housing necessitates the construction of cost-effective residences and incorporating practices and technologies that mitigate environmental impact and enhance urban communities' resilience (Zhang et al., 2020).

In this context, Multi-Criteria Decision Methods (MCDM) are presented as essential tools for evaluating and prioritizing various options based on multiple factors. These methods provide a structured framework for informed decision-making, integrating quantitative and qualitative criteria in various fields of application. For instance, Ordu and Der (2023), Der et al. (2024a, 2024b), and Siva Bhaskar and Khan (2022) highlight the advantages of integrating different MCDM techniques to enhance decision-making in polymeric material selection, thermal management, and manufacturing processes. Additionally, Kabir et al. (2014), Stojčić et al. (2019) and Ogrodnik (2019) explored decision-making applications in civil engineering and construction; Schramm et al. (2020) in sustainable supplier selection; Si et al. (2016) in green building technologies; Govindan et al. (2016) in sustainable materials selection. Studies of the applications of MCDMs in combination with other tools have also been carried out (Lozano et al., 2023; Tan et al., 2021).

Similarly, MCDM serves as a tool to evaluate and select the best alternatives in designing and managing social housing projects. These methods allow consideration of a variety of relevant criteria, such as cost (Chen & Gallardo, 2024), accessibility (Maliene et al., 2018), quality of life (Hu & Tzeng, 2019), and energy efficiency (Khadra et al., 2020), among others, and provide an analytical framework for making informed and equitable decisions. The study of these is the basis for comparing and evaluating project performance. Importantly, MCDMs are not just tools, but they are tools that align with the Sustainable Development Goals (SDGs) set by the United Nations. This article conducts a systematic review of the role of MCDMs in analyzing social housing, demonstrating their relevance to global priorities. Through a structured literature review, we examine how these approaches can contribute to building more resilient, inclusive, and sustainable communities, thereby addressing the emerging challenges of contemporary urbanization. By synthesizing key trends and methodological advancements, this study identifies critical research gaps and future directions in the application of MCDMs to social housing projects.

2. Materials and methods

2.1. Data collection strategy

Figure 1 provides an overview of the various stages of this research. The primary goal of the first stage is to generate an initial set of contributions that will serve as the bedrock for the subsequent stage. This is achieved through a meticulous filtering and broadening procedure in the second stage, ensuring that the research makes significant and valuable contributions to the field. The research questions are initially defined, and keywords are established for the search process. These keywords comprehensively cover the research topic, scope, and specific areas of interest, forming a search algorithm to identify articles from an initial set. The exploration primarily uses academic databases such as Web of Science and Scopus. The search period spans from 1994 to March 2025, as the first relevant article on the topic was published in 1994, as identified in the preliminary review of the literature.

The search process commenced with a combination of three distinct terms connected by the Boolean operators AND and OR. In Figure 1, the term 'social housing' encapsulates the research objective, with keywords like 'social housing', 'social interest housing', 'social interest housing projects', 'low-income housing', 'housing of social interest', 'housing projects', 'mass housing', 'mass housing construction project', 'mass housing projects', 'mass housing construction', 'public housing', 'low-cost housing', and 'affordable housing'. This broad scope is crucial as it provides a comprehensive understanding of the social housing landscape. The second term relates to the methods used, represented by 'MCDM' (Multi-Criteria Decision Making). Literature reviews of the most utilized MCDM methods in civil engineering, as documented by sources Minhas et al. (2018), Zhu et al. (2021), Nadkarni and Puthuvayi (2020), and Zavadskas et al. (2017) were considered. Keywords for this term include 'MCDM', 'multi-criteria decision making', 'decision making', 'multi-attribute decision making', 'AHP', 'ANP', 'COPRAS', 'ELECTRE', 'FUZZY', 'MAUT', 'PROMETHEE', 'TOPSIS', 'VIKOR', 'MIVES', 'DEMATEL', 'ARAS', 'MOORA', 'MABAC', 'WASPAS', and 'WSM'.

The third term, 'structure type', delimits the type of structure with keywords such as 'house', 'home', 'residential', and 'building'.

2.2. Quantitative analysis

This stage centers on examining the 93 identified articles, employing quantitative methods to discern patterns, trends, and numerical relationships within the reviewed scientific literature. Such scrutiny lends a more objective and systematic perspective to the available evidence in the realm of social housing, enabling the interpretation of findings for pertinent and contemporary insights through qualitative analysis.

2.3. Qualitative analysis

Qualitative analysis encompasses the evaluation and interpretation of data garnered through systematic review processes. It endeavors to identify research themes, relationships, and trends elucidated within the literature; this may involve coding data and categorizing similar findings into thematic clusters.

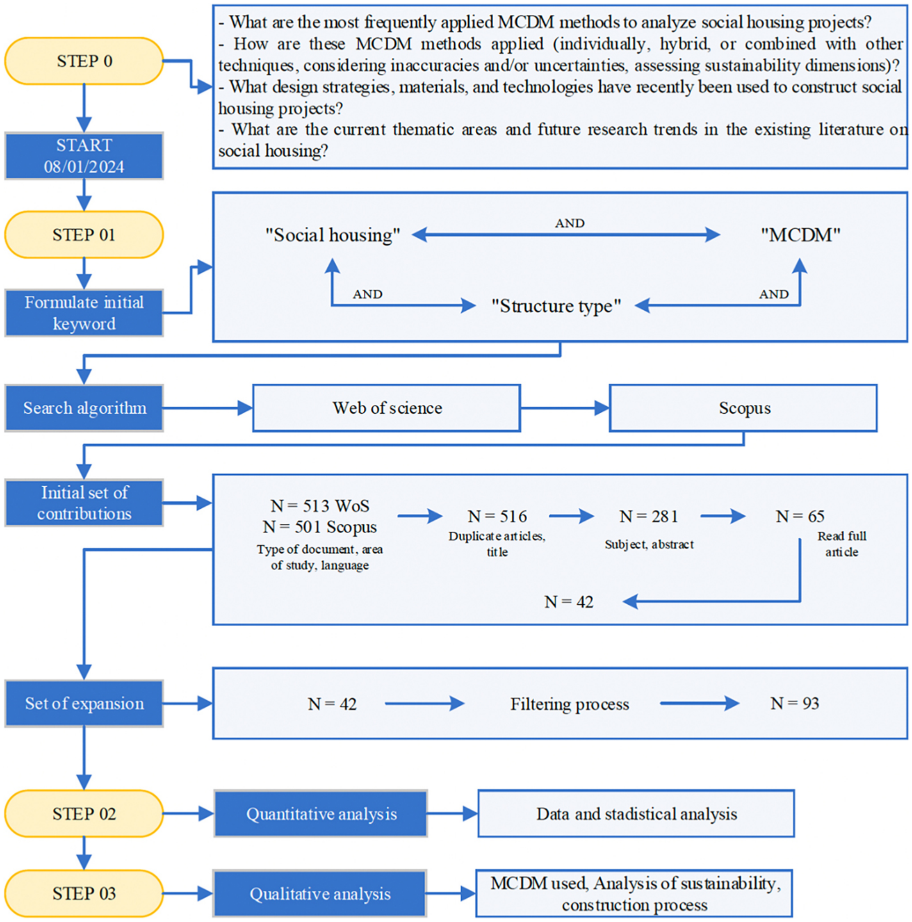

Figure 1. Flow chart illustrating the systematic data sampling process

3. Analysis of the results

3.1. General overview of the data

The significance of social housing is that it exhibits considerable variation from one country to another, influenced by many factors such as political ideologies, economic structures, and population-specific needs. Figure 2 illustrates the distribution of publications by country of origin, shedding light on the extent of research endeavors in social housing and emphasizing the contributions made by various nations in this domain. Notably, China leads with 16 papers, followed closely by Spain (13 papers) and Iran (10 papers), with Lithuania (8 papers) and Brazil (7 papers) trailing behind. China's prolific publication output aligns with its extensive urbanization efforts, prioritizing ecosystem service-oriented urban development and emphasizing environmental, social, and economic sustainability (Huang et al., 2022). In Europe, Spain and Lithuania stand out for their research predominantly focused on single-family dwellings, notwithstanding the prevalence of residential buildings, especially in densely populated urban zones where apartments dominate. Latin America, characterized by high urbanization rates and significant rural-to-urban migration, highlights Brazil's noteworthy contribution to social housing literature. It underscores the nation's challenges in addressing informal settlements across diverse bioclimatic zones. The housing sector in Brazil accounts for a substantial portion of the construction industry's capital flow, attributable to pervasive housing inadequacies prevalent in many developing nations. Iranian cities, experiencing rapid urban growth, grapple with mounting demand for affordable housing, compounded by urban sprawl issues stemming from inadequate infrastructure and urban planning deficiencies. Consequently, international building assessment tools find utility in addressing these challenges, particularly within the residential sector (Zarghami et al., 2018).

Table 1 provides a Quantitative Analysis of Scientific Production, offering a concise overview of the development, dynamics, trends, and interrelations within scientific practice (Michán & Muñoz-Velasco, 2013). Notably, China, Spain, and Iran emerge as prominent contributors in publication volume, yet England and Lithuania lead in citation count, signifying their active engagement within the scientific community. However, when evaluating the generation of noteworthy research outcomes (average number of citations) and impactful contributions to ongoing research (average number of normalized citations), England, Italy, and Australia assume leadership positions. Additionally, the Total Link indicator highlights the interconnections between

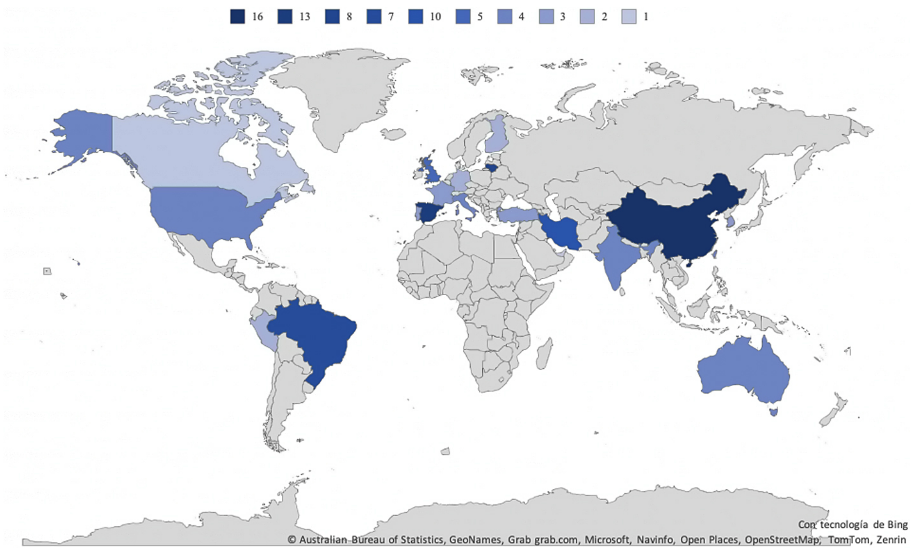

Figure 2. Distribution of publications by country

countries based on their collaborative publications, providing insight into the strength of the global research network in this field. Notably, Iran and China exhibit the strongest links, indicating the most significant collaborative relationships in the context of this research. It is worth noting that while countries like China, Spain, and Iran exhibit prolific publication rates, their relatively lower citation metrics suggest a disparity in the perceived relevance of their contributions to the field.

Table 2 presents the nine Most Significant Sources, each containing more than three articles. This analysis provides insights into the link strength, number of published articles, and citations associated with each source. The Total link indicator in measures the interconnections between these journals based on mutual citations, providing insight into their influence and relationship within the broader scientific network. Topping the list is *Sustainability* journal with 11 articles (12%), trailed by *Building and Environment* (9%) and *Journal of Building Engineering* (8%). Further down the ranking, we find *Journal of Construction Engineering and Management* (5%), *Journal of Civil Engineering and Management*, and *Journal of Cleaner Production* (4% each). In terms of publication influence, journals boasting the highest average number of citations per article include *Sustainability*, *Building and Environment*, *Journal of Building Engineering*, and *Journal of Construction Engineering and Management*. A higher average number of normalized citations underscores a significant impact within their respective fields. Leading the pack in this regard are *Building and Environment*, *Journal of Civil Engineering and Management*, and *Journal of Cleaner Production*, closely followed by *Sustainable Cities and Society*, thus exemplifying their current influence through average normalized citation metrics.

Figure 3 illustrates publications' temporal distribution and trajectory about MCDM and social housing. While the earliest research dates back to 1994, the volume of annual publications remained relatively low until 2012, marking the onset of a significant upsurge. Although this study did not restrict publication periods, over 77% of publications applying MCDM techniques to social housing emerged between 2016 and the present, delineating a pronounced trend within the scientific area of social housing. Moreover, this surge aligns with adopting the 2030 Agenda in

Table 1. Countries active in research

Countries	Total Link	Document	Citations	Avg. Pub. Year	Avg. Citations	Norm. Citations	Avg. Norm. Citations
China	6	16	350	2019	21.88	24.86	1.55
Spain	4	13	431	2020	33.15	36.17	2.78
Lithuania	3	8	661	2017	66.10	36.61	3.66
Brazil	4	7	285	2019	40.71	23.75	3.39
Iran	8	10	280	2022	23.33	23.42	1.95
England	3	5	651	2016	130.20	46.57	9.31
Australia	4	6	239	2019	39.83	26.33	4.39
Italy	4	4	166	2018	41.50	20.75	5.19
USA	4	7	291	1999	41.57	11.31	1.62
France	2	3	14	2023	4.67	5.00	1.67
India	2	4	58	2022	14.50	9.63	2.41
Portugal	2	3	63	2014	21.00	3.74	1.25

2015, which encompasses Sustainable Development Goal 11 (SDG 11), emphasizing "Sustainable Cities and Communities". SDG 11 endeavors to ensure access to adequate, safe, affordable, and sustainable housing for all, alongside enhancing disaster resilience in human settlements. Concurrently, 2015 witnessed the United Nations Conference on Human Settlements (Habitat III) convening, where the New Urban Agenda was adopted. This agenda serves as a global blueprint for sustainable urban development in the ensuing decades, underscoring the pivotal role of adequate and sustainable housing as a cornerstone for achieving sustainable cities.

The comprehensive examination of the selected works reveals that the articles can be categorized into three fundamental types of structures: Single-family houses (35 articles), collective housing projects (31 articles), and residential buildings (27 articles). These categories constitute the bedrock upon which the housing fabric of the studied populations is constructed. Housing, perceived as both a physical and emotional space where daily activities unfold, will be scrutinized through its dimensions of accessibility, habitability, and functionality (Golubchikov & Badyina, 2012). Recognizing the significance of social housing in enhancing living conditions, various stakeholders, including governmental entities, municipalities (Jiang et al., 2023), developers, builders, and consumers (Natividade-Jesus et al., 2007), are vested in its improvement. Housing projects envisioned and executed by the construction sector to address the burgeoning demand for housing (Karji et al., 2019) encompass considerations such as location (Banaitiene et al., 2008), architectural design (Balali et al., 2014), materials used (Karamoozian & Hong, 2023), and social inclusion policies (Tupenaite et al., 2018).

Meanwhile, residential buildings, serving as collective housing units (Gou et al., 2018), will be evaluated for their capacity to foster community coexistence and ensure the provision of essential services (Klumbyte et al., 2021). An in-depth analysis of each component will not only elucidate the physical and architectural infrastructure but also shed light on the planning (Kontu et al., 2015), design (Usman & Frey, 2022), and implementation (Balasbaneh & Sher, 2021) processes integral to creating and managing affordable and suitable housing spaces for the populace. From the individual scale of housing to the collective scale of residential buildings, various social, economic, environmental, and technical aspects influencing the effectiveness and sustainability of social housing will be explored. This research primarily employs case studies that illustrate various stages of the construction process for single-family housing projects, group housing projects, and residential buildings.

Table 2. Source analysis

Journal	Total link	Documents	Citations	Avg. Pub. Year	Avg. Citations	Norm. Citations	Avg. Norm. Citations
Sustainability	28	11	645	2022	58.64	15.89	1.44
Building and environment	21	8	617	2017	77.13	48.65	6.08
Journal of Building Engineering	19	7	493	2022	70.43	27.17	3.88
Journal of Construction Engineering and Management	11	5	308	2014	61.60	15.88	3.18
Journal of Civil Engineering and Management	4	4	126	2013	31.50	23.44	5.86
Journal of Cleaner Production	12	4	230	2020	57.50	20.20	5.05
Energies	5	3	212	2019	70.67	3.23	1.08
Engineering Construction and Architectural Management	7	3	232	2021	77.33	7.83	2.61
Sustainable Cities and Society	6	3	275	2019	91.67	13.20	4.40

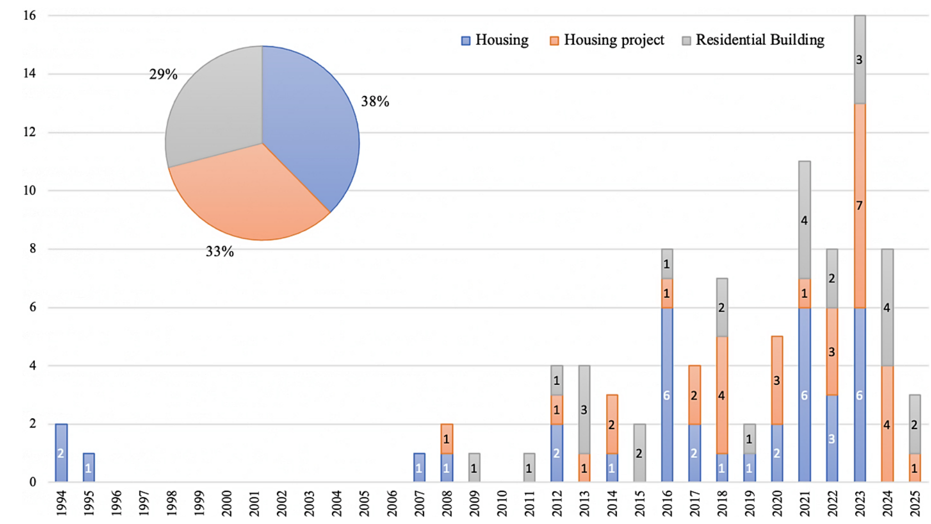

Figure 3. Number of publications grouped by year and structure type (1994 – March 2025)

These stages align with the design and construction phases identified by sources (Klinger & Susong, 2006; Bley, 2002). Five essential phases have been identified in this process: Conceptual planning, Design, Procurement, Construction, and Maintenance and commissioning. These phases are crucial for the successful development and implementation of construction projects.

3.2. Distribution by MCDM methods applied

MCDM methods serve as potent decision-making tools in multiple objectives or criteria scenarios. They facilitate evaluating and comparing alternatives based on several crucial aspects, aiding in making informed and balanced decisions. These methods can be categorized into distinct groups based on similar characteristics: scoring methods, distance-based methods, pairwise comparison methods, outranking methods, and multi-attribute utility methods (De Brito & Evers, 2016; Hajkowicz & Collins, 2007):

- **Scoring Methods:** These methods involve assigning numerical scores to relevant criteria, facilitating comparison and evaluation of hierarchically structured complex quantities. According to Podvezko (2011), Simple Additive Weighting (SAW) and Complex Proportional Assessment (COPRAS) have common properties that allow them to be used for the comparison and assessment of criteria and to describe hierarchically structured complex quantities, which are of the same hierarchical level.
- **Distance-based Methods:** Utilized to evaluate and compare alternatives by measuring the distance between them, these methods determine the shortest distance from the positive ideal point and the longest distance to the negative ideal point (Zhu et al., 2021). Some of them are TOPSIS, Multi-criteria Optimization and Compromise Solution (VIKOR), Additive Ratio Assessment (ARAS), and Evaluation Based on Distance to Average Solution (EDAS).
- **Pairwise Comparison Methods:** These methods entail directly comparing alternatives to determine preferences based on specific criteria. Representative examples include the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP).
- **Outranking Methods:** Based on the notion of a single optimal alternative being preferable if it is equal or superior in all criteria and at least one of them. Prominent examples include the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE) and the Elimination and Choice Expressing Reality Method (ELECTRE).
- **Multi-attribute Utility (Value) Functions:** These methods represent the decision-maker's preferences and satisfaction through utility/value functions. Examples include the Multi-Attribute Utility Methods (MAUT), Scaled Weighted Assessment Ratio Analysis (SWARA), and Model Integrated Value for Sustainable Evaluation (MIVES).

Figure 4 illustrates the frequency of MCDM methods employed in the final ranking of social housing research. The most prevalent category is pairwise comparison, constituting 48% of the reviewed articles, with AHP being the standout method utilized in 41 articles. The following is the category of distance-based methods, which account for approximately 21% of usage, with TOPSIS emerging as the predominant choice. COPRAS and MIVES also garnered notable usage in 6 and 5 articles, respectively. In the "Other" category, researchers explore additional methods, including CORST (Complex Proportional Assessment), ARCAS (Additive Ratio Compromise Assessment), SMAA (Stochastic Multicriteria Acceptability Analysis), DEMATEL (Decision Making Trial and Evaluation Laboratory), and WASPAS (Weighted Aggregated Sum Product Assessment). MCDMs are utilized in their singular form, called single MCDMs (53 articles), or combined with other MCDMs, known as hybrid MCDMs (40 articles).

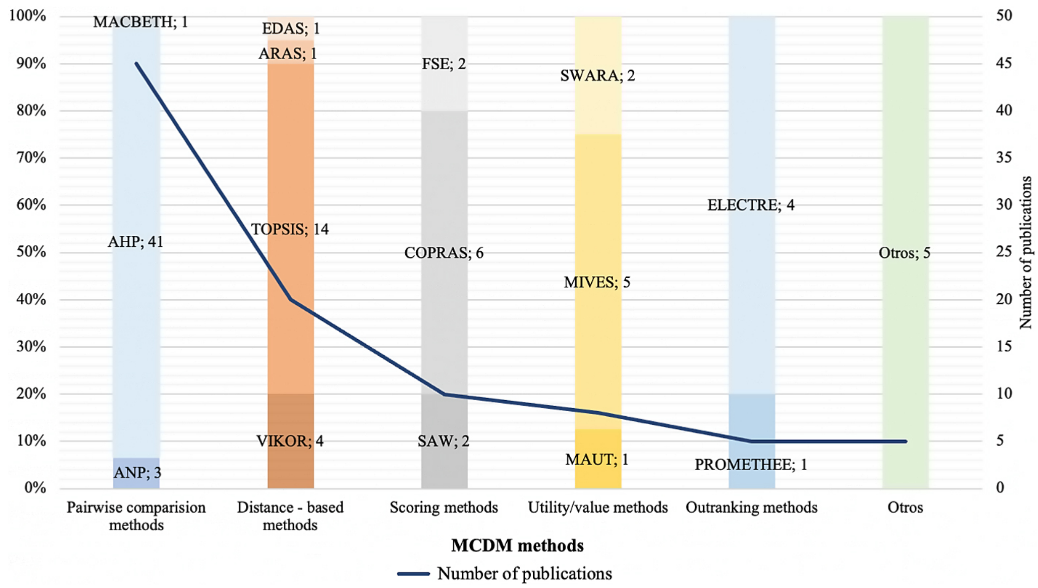

Figure 4. MCDM methods used in social housing by category

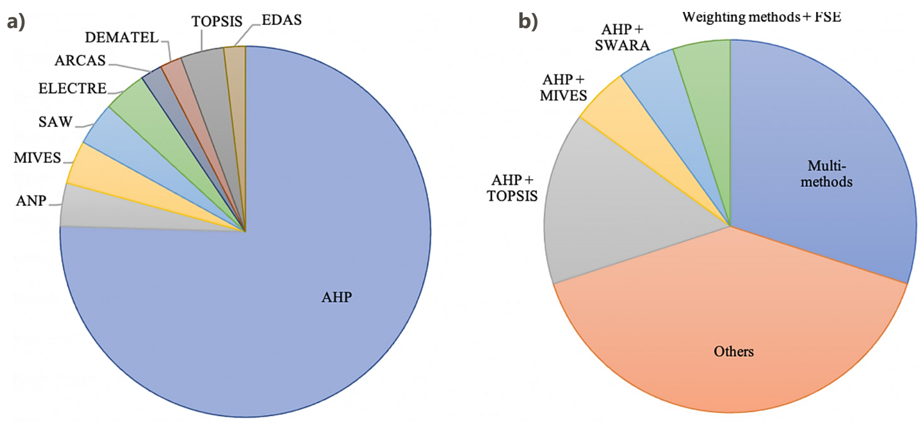

Figure 5. MCDM methods used in social housing: a – individual MCDM; b – hybrid MCDM

Figure 5 illustrates the individual MCDMs explored in the literature. AHP emerges as the dominant method, comprising 75% of the cases. Pioneering works by Schniederjans et al. (1995) and Ball and Srinivasan (1994) utilize MCDMs in housing evaluation, considering social and architectural aspects to facilitate optimal decision-making regarding attribute selection. Notably, within this percentage, Abastante et al. (2018) employ the Parsimonious AHP, which streamlines the conventional AHP by necessitating pairwise comparisons only for a subset of benchmark assessments defined for each criterion. Akola et al. (2023) employ an AHP-SWOT analysis to compare pairwise factors promoting infrastructure in informal settlements. ANP finds application in studies by Dezhi et al. (2016) and Li et al. (2014), while ARCAS is utilized by Flores-Abascal et al. (2023) to assess MEP (Mechanical, Electrical, and Plumbing) facility renovations in a multi-family building. MIVES is applied by Cardenas-Gomez et al. (2021) and Zolfaghari et al. (2023), while Falcao et al. (2021) leverages SAW with spatial indicators calculated via Geographic Information Systems (GIS) to evaluate historic residential buildings. Tupenaite et al. (2018) also utilize SAW to evaluate residential buildings. In assessing energy performance, Baseer et al. (2023) and Daniel and Ghiaus (2023) employ ELECTRE-Tri, which allows for categorizing alternatives based on probabilities rather than precise values, enabling the utilization of extensive energy measurement data. While individual methods offer a focused approach to decision-making, their rigidity in handling diverse decision scenarios underscores the importance of transitioning towards hybrid methods. Hybrid methods integrate MCDM techniques with other tools to enhance decision-support capabilities (Ye et al., 2022). Zavadskas et al. (2016) advocate for combinations of methods dedicated to ranking alternatives, including:

- MCDM method + method for identifying criteria importance (relative significance).
- MCDM method + one or more MCDM methods.
- MCDM method + other methods.

Hybrid MCDMs, primarily combinations of MCDM methods, frequently feature the AHP + TOPSIS combination, although its widespread adoption remains limited. This preference stems from AHP's ability to structure decision criteria systematically and TOPSIS's capacity to identify and rank alternatives based on real-world considerations (Tan et al., 2021). For instance, Francis and Thomas (2023a) utilize this hybrid approach for multiple building scenarios, while Silva et al. (2016) underscore its advantages in building simulation to enhance performance. In contrast, Sharghi et al. (2023) employ AHP, TOPSIS, and GIS to locate affordable housing. Usman and Frey (2022) utilize Criteria Importance Through Intercriteria Correlation (CRITIC) for weighting attributes and TOPSIS for ranking energy system alternatives combined with design parameters. Nikbakht et al. (2024) used AHP and VIKOR methods to identify project delays, noting that their impacts on cost, time, and quality are not uniform. Multiple methods are employed in several studies, including weighted sum, weighted product, TOPSIS, ELECTRE, VIKOR, MIVES, COPRAS, and PROMETHEE. Mela et al. (2012) note that the Weighted Sum Mode (WSM), Weighted Product Model (WPM), and TOPSIS yield nearly identical results when evaluating dwelling retrofitting based on cost, resource efficiency, and aesthetic preferences. In sustainability evaluations, Hosseini et al. (2016b) and Sánchez-Garrido et al. (2022b) affirm MIVES's suitability for multi-criteria decisions in social housing and modern construction methods, respectively. Similar results are found with TOPSIS and COPRAS (Sánchez-Garrido et al., 2022a), while Mulliner et al. (2016) observe similarities among TOPSIS, COPRAS, WSM, and AHP. Zavadskas et al. (2024) identify parallels between ARAS and SAW, highlighting the importance of method compatibility depending on the problem or decision context. Kamali et al. (2018) employ a combination of AHP, ELECTRE, and TOPSIS, assigning criteria weights via AHP, analyzing construction experts' feedback using ELECTRE to rank sustainability performance criteria, and using TOPSIS to develop sustainability indices.

Crispy numbers, also called crisp numbers, represent precise values assigned to each alternative in a multi-criteria evaluation process, aiding in incorporating the inherent imprecision or vagueness of many human concepts. They facilitate converting qualitative information into quantitative data, thereby streamlining analysis and comparison among alternatives. Despite using similar terminology, individual judgments of events may vary significantly due to differences in subjective perspectives (Abdel-Malak et al., 2017). Hence, in some instances, using crispy numbers may only partially capture the associated uncertainty or variability, necessitating consideration of methods capable of handling such uncertainties. Issa et al. (2019) highlight that MCDM problems in civil engineering are complex due to many evaluation criteria and inherent conflicts, such as the trade-off between high quality and low cost.

Consequently, fuzzy numbers are essential for quantitatively expressing linguistic variables that describe decision-makers' subjective judgments (Nădăban et al., 2016). However, its incorporation into the research setting is not always evident despite the need for fuzzy logic. These models, categorized into individual fuzzy MCDM models and hybrid fuzzy MCDM models based on the number of decision methods used, underscore the versatility of fuzzy logic in decision-making processes. Among individual MCDM methods, combining the AHP method with fuzzy logic is studied by Hsueh (2012) and Zarghami et al. (2018), which incorporate the Delphi method and utility theory into their evaluations, respectively. Additionally, Figueiredo et al. (2021) and Zhang et al. (2021a) integrate fuzzy AHP with the Building Information Modelling (BIM) methodology. An innovative approach is demonstrated by Raut and Mahajan (2015), who integrate the QFD (Quality Function Deployment) benchmarking process methodology with fuzzy-AHP to identify areas for achieving user satisfaction. Hatefi et al. (2025) combine the fuzzy methodology with the EDAS method to assess risks in massive construction projects, considering the high volume of work involved.

Similarly, Wu et al. (2024) combine the DEMATEL method with fuzzy logic to elucidate cause-effect relationships in promoting prefabricated housing, represented through dynamic systems. Other researchers explore combinations such as fuzzy TOPSIS, as seen in Malakouti et al. (2019), which relates to QFD. Within hybrid MCDM methods, few studies combine the fuzzy synthetic evaluation technique (FSE) with scoring methods, as observed in studies by Adabre and Chan (2020) and Chadee et al. (2023). Furthermore, Jiang et al. (2023) employ the fuzzy Decision Evaluation and Testing Laboratory (fuzzy DEMATEL) technique combined with ANP (DANP) to prioritize performance improvements for each alternative. Finally, in the study by Aghazadeh et al. (2022), a hybrid MCDM method is based on fuzzy SWARA and fuzzy ARAS methods to evaluate critical factors in the sustainable materials selection process.

As depicted in Figure 6, the prevalence of studies employing crisp numbers is evident, with 78 articles (84%) utilizing this mathematical logic. This dominance suggests that information on social housing is mainly based on exact and absolute data without considering the complexity of human cognition. Given that housing encompasses physical and social dimensions (Golubchikov & Badyina, 2012), it becomes imperative to acknowledge the uncertainty and ambiguity inherent in human data. Consequently, fuzzy numbers emerge as invaluable tools in such research endeavors. Efforts to incorporate fuzzy number research, individually and in hybrid forms, have been noticeable since 2011, with 14 manuscripts (15%) employing various weighting techniques to evaluate social housing. Neutrosophic logic has been utilized in a study (1%) evaluates sustainable alternatives for single-family housing structures. Sánchez-Garrido et al. (2021) utilized neutrosophic logic to derive weights in a Hierarchical Analytical Process (N-AHP), considering the subjectivity of a group of experts in complex decision-making processes. In MCDM studies, sensitivity analysis is paramount in determining the robustness of methods and the validity of results (Şahin, 2020), assisting decision-makers in gauging the sufficiency of robustness and accuracy. The literature reviewed reveals that most authors undertake sensitivity analysis by varying criteria weights (Ali & Al Nsairat, 2009; Falcao et al., 2021; Francis & Thomas, 2023a; Kama-

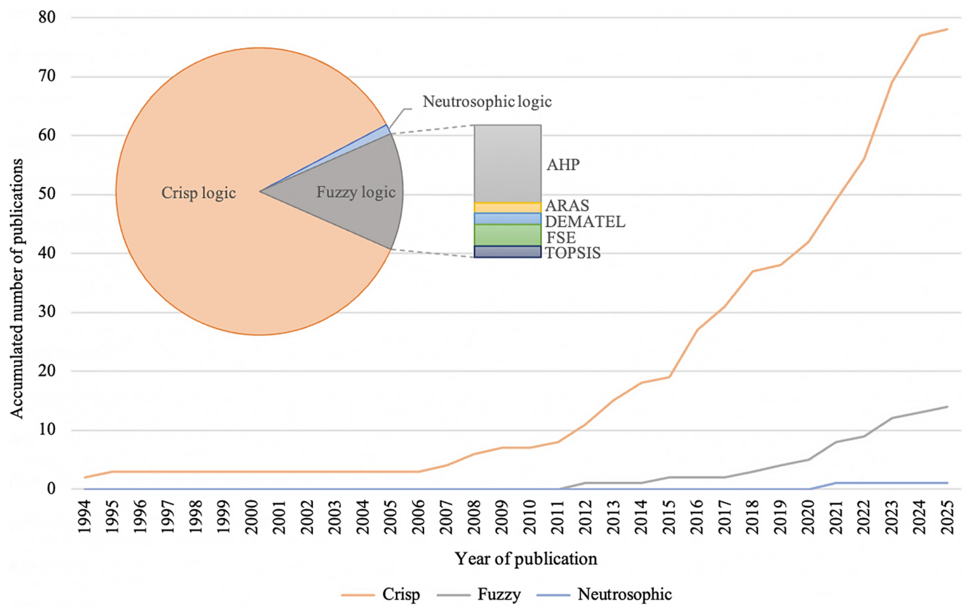

Figure 6. Distribution of MCDMs under uncertainty management (1994 – March 2025)

li et al., 2018; Sánchez-Garrido & Yepes, 2020; Seth et al., 2018). Alternatively, others assess sensitivity by considering one or more criteria as dominant (Sharghi et al., 2023; Zarghami et al., 2018). Silva et al. (2016) create new scenarios based on climatological zone variables they analyze, contrasting them against existing ones. Another approach involves calculating all possible combinations (Sánchez-Garrido et al., 2022b; Zolfaghari et al., 2023). Sánchez-Garrido et al. (2022a) assess the stability of the chosen method by juxtaposing it with other MCDMs (e.g., TOPSIS and COPRAS). de Azevedo et al. (2013) conducted their analysis utilizing software tools. Moreover, according to Antucheviciene et al. (2015), two types of sensitivity analysis exist: local and global. Local analysis evaluates how model results vary around a specific point in the variable space, whereas global analysis perturbs the entire input parameter space. In line with this classification, Amorocho and Hartmann (2022) employ both analyses, utilizing the local one to assess the performance of model-involved parties and the global one to formulate new scenarios for all variables. Despite its crucial role in ensuring model certainty, only 17 of the reviewed articles employed sensitivity analysis to enhance the robustness of results. Similarly, scant utilization of fuzzy logic is present in the reviewed articles, with only 12 instances identified.

3.3. Distribution by criteria assessed

The selection and development of criteria require parameters related to reliability, appropriateness, feasibility, and measurement limitations (Wang et al., 2009). Articles considering economic, social, environmental, and technical criteria allow for a comprehensive assessment of housing sustainability. However, technical criteria, including construction quality, energy efficiency, and structural safety, are particularly crucial (Hill & Bowen, 1997). This study's criteria for evaluating social housing are divided into four categories: technical, economic, environmental, and social. These criteria are essential for ensuring housing habitability, safety, comfort, technical performance, and operational efficiency. Seven articles (7.5%) assessed housing based on a single criterion, while 22 (24%) used a two-dimensional approach, 47 (50.5%) utilized three-dimensional criteria, and 17 (18%) considered all four dimensions. The numerous indicators and measurement tools being developed underscore the importance of conceptual and methodological advancements in social housing.

Table 3 outlines the primary indicators for economic, environmental, social, and technical criteria. Economic considerations feature in 63 (68%) articles, predominantly focusing on construction, repair and maintenance costs, and operational expenses of housing projects. Material costs (Daniel & Ghiaus, 2023) and manufacturing costs (Aghazadeh et al., 2022) are notable components of construction expenses. Some studies evaluate repair and maintenance costs over varying periods, ranging from 10 to 50 years (Salim & Dabous, 2025; Sánchez-Garrido et al., 2022a; Sánchez-Garrido & Yepes, 2020; Zolfaghari et al., 2023). Only seven items include the life cycle cost (LCC) indicator defined by ISO 15686-5 (International Organization for Standardization [ISO], 2017) this standard divides LCC into four parts: construction, operation, maintenance, and end-of-life costs. It is worth noting that the scope of LCC is not static and can increase or decrease depending on the actual situation (Lu et al., 2023).

Environmental criteria in 62 (67%) articles encompass five main aspects of the reviewed studies: energy consumption, water efficiency, pollutant emissions, waste management, and life cycle energy (LCE). 28.8% of the studies include energy consumption assessment. Most articles focus on identifying energy consumption patterns and potential areas for improvement (de Azevedo et al., 2013; Vitorio Jr. et al., 2022; Zhu et al., 2021), while some, like Hsueh (2012), consider energy consumed during material manufacturing processes. Pollutant emissions are the second most evaluated environmental aspect, with studies like Hosseini et al. (2020) and Francis and Thomas (2023b) considering emissions across the life cycle. Hosseini et al. (2016b) and Namaki et al. (2024) quantify the volume of CO_2 emissions relative to the preparatory activities undertaken at each construction site during the construction phase, as well as the transportation requirements for each site during both the construction and demolition phases. Waste management is addressed in various contexts, from recycling process enhancements (Mulliner et al., 2013) to waste management in manufacturing, construction, and demolition procedures (Hosseini et al., 2020; Sánchez-Garrido et al., 2022a, 2022b). As Francis and Thomas (2023a) and Kung et al. (2025) conducted, LCE assessment encompasses total energy consumption across all building phases, including embodied energy, construction, operation, maintenance, and demolition energy.

The social approach is present in 73 articles (78%), and the criteria evaluated in the studies reviewed include health and safety, level of comfort, ease of services, and user satisfaction. Health and safety evaluations cover construction company practices to protect workers and infrastructure user safety (Aghazadeh et al., 2022; Pan et al., 2012; Pons & de la Fuente, 2013) and health risks for housing occupants (Sánchez-Garrido et al., 2022a). Comfort assessments span thermal, acoustic (Amorocho & Hartmann, 2022; Baseer et al., 2023; Daniel & Ghiaus, 2023), and indoor air comfort levels (Chen et al., 2017), as well as aesthetic comfort (Adabre & Chan, 2020). Evaluations of service accessibility, including public transport, essential services, and proximity to amenities, aim to enhance the quality of life (Han et al., 2024). User satisfaction, a key indicator, is evaluated based on amenities, neighborhood inclusivity, and homeowner contentment (Hosseini et al., 2016b; Wu et al., 2021).

In the technical dimension, 62 (67%) articles include project specifications, design, construction, and scheduling criteria. Project specifications encompass technical standards and design, with considerations for material selection, equipment, and regulatory compliance (Aghazadeh et al., 2022; Chen et al., 2017; Faraji et al., 2024; Natividade-Jesus et al., 2007). Design criteria emphasize space

Table 3. Main criteria and indicators

	Criteria	Indicator	Assessment	Relevant papers
Economic Criteria	Construction cost	€/output unit	Quantitative	Ali and Al Nsairat (2009), Hosseini et al. (2016a, 2016b), Balali et al. (2014), Bianchi et al. (2021), Cardenas-Gomez et al. (2021), de Azevedo et al. (2013), Jiang et al. (2023), Lazar and Chithra (2021), Sánchez-Garrido et al. (2022b)
	Repair and maintenance cost	€/m^2 × period of time in years	Quantitative	Adabre and Chan (2020), Hosseini et al. (2016b), Salim and Dabous (2025), Sánchez-Garrido et al. (2022a, 2022b), Sánchez-Garrido and Yepes (2020)
	Operational cost	€/output unit	Quantitative	Huh et al. (2012), Invidiata et al. (2018), Mela et al. (2012), Schniederjans et al. (1995)
	Property value	€/output unit	Quantitative	Mulliner et al. (2016), Tupenaite et al. (2018)
	Life cycle energy	€/m^2	Quantitative	Balasbaneh and Sher (2021), Dezhi et al. (2016), Figueiredo et al. (2021), Motuziene et al., (2016)
Environmental Criteria	Criteria	Indicator	Assessment	Relevant papers
	Energy consumption	kWh/m^2 × year	Quantitative	Flores-Abascal et al. (2023), Hsueh (2012), Karamoozian and Hong (2023), Mela et al. (2012), Mulliner et al. (2013), Pan et al. (2012), Raut et al. (2016), Staniunas et al. (2013), Zarghami et al. (2018)
	Water efficiency	KL or points	Quantitative	Dezhi et al. (2016), Francis and Thomas (2023a), Sánchez-Garrido et al. (2022a)
	Emissions	CO_2 / NO_2 emissions	Quantitative	Aljalal et al. (2023), Daget and Zhang (2020), Flores-Abascal et al. (2023), Namaki et al. (2024), Pons and de la Fuente (2013), Sharghi et al. (2023)
	Waste management	kg/m^2	Quantitative	Hosseini et al. (2016a), Balasbaneh and Sher (2021), Eryuruk et al. (2022), Karamoozian and Hong (2023), Mulliner et al. (2016)
	Life cycle energy	GJ	Quantitative	Francis and Thomas (2023a), Kung et al. (2025), Lotfi et al. (2024)
Social Criteria	Criteria	Indicator	Assessment	Relevant papers
	Accessibility	Using GIS interface	Qualitative	Amorocho and Hartmann (2022), Cardona-Trujillo et al. (2023), Falcao et al. (2021), Zhang et al. (2021), Zolfaghari et al. (2023)
	Ease of services	Public transport	Qualitative	Chadchan et al. (2024), Han et al. (2024), Jiang et al. (2023), Klumbyte et al. (2021), Mulliner et al. (2016), Raut and Mahajan (2015)
		Provision of essential services (light, water)	Quantitative	
		Access to hospitals, schools, restaurants	Quantitative	
	Comfort level	Thermal comfort	Qualitative	Apolinário and Kowalski (2023), Balasbaneh and Sher (2021), Daniel and Ghiaus (2023), Hosseini et al. (2020), Lai and Yik (2011), Natividade-Jesus et al. (2007), Silva et al. (2016), Wu et al. (2017)
		Acoustic comfort	Qualitative	
		Lighting comfort	Qualitative	
		Indoor air quality	Qualitative	
		Aesthetic and building beauty	Qualitative	
	Health and safety	Prevention of occupational risk	Quantitative	Lai and Yik (2011), Li et al. (2014), Sánchez-Garrido et al. (2021, 2022a), Sarvari et al. (2021), Sharghi et al. (2023), Usman and Frey (2022), Vitorio Jr. et al. (2022)
		Building process	Quantitative	
	Inclusion	Social inclusion in the neighborhood	Qualitative	Akola et al. (2023), Chadee et al. (2023), Falcao et al. (2021), Kang et al. (2014)
	Political	Urban policies	Quantitative	Huh et al. (2012), Tupenaite et al. (2018)
	User satisfaction	Point scale	Qualitative	Chen et al. (2017), Kamali et al. (2018), Li et al. (2014), Wu and Perng (2017), Wu et al. (2024)
	Cultural identity	Point scale	Qualitative	Cardenas-Gomez et al. (2021), Fang et al. (2022), Wu et al. (2021)
Technical Criteria	Criteria	Indicator	Assessment	Relevant papers
	Project specifications	Technical standards	Qualitative	Ball and Srinivasan (1994), Faraji et al. (2024), Malakouti et al. (2019), Nartkaya and Dinçer (2024), Natividade-Jesus et al. (2007), Nikbakht et al. (2024)
		Design	Qualitative	Aghazadeh et al. (2022), Apolinário and Kowalski (2023), Armacost et al. (1994), Bausys and Juodagalviene (2017), Daniel and Ghiaus (2023), Falcao et al. (2021), Hyun et al. (2008), Lim et al. (2023), Mela et al. (2012), Seth et al. (2018), Tarque et al. (2019), Zarghami et al. (2018), Zavadskas et al. (2024)
	Build control during construction	Constructive methods	Qualitative	Fan et al. (2025), Klumbyte et al. (2021), Kontu et al. (2015), Silva et al. (2016), Turskis and Juodagalviene (2016)
		Re works	Quantitative	
	Execution schedule	days/m^2	Quantitative	Balali et al. (2014), Baseer et al. (2023), Hatefi et al. (2025), Marzouk and Al Daour (2018), Shahpari et al. (2020), Zavadskas et al. (2008)

allocation per user, finishing quality, and ergonomic considerations (Armacost et al., 1994; Falcao et al., 2021; Hyun et al., 2008; Turskis & Juodagalviene, 2016). Construction criteria prioritize innovation, quality, and schedule adherence, aiming for cost-effectiveness and efficiency (Ali & Al Nsairat, 2009; Chadee et al., 2023; Eryuruk et al., 2022; Raut et al., 2016; Tarque et al., 2019). The integration of economic, environmental, social, and technical criteria aligns with principles of sustainable construction highlighted by Hill and Bowen (1997) and Akadiri et al. (2012), which advocate for a holistic approach to sustainability.

3.4. Distribution by phases in the construction process

Figure 7 illustrates the distribution of studies across various constructability phases. It is evident that the highest number of studies concentrate on the Design phase (53 articles), followed by the Conceptual Planning stage (23 articles), and thirdly, the Maintenance and Commissioning phase (14 articles).

3.4.1. Conceptual planning

Approximately 25% of the analyzed contributions are dedicated to assessing the conceptual planning phase concerning housing design (11 articles), collective housing projects (8 articles), and residential buildings (4 articles). Gambatese et al. (2007) note that the project's purpose and requirements are established during this phase. Similarly, Bley (2002) suggests that early adoption of an integrated and coordinated program during this phase can lead to achieving all project activities and objectives, including organization, operational procedures, program, budget, and overall project strategy. While some authors have emphasized the economic feasibility of projects, others consider project site analysis (Fang et al., 2022; Huh et al., 2012; Sharghi et al., 2023). A critical aspect of housing projects is addressing the inhabitants' needs and safety, which becomes a crucial objective in strategic urban planning (Salas & Yepes, 2018b). For example, the availability of public services, transport, security (Chadchan et al., 2024; Sarvari et al., 2021; Wu et al., 2021) or considerations of landscaping and recreational areas (Bausys & Juodagalviene, 2017; Lai & Yik, 2011) are explored. Lotfi et al. (2024) look at safety by focusing on the performance of housing structures in the face of earthquakes.

3.4.2. Design

57% of the reviewed manuscripts (53 articles) focus on evaluating the design phase. According to Lee et al. (2018), the building design process can be divided into architectural, structural, and MEP facility design disciplines. In architectural design, the focus is often on interior design optimization across various housing projects. For instance, in housing projects, authors explore optimal interior space distribution (Bausys & Juodagalviene, 2017; Turskis & Juodagalviene, 2016; Zavadskas et al., 2024), while authors like Armacost et al. (1994) propose strategies to prioritize construction quality for client satisfaction. Temporary housing design is a common focus for authors (Hosseini et al., 2020; Marzouk & Al Daour, 2018), emphasizing interior design considerations. In collective housing projects, issues such as interior comfort (Wu & Perng, 2017), ventilation, sunlight (Hyun et al., 2008), and final finishes assessment (Eryuruk et al., 2022) are addressed. Additionally, some authors (Daget & Zhang, 2020; Lim et al., 2023; Shahpari et al., 2020) delve into construction system selection, considering semi-prefabricated and prestressed concrete and steel construction systems while evaluating project productivity (cost, time, labor, and compliance with architectural design). Similarly, interior design parameters in residential buildings are tailored to different project locations (Kontu et al., 2015; Usman & Frey, 2022). For structural design, studies in both dwellings and collec-

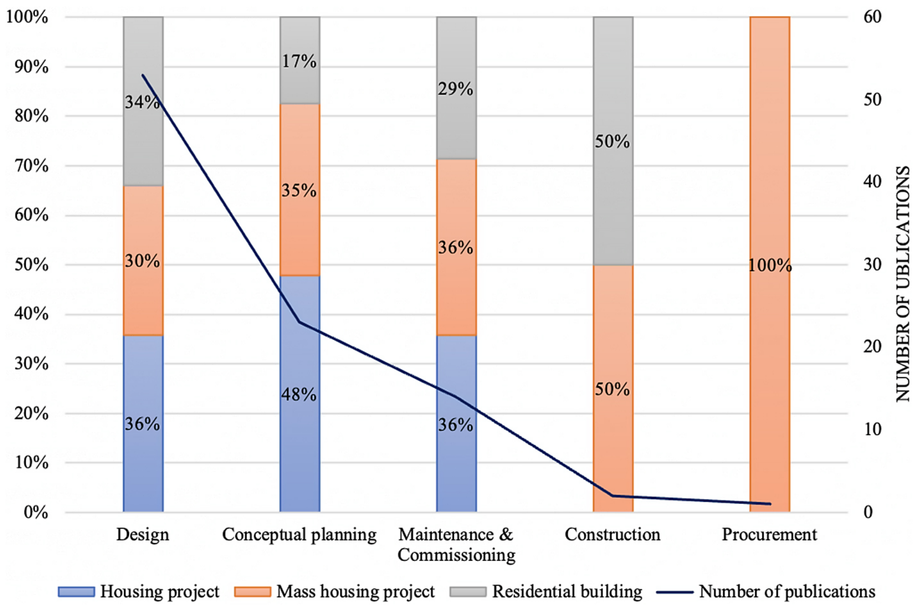

Figure 7. Constructability phases applied in the documents reviewed by structure type

tive housing projects focus on selecting optimal construction systems (Aghazadeh et al., 2022; Balali et al., 2014; Karamoozian & Hong, 2023; Pan et al., 2012). Some authors explore sustainability in structural design by considering materials and construction techniques (Figueiredo et al., 2021; Sánchez-Garrido & Yepes, 2020). Vitorio Jr. et al. (2022) and Motuziene et al. (2016) compare sustainable alternatives in single-family social housing projects, specifically comparing brick block masonry and concrete masonry. Lastly, in MEP design, thermal comfort is prioritized across all three unit types (Aljalal et al., 2023; Apolinário & Kowalski, 2023; Lazar & Chithra, 2021; Silva et al., 2016), which aligns with evaluating projects in countries with diverse bioclimatic zones. Another exciting aspect that focuses on thermal satisfaction is the cost-effectiveness of applying multi-layer external walls in dwellings, which is an interesting question for investors. For instance, Fan et al. (2025) developed a green assessment method for prefabricated buildings. Three basic material configurations were considered for multi-layer walls: insulation inside or outside the bulk layer and insulation between two bulk layers (Zavadskas et al., 2008).

3.4.3. Procurement

According to Quayle (2006), the procurement process encompasses five key steps: defining requirements, selecting suppliers, developing agreements, managing day-to-day activities, and evaluating supplier performance. This phase plays a critical role in ensuring construction success by ensuring timely access to quality materials and services, managing costs and schedules, and mitigating risks associated with project implementation. Only one article (1%) dedicated to evaluating suppliers for the supply chains of a large-scale housing project (Seth et al., 2018) addresses this phase. Considerations such as the supplier's competitive advantage, delivery capacity, and performance record were taken into account in this study.

3.4.4. Construction

Only 2% of the papers (2 articles) focus on the construction phase of social housing, mass housing projects, and residential buildings. This phase involves the utilization of machinery, materials, labor, and other inherent construction stage factors. It is closely intertwined with architectural, structural, and MEP design decisions. Safety concerns, particularly emergency workforce evacuation on construction sites in residential buildings, were addressed by Marzouk and Al Daour (2018), impacting contractor worker provision time. Additionally, Balasbaneh and Sher (2021) evaluated different cast-in-place concrete techniques due to accessibility issues at site locations, reflecting real-time challenges necessitating prompt and collaborative decisions using MCDMs.

3.4.5. Maintenance and commissioning

15% of the reviewed contributions (14 papers) focus on evaluating the maintenance and commissioning phase, with five papers addressing housing, five focusing on collective housing projects, and four targeting residential buildings. During this stage, four key strategies emerge: assessing occupants' well-being, conducting architectural renovations, implementing energy renovations in MEP designs, and employing structural strengthening techniques. Regarding occupants' well-being and health in social housing, two studies stand out: Cardona-Trujillo et al. (2023), which examines the correlation between residents' health and their living conditions using criteria from the Multidimensional Index of Living Conditions (IMCV), and Kang et al. (2014), which utilizes the "Public Housing Health Performance Indicator" to assess physical, social, mental, and managerial dimensions. Comfort emerges as a crucial attribute in the physical dimension, underscoring the importance of dwelling design, followed by self-sufficiency in the social dimension, which pertains to access to natural environment services and education. Architectural renovations serve various purposes, such as reintegrating housing into the affordable rental market (Falcao et al., 2021) or enhancing interior environments while considering economic, environmental, and social dimensions (Amorocho & Hartmann, 2022). Energy renovation holds significant appeal for homeowners due to its substantial improvement in living conditions. Articles aim to establish models for assessing energy savings (Hsueh, 2012), as excessive energy consumption during the heating season and increasing greenhouse gas emissions from fuel combustion have become pressing concerns (Staniunas et al., 2013). Notably, Flores-Abascal et al. (2023) address three critical aspects of energy renovation: energy efficiency, energy poverty, and indoor environmental quality. In their article, Nartkaya and Dinçer (2024) address the preservation of war-affected social housing areas, proposing strategies for their recovery and long-term sustainability. Lastly, Cardenas-Gomez et al. (2021) incorporate sustainability criteria to evaluate retrofitting techniques for social housing in rural settings.

4. Discussion and future research directions

4.1. Overview

The results of the current literature review underscore the widespread utilization of the AHP as the predominant technique in addressing social housing challenges. AHP's flexibility, grounded in its adherence to principles such as reciprocal judgments, homogeneous elements, hierarchical structures with feedback, and rank order expectations, renders it a versatile method (Saaty, 2016). However, despite its advantages in simplicity and adaptability, AHP's limitations in accommodating a restricted number of criteria and alternatives, alongside the necessity for stringent levels of independence (Tan et al., 2021) and positive reciprocal matrices (Abdelrasoul et al., 2022), pose potential drawbacks.

Following AHP, MCDM methods such as TOPSIS, COPRAS, and MIVES emerge as preferred alternatives. In the

TOPSIS method, the significance of each criterion is determined externally, unlike other multi-criteria decision-making approaches that assess the performance levels of the criteria. Its transparency throughout the decision-making process, the ability to represent human thought processes, and consistent procedural framework regardless of problem size (Marchetti & Wanke, 2020) are advantageous traits in housing construction projects; this facilitates efficient adaptation to changes and adjustments during decision-making. This discussion further supports our response to the first research question, detailing the range of methods applied in the analysis of social housing projects. TOPSIS finds application across various sectors, including construction, as demonstrated by studies such as by Alam Bhuiyan and Hammad (2023), which employ a hybrid method for selecting more sustainable structural materials, and (Francis & Thomas, 2023b), which conduct policy analyses related to sustainability and decision-making in built environments. Additionally, in civil engineering domains like (Wang et al., 2023), TOPSIS explores artificial intelligence in the construction industry through hybrid fuzzy-TOPSIS approaches. Another notable method is COPRAS, belonging to the scoring method family. It facilitates multi-criteria evaluation, accommodating both maximization and minimization of criteria values (Podvezko, 2011). Suitable for scenarios involving multiple criteria and alternatives, COPRAS has been effectively applied across diverse fields, including business management, urban planning, public policy evaluation, and engineering decision-making, showcasing its utility and adaptability in various contexts (Kaklauskas et al., 2010).

Another emerging method is MIVES, which belongs to the multi-criteria utility/value method family. MIVES has been successfully applied in numerous sustainability studies within the construction sector. As Gambatese et al. (2007) defined, MIVES integrates decision-making with function value analysis, employing standardized indexed dimensions/units to compare indicators, including those with varying units and qualitative characteristics. Despite the challenges highlighted by Lee et al. (2018) regarding the time and expertise required to define specialized assessment tools, MIVES's unparalleled effectiveness in evaluating sustainability across various construction scenarios offsets these drawbacks. As we delve into the results, it becomes clear that individual MCDMs hold a dominant position in the social housing domain, with hybrid MCDMs yet to significantly influence this statistical trend. This finding addresses the second research question, as it provides insight into how MCDM methods are being applied, either individually or in combination with other techniques, to better capture sustainability considerations and uncertainties. However, the importance of energy efficiency, sustainability, and environmental conservation, as underlined by recent studies by Bianchi et al. (2021), is leading to an increasing adoption of hybrid MCDMs to address these concerns. Despite the minimal application of fuzzy logic in individual and hybrid MCDMs, this trend is a significant development in the field. Despite intentions to incorporate fuzzy logic into individual MCDMs, this inclusion remains remarkably limited compared to other engineering disciplines (Abdelrasoul et al., 2022; Enshassi et al., 2016; Marchetti & Wanke, 2020; Saaty, 2016), a trend that is reflected in the statistical data (Figure 6).

Furthermore, it should be noted that the most recurrent technique in this research, fuzzy AHP, is an outdated methodology that may not adequately adjust to the changing challenges of civil engineering, especially about social housing. Hybrid fuzzy MCDMs follow a similar pattern to the individual fuzzy methods, with the combined FSE + ranking method being the only approach with two publications. Examining the critical indicators according to economic, environmental, social, and technical criteria reveals various trends and methodologies in the studies analyzed. From an economic point of view, a predominant focus on construction, repair, and maintenance costs is observed, along with the emergence of indicators such as LCC. Regarding environmental criteria, the key factors are energy consumption and pollutant emissions, while social considerations include health and safety, comfort, serviceability, and user satisfaction. On the technical level, project specifications, design, construction, and delivery times are emphasized, emphasizing innovation, quality, and efficiency of the construction process. Authors such as Alam Bhuiyan and Hammad (2023) advocate that technical criteria should be considered to ensure alignment with sustainability objectives.

Furthermore, Pons and de la Fuente (2013) reaffirm that sustainable construction starts at the planning stage and extends throughout the entire life cycle, emphasizing the main factors, which are social, economic, environmental, as well as technical. Despite the growing recognition of the importance of sustainability in the construction sector, many projects – especially social housing projects – still need to integrate sustainability criteria adequately. With only 16% of the data collected assessing sustainability, this lack of integration can lead to sub-optimal decisions and missed opportunities to improve the long-term performance of buildings. Furthermore, the absence of a predominant focus on individual MCDMs suggests weak connections between attributes and criteria, leading to a complex deficiency in their interdependence. These technical criteria also influence the selection of construction strategies and materials, reinforcing the response to the third research question regarding recent trends in social housing design and technologies. This lack of integration underscores the need to explore how design strategies, materials, and technologies contribute to enhancing sustainability in social housing projects.

Research on conceptual planning, which constitutes 21% of the articles reviewed (17 articles), focuses mainly on assessing the economic viability of projects, considering investment costs, licenses, taxes and cost deviations. It also highlights the importance of choosing suitable locations and considering the needs of the inhabitants, such as access to public services, transport, security and recreational spaces, directly impacting on the quality of life of residents.

The majority of the studies (42%) have a significant impact on project design, covering single-family homes, group housing projects and residential buildings, with three main trends: architectural, structural and MEP design. These aspects are directly linked to the third research question, as they reflect the predominant design strategies, materials, and technologies recently implemented in social housing projects. Architectural design aims to optimise space allocation, prioritise construction quality and meet client requirements. Structural design research focuses on selecting optimal construction systems, such as semi-precast concrete and steel, and evaluating project productivity. MEP design focuses on thermal, acoustic and visual comfort, aligned with interior design considerations. Research on the procurement phase constitutes only 1% of the articles, focusing on the evaluation of suppliers within the supply chain of large-scale housing projects. Despite its under-representation, procurement is vital to project success, ensuring timely availability of quality materials and services, cost and schedule management, and risk mitigation.

Despite building science interventions focusing on building knowledge, planning, procurement, and execution (Kifokeris & Xenidis, 2017), research in this domain primarily addresses conventional issues rather than emerging concepts like circular economy and full Life Cycle Assessment (LCA). The use of modern methods of construction (MMC) is becoming increasingly important due to their potential to mitigate climate change and promote sustainable building practices. Despite their significance, these methods are underrepresented in current research. This analysis directly addresses the fourth research question, identifying current thematic areas and future research trends in social housing literature.

4.2. Statistical discussion

The study conducted a statistical analysis to identify prevailing patterns. Simple correspondence analysis, a statistical technique, was employed to delve into the relationships of inertia and association among variables within the dataset. This form of multivariate analysis reveals the joint frequency of occurrence of two or more variables. It aims to visually represent the relationships between categories of variables in a two-dimensional space. Doing so illustrates how the distances between categories reflect their similarities or differences regarding the joint frequency of occurrence. IBM SPSS Statistics 26.0 software facilitated this analysis, elucidating how the MCDM categories interact with the assessed dimensions of the study. To validate the results, the p-value was analyzed, yielding a value of 0.010. This result indicates a significant association between the MCDM methods and the evaluated dimensions, with a significance level of 5% ($p < 0.05$).

The correspondence analysis depicted in Figure 8 illustrates the relationship between the criteria assessed (one-dimensional, two-dimensional, three-dimensional, and four-dimensional) and the MCDM methods employed in the articles. A closer correlation indicates a stronger relationship. Notably, pairwise comparison (AHP and ANP) shows a strong relationship with 2D and 4D assessments, indicating its versatility in studies with both limited combinations of criteria and more comprehensive ones. Outranking (PROMETHEE and ELECTRE) is also linked with 4D, consolidating its role in studies requiring a more robust approach to evaluate projects while considering economic, technical, social, and environmental impacts. On the other hand, methods associated with 3D, such as distance-based (TOPSIS and VIKOR), present a significant connection with studies focused on social housing design, where they seek to balance multiple factors without achieving a holistic evaluation. Scoring (SAW and COPRAS) is also associated with 3D, with frequent use in sustainability assessment by integrating economic, environmental, and social criteria, underlining its relevance in selecting sustainable design strategies (Invidiata et al., 2018). Further away from the center, utility-value appears linked to 4D, suggesting its preference in studies with a fully holistic approach to social housing assessment. In contrast, 1D analyses and methods categorized as Other (CORST and WASPAS) are placed at the graph's periphery, indicating their predominant use in one-dimensional studies with lower integration.

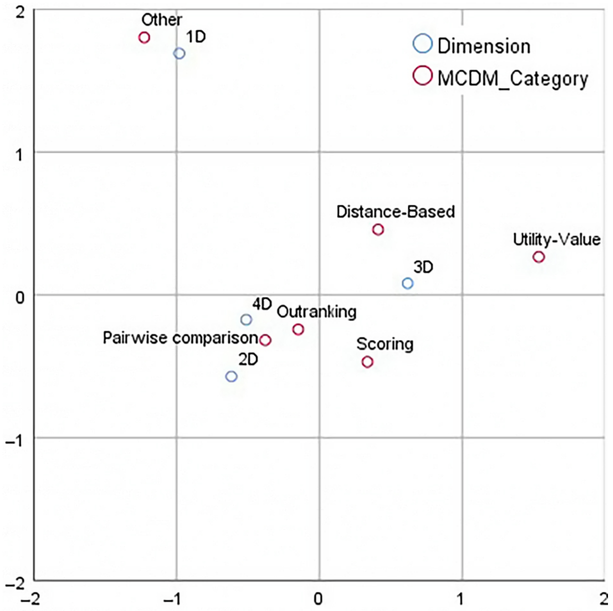

Figure 8. Simple correspondence analysis for dimensional assessment and MCDM category use

The findings confirm a shift towards multidimensional assessments, with pairwise comparison, outranking, and distance-based methods emerging as essential tools in social housing decision-making. However, some techniques, such as FSE, MAUT, SWARA, and MACBETH, exhibit weak statistical associations with the analyzed variables, suggesting their limited application in this domain. Despite its potential to integrate multiple sustainability dimensions, MIVES does not show a significant statistical correlation in this analysis, reinforcing the necessity for further research to explore its applicability. Based on the findings, it is evident that analyses incorporating three and four dimensions of sustainability should be pivotal considerations in construction endeavors. Additionally, further comprehensive studies are warranted to address the identified knowledge gaps.

4.3. Future directions

The use of MCDM methods in the construction sector has garnered widespread recognition as a potent tool for enhancing decision-making across various stages of the project life cycle (Hagag et al., 2023; Zhu et al., 2021). Even with significant strides in this domain, a notable gap exists in understanding how MCDMs can be effectively incorporated into the constructability phases, from conceptual planning to project execution and delivery. This knowledge deficit prompts crucial inquiries into how MCDMs can be optimally leveraged to enhance the constructability of construction projects, particularly in the realm of social housing, mass housing initiatives, and residential buildings, with a focus on enhancing their performance in terms of cost, time, quality, satisfaction, and safety. For instance, within the conceptual planning phase, broadening the scope beyond mere economic feasibility to encompass social, technical, and environmental feasibility is imperative. Such considerations should inform the formulation of policies and regulations geared towards sustainability.

Understanding the needs and preferences of the inhabitants is crucial, as they influence the design of the home, interior aesthetics and layout of the space, which impacts their quality of life and well-being. At the procurement stage, managing supply chain risks such as material availability and market fluctuations is vital. MCDM methods allow these risks to be assessed and prioritized, mitigation strategies identified, and effectiveness evaluated and aligned with environmental, social, and economic sustainability criteria. These criteria include sustainable manufacturing practices, use of recycled materials and corporate social responsibility policies. As practices and technologies in the construction sector evolve, new procurement models are required, such as performance-based contracts, strategic alliances, and integrated collaborations, which consider multiple criteria such as cost, risk, and flexibility. The adoption of modular and prefabricated construction is increasing due to its potential to reduce costs, accelerate construction times, and improve quality.

With the increasing emphasis on sustainability and energy efficiency, it is crucial to integrate renewable energy sources, sustainable materials and advanced construction methods. This includes new formwork systems to improve quality and speed up construction, assessing the durability of necessary equipment and incorporating efficient designs. Waste management and recycling are increasingly important in housing construction, with innovations in the recycling of building materials. The commissioning and maintenance phase offers opportunities to integrate emerging technologies that improve occupant well-being, such as indoor air quality monitoring systems. Architectural renovations should prioritise sustainability by improving energy efficiency in MEP designs, innovating structural strengthening techniques and integrating sustainability criteria into the evaluation of housing projects. These efforts reflect a greater focus on quality, efficiency and sustainability in housing construction and maintenance. With new decision-making methods, social housing challenges can be better addressed, and it is essential that research professionals and decision-makers integrate modern MCDM methods into their approach.

Under this paradigm, one can compare AHP with the Best-Worst Method (BWM) (Zhu et al., 2021). According to Pamučar et al. (2020), this method diminishes result inconsistencies and reduces the pairwise comparisons required. Recent literature has demonstrated that BWM optimizes criteria weighting with a lower comparative burden for decision-makers (Goldani & Ishizaka, 2024), making it a compelling alternative to AHP when the number of criteria increases or when consistency in expert judgment is crucial. Furthermore, innovative variations of the BWM, such as the ZBWM or the Enhanced BWM (BWM-I), empower decision-makers to articulate their preferences even when faced with multiple best or worst criteria (Aboutorab et al., 2018). Another approach worth considering is the Combinative Distance-Based Assessment (CODAS), employed by Ashofteh et al. (2023), which computes the distance of each alternative to the negative ideal point using a blend of different game theories and Euclidean distance metrics. Compared to traditional distance-based methods like TOPSIS or VIKOR, CODAS enhances alternative discrimination, especially in scenarios with high-dimensional and complex criteria (Baydaş et al., 2024; Keshavarz Ghorabaee et al., 2016), offering a more refined selection process in infrastructure and housing projects. Similarly, alternative methods like Grey TOPSIS (Yang et al., 2019) and Fuzzy TOPSIS (Yazdani-Chamzini & Yakhchali, 2012) have emerged for TOPSIS. Fuzzy MCDM approaches, in particular, help model the uncertainty inherent in subjective expert evaluations (Kutlu Gündoğdu & Kahraman, 2020) which can be crucial in social housing decisions where qualitative factors such as perceived comfort, safety, and community well-being are difficult to quantify with crisp values. Additionally, contemporary alternatives to the VIKOR method, such as EDAS (Ashofteh et al., 2023), are worth considering. Innovative alternatives to COPRAS might consider MOORA (Sisto et al., 2022; Soni et al., 2023) and ARAS (Zavadskas et al., 2010). As for MIVES, hybrid alternatives such as Fuzzy MIVES (Yang et al., 2019) or a combination of Fuzzy AHP and MIVES (Yazdani-Chamzini & Yakhchali, 2012) provide additional avenues of exploration. While fuzzy MCDMs are widely used in civil engineering decision-making, their application in this literature review is limited. Authors like Abbasianjahromi and Rajaie (2012), Eghbali-Zarch et al. (2022), Matić et al. (2022), Turskis and Juodagalviene (2016), Zhang et al. (2021b) have explored fuzzy sets in various project construction stages, as well as different expressions of fuzzy information, such as linguistic terms: probabilistic, neutrosophic, fuzzy wavering and interval-valued continuous (Wen et al., 2021), but these have not been extensively utilized in the reviewed literature. This suggests an opportunity to explore how hybrid models, combining classical methods with newer approaches could provide a more comprehensive decision-making framework for social housing, balancing quantitative performance metrics with nuanced qualitative assessments. Similarly, sensitivity analyses are not widely employed despite their importance in testing decision correctness under varying hypotheses. Thus, linguistic terms and sensitivity analyses could enhance the expression of evaluation information related to social housing.

While the articles examined operate within the framework of the four dimensions mentioned, it is crucial to acknowledge the significant variation in the criteria considered in their analyses; this underscores the need to acknowledge criteria interdependence in the construction field. This interdependence can challenge individual MCDM approaches, especially when addressing complex issues like sustainability assessment in durable structures. Due to sustainability's holistic and multifaceted nature, criteria are inherently interconnected, necessitating careful consideration of how decisions in one area may impact others. Comprehensive acknowledgment of this interdependence in decision-making processes is vital to ensure truly sustainable and balanced outcomes across all relevant aspects.

The sustainability of structures is now as paramount as their safety. In addition to structural integrity, there is a growing emphasis on adopting sustainable practices throughout the construction process; this includes clean construction methods, optimized transportation, and facilities for assembly and disassembly, all aimed at minimizing environmental impact (Guaygua et al., 2023). While economic, environmental, and social criteria are often addressed, the technical dimension, encompassing construction quality, energy efficiency, and structural safety, is equally essential. Data analysis reveals that the social dimension is most frequently analyzed, followed by economic, environmental, and technical dimensions. This result aligns with Golubchikov and Badyina (2012), who stated that "dwellings are not only physical but also social structures". standardizing sustainability assessment criteria in construction is imperative to foster responsible and balanced practices throughout project development and implementation (Hill & Bowen, 1997); this could be achieved through a Sustainability Life Cycle Assessment (SLCA) approach, encompassing LCA, SLCA, and LCC. However, SLCA has yet to be extensively reflected in the review despite its relevance to indicators strongly associated with social housing.

The integration of GIS, BIM, and MCDM has proven to be effective in various areas of civil engineering, allowing spatial and temporal multi-criteria analysis to optimize resources and solutions (Lozano et al., 2023; Santos et al., 2024; Tan et al., 2021). Integrating spatial data, building models, and decision analysis methods can identify opportunities to optimize resource use and contribute to sustainable planning and development of social housing. GIS facilitates the identification of critical factors such as accessibility, natural hazards, and infrastructure, enriching MCDM models. BIM makes it possible to simulate scenarios, analyze costs, and evaluate sustainability throughout the building's life cycle. MCDM, on the other hand, selects the best option based on multiple criteria. This integration has improved decision-making in infrastructure projects and in social housing; it could optimize site selection, resource use, and long-term sustainable planning (Santos et al., 2024). However, this combination is limited in the scope of this literature review, with individual studies utilizing these tools separately (Figueiredo et al., 2021; Marzouk & Al Daour, 2018; Sharghi et al., 2023; Zhang et al., 2021a).

The application of MCDM in social housing faces the challenge of the great variety of techniques available since not all of them are suitable for each context. Currently, no single model is capable of addressing all complex problems in the construction sector (Villalba et al., 2025). Future research should focus on developing more efficient methods considering key aspects such as decision-making uncertainty, criteria hierarchization, and their interrelation (Baykasoğlu & Gölcük, 2015). Optimization of hybrid models integrating advanced approaches could improve the accuracy of assessments and facilitate their implementation in projects of social interest. This would broaden their applicability and usefulness within the sector, driving more informed and sustainable decision-making.

5. Conclusions

In response to the article's main objective, this study reviewed 93 articles applying MCDM to evaluate social housing projects, offering a comprehensive view of the diversity and applicability of these methods. The scientometric analysis revealed key trends, including a steady growth in publications, with a marked increase starting in 2016, and strong research collaborations, especially between China and Spain. The review identified three main lines of study: MCDM as a multidimensional assessment tool, constructability in project design and implementation, and sustainability from an integrated perspective. The main conclusions drawn from this analysis are presented below:

- Various MCDM methodologies were identified, ranging from classical techniques to advanced hybrid models. AHP is the most commonly used weighting technique, individually and in hybrid form, followed by TOPSIS and COPRAS. MIVES, although less frequent, stands out for its alignment with sustainability objectives.
- Most studies (84%) employ quantitative approaches, but since 2011, the use of MCDM with fuzzy logic has increased, with fuzzy AHP standing out. In 2020, the first study with neutrosophic logic was reported, indicating an emerging exploration of more advanced methods.
- Given the complexity and multidimensionality of social housing projects, hybrid approaches integrating MCDM with fuzzy or neutrosophic logic are recommended, allowing more accurate assessments adapted to uncertainty.

- Sustainability is an increasingly relevant factor in the evaluation of these projects. Seventy-three percent of the studies analyze the social dimension, 67% the environmental dimension, 63% the economic dimension, and 62% the technical dimension. However, there is still a lack of consensus on the evaluation criteria, which underlines the need for a standardized framework that systematically integrates these aspects.
- Furthermore, it is advisable to integrate LCA into assessments of social housing projects to comprehensively assess environmental impacts in all project phases, from planning to maintenance.
- The application of MCDM in all phases of the construction process improves decision-making, optimizes the use of resources, and allows early identification of risks, contributing to more efficient and viable projects.
- The wide variety of MCDM techniques available presents the challenge of selecting the most appropriate one according to the characteristics of the project. It is recommended that the hierarchization of criteria and the optimization of hybrid models be investigated in depth to improve their applicability in projects of social interest.
- Adopting innovations in construction, such as modular construction and using sustainable materials, can improve the efficiency and sustainability of social housing projects.

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Author contributions

This paper represents a result of teamwork. The authors jointly designed the research. X. L. developed the methodology, investigated, and drafted the original manuscript. X. L. and V. Y. edited and improved the manuscript until all authors were satisfied with the final version. All authors have read and agreed to the published version of the manuscript.

Disclosure statement

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