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BIBLIOMETRIC MAPPING OF MCDM METHODS IN AEC INDUSTRY: IDENTIFYING TRENDS FOR SUSTAINABLE DEVELOPMENT

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Highlights:
- MCDM methods are vital in construction and sustainability;
- MCDM and MADM optimize material and contractor selection, waste and risk management, and enhance project performance;
- hybrid MCDM approaches are very effective.

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Abstract. This study investigates integrating multi-criteria decision-making (MCDM) approaches to improve sustainability in the architecture, engineering, and construction (AEC) industry. Through a systemic literature analysis done through the Scopus database and the visualization of key elements through VOSViewer, the study examines the applications of MCDM in sustainable construction, with particular attention to material selection, contractor procurement, waste management, risk assessment, and technological integration, which are essential elements towards sustainable development of the AEC industry. The results highlight how common and successful hybrid MCDM and MADM methods are. These approaches provide all-encompassing answers to challenging problems, from project mitigation to material procurement. The evaluation emphasizes the value of MCDM methods in supporting sustainable practices across the construction lifecycle, streamlining supply chains, and enabling well-informed decision-making. In the end, this study emphasizes how critical it is to carry out further research and apply MCDM frameworks to promote sustainable development in the construction sector and balance development objectives with the protection of the environment and the welfare of society.

Keywords: hybrid decision-making, bibliometric trends, sustainable construction, multi-criteria decision-making.

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1. Introduction

One of the critical sectors that control the development of a nation anywhere on the globe is the construction industry. It has advanced globally regarding social, technical, and environmental aspects (Alaloul et al., 2021; Musarat et al., 2021; Zhu et al., 2021a). Urbanization occurs together with population expansion. Due to its fast growth, the building industry has become an environmental threat (Ahmad et al., 2019; Vasilca et al., 2021). Stakeholders implement international laws and policies to ensure the built environment is sustainable. Sustainability has emerged as a crucial need in the construction industry in response to growing environmental concerns and societal expectations (Liu et al., 2020; Zavadskas et al., 2021). This need is a result of the realization of the AEC industry's substantial ecological footprint, which includes resource extraction, energy consumption, waste production, and carbon emissions (Zvirgzdiņš et al., 2018, 2019; Pomè et al., 2021; Freire-Guerrero et al., 2019; Udomsap & Hallinger, 2020). It guarantees long-term socioeconomic viability, implements recycling and reusing procedures of waste, embraces eco-efficient technology, green building standards, and, most importantly, sustainable designs (Ferreira et al., 2024; Hossain & Ng, 2019; Lima et al., 2021; Weerakoon et al., 2023; Wei et al., 2020). The efforts are emphasized by the increasing agreement that it is imperative to balance sustainable development goals (SDGs) with environmental constraints and social welfare, which calls for creative solutions and revolutionary methods in the building industry (Hariram et al., 2023; Moallemi et al., 2020; Fei et al., 2021).

As a result, the AEC industry has made sustainability a top priority to balance development with social justice and ecological integrity (Goh et al., 2023; Patel & Patel, 2021). The AEC industry is essential for sustainable development as it shapes the built environment, affects the consumption of resources, and provides substantial potential to mitigate environmental impact via creative design, construction, and operational practices. While many strategic approaches have been taken to confirm the sustainability of this sector, still a clear knowledge on how decision-making impacts sustainable development is lacking. Therefore, the use of MCDM techniques has attracted a lot of interest due to their capacity to manage the intricate trade-offs present in environmentally friendly construction approaches (Bertoni, 2019; Tan et al., 2021). Construction project decision-making procedures are made more accessible by the methodical frameworks provided by MCDM approaches, which allow for the evaluation of several alternatives against a variety of criteria (Zhu et al., 2021b; Klinsky & Mavrogianni, 2020). These techniques enable stakeholders to assess trade-offs between technical feasibility, social acceptability, environmental effect, and economic viability. The MCDM approaches offer an organized strategy for prioritizing sustainable solutions by including expert assessments and stakeholder preferences. They improve building projects' long-term profitability and resilience of (Zavadskas et al., 2014, 2017).

Despite the various decision-making frameworks examined by decision-makers in individual studies, a significant problem persists in the thorough synthesis and analysis of existing knowledge regarding MCDM methods in sustainable construction, as few reviews offer a comprehensive overview of the approaches most relevant to these intricate scenarios (Stojčić et al., 2019). The research gap extensively pinpoints that the literature currently lacks a thorough analysis and synthesis of empirical data to determine best practices, emerging trends, and unresolved challenges in the application of MCDM methodologies to sustainable construction (Penadés-Plà et al., 2016), highlighting the necessity for a more systematic and comprehensive investigation. Therefore, this article aims to conduct a systematic review that attempts to bridge the gap by carrying out extensive bibliometric mapping of MCDM applications that focus on sustainability in the AEC industry. The systematic review is notable for synthesizing various MCDM methodologies in sustainable construction while also performing a detailed bibliometric analysis to identify emerging trends, highlight significant knowledge gaps, and suggest strategic directions for future research–thus providing a comprehensive, evidence-based perspective that surpasses conventional literature reviews and directly aids the industry's sustainability objectives. By applying bibliometric analytic tools, this study aims to determine hotspots and emerging trends, clarify the development of research themes, and highlight crucial contributions in the multidisciplinary field of decision sciences and building sustainability.

2. MCDM methods in a nutshell

Robust decision-making frameworks are more important than ever as the global construction sector continues to evolve quickly due to population changes, technology breakthroughs, and environmental requirements (Vakili et al., 2021; Bolomope et al., 2022; Musonda & Okoro, 2021). When negotiating the difficulties of sustainable construction strategies, MCDM approaches provide a methodical approach that enables stakeholders to reconcile various criteria, balance competing goals, and rank the best possible solutions (Tan et al., 2021; Marcher et al., 2020). Thus, to promote resilient built environments and sustainable building practices, it is imperative to comprehend the present state of MCDM approaches (Jato-Espino et al., 2014; Klumbytė et al., 2021; Uzair & Kazmi, 2023).

One of the most popular MCDM techniques is the Analytic Hierarchy Process (AHP). AHP, invented by Saaty in 1980 (Schmidt et al., 2015), offers a methodical structure for breaking down complicated decision issues into hierarchies of criteria and options (Saaty, 1977, 1990). Such an approach helps decision-makers easier to compare options side by side and determine priority weights (Janković & Popović, 2019; Medineckienė et al., 2015). AHP is an adaptable instrument for balancing social, environmental, and economic factors in building projects (Amponsah, 2013) because of its versatility in handling both qualitative and quantitative data (Zhu, 2020) and its capacity to take stakeholder preferences into account (Darko et al., 2018). Years later, to describe complicated choice issues with interdependent criteria and options, Saaty (1996, 2005) created the analytic network process (ANP) to describe complicated choice issues with interdependent criteria and options. Decision-makers can capture feedback and dependencies between elements using ANP, which depicts decision hierarchies as networks of criteria and relationships (Becker et al., 2017; Ley & Lina, 2020). A more thorough and accurate depiction of choice settings is made possible by the ability to take into account both concrete and intangible aspects, as well as the interactions between criteria (Wu et al., 2009). Another common MCDM technique that is frequently applied in decision-making is TOPSIS. TOPSIS, which was first presented by Hwang and Yoon in 1981 (Enginoğlu et al., 2019), seeks to determine which option is closest to the ideal solution while minimizing the distance from the ideal solution that is positive and increasing the distance from the ideal solution that is negative (Hwang & Yoon, 1981; Huang & Jiang, 2017). TOPSIS has been utilized in a variety of sustainable construction contexts, including selecting materials, vendor evaluation, cost estimation, pollutant emission, and green construction evaluation (Dehdasht et al., 2020; Chen, 2019; Bai & Sarkis, 2018; Zhou et al., 2021).

MacCrimmon (1968) presented simple additive weighting (SAW), a basic MCDM method (Sánchez-Garrido et al., 2022). It weighs options and criteria relative to relevance (Jovanović et al., 2016). The process involves adding the data to get a composite score for each alternative and then multiplying the normalized scores of the options by the respective weights (Mukhametzyanov & Pamučar, 2018). SAW is perceived to provide transparency and simplicity in decision-making (Kabassi & Virvou, 2004). Nevertheless, detractors contend that it may oversimplify intricate situations and ignore the interdependencies across criteria, which might result in biased conclusions (Afshari et al., 2017). VIekriterijumsko KOmpromisno Rangiranje, or the multi-criteria optimization and compromise solution

(VIKOR), is a MCDM method introduced by Opricovic (1998) that aims to identify the compromise solution that provides the best compromise between conflicting criteria. VIKOR employs a compromise programming approach to rank alternatives based on their distance to the ideal solution and the distance to the worst solution (Ashtiani & Azgomi, 2014).

Above are some of the commonly used MCDM methods used in decision-making while the other methods such as the DELPHI method introduced by Dalkey and Helmer (1963), facilitate consensus among experts (Niederberger & Spranger, 2020), CoCoSo (Combined Compromise Solution) introduced by Yazdani et al. (2018) aggregates preferences into collective decisions (Peng & Huang, 2020), and SWARA (Step-wise Weight Ratio Assessment) introduced by Keršulienė et al. (2010) prioritizes criteria through pairwise comparisons (Karabašević et al., 2019). These methods have been widely applied in sustainable construction for diverse purposes, including green building assessment, material selection, and stakeholder engagement. In summary, other relevant MCDM methods, along with the authors and their descriptions, are given in Table 1.

In conclusion, MCDM approaches have helped stakeholders study infrastructure development and construction for several years. However, the approach needs to focus on the sustainable development of the built environment and the study discusses it broadly.

3. Methodology

3.1. Method of review

The current review article's methodology is briefly described in this section. A description and some clarification of the procedures involved in the review process are provided.

This research specifies and focuses on MCDM approaches towards sustainable development in the construction industry. A conducted systemic literature review (SLR) helps to analyze the current state of research. This review methodology is one of the rigorous and transparent strategies that are currently in use by many researchers to identify, evaluate, and synthesize existing literature relevant to a particular research topic (Páez, 2017;

Table 1. Other MCDM methods and their authors and descriptions

Method	Author(s)	Description
TODIM	(Gomes & Lima, 1991)	TODIM (an acronym in Portuguese for Interactive and Multi-Criteria Decision-Making) is a method for evaluating alternatives based on decision-maker preferences and uncertainty and ranking them based on dominance or compromise
BWM	(Rezaei, 2015)	The Best Worst Method (BWM) is a decision-making approach that uses a pairwise comparison procedure to find the best and worst criterion weights, allowing alternate rankings
WASPAS	(Chakraborty & Zavadskas, 2014)	WASPAS (Weighted Aggregated Sum Product Assessment) is a method that combines weighted sum and weighted product methodologies to evaluate alternatives in MCDM taking into account quantitative and qualitative considerations
MABAC	(Pamučar & Ćirović, 2015)	MABAC (Multi-Attributive Border Approximation Area Comparison) is an MCDM system that ranks options based on the attractiveness of their fuzzy regions
CODAS	(Ghorabaee et al., 2016)	CODAS (Combinative Distance-based Assessment) is a method for ranking options in MCDM based on their global utility and distance from the ideal answer
MULTI-MOORA	(Brauers & Zavadskas, 2010, 2011)	MULTIMOORA is a strategy combining MOORA and multiplicative methodologies to evaluate options in MCDM, stressing advantages and disadvantages
ELECTRE	(Roy, 1990)	ELECTRE (Élimination and Choice Translating Reality) is an MCDM process that removes less desired alternatives based on outranking relationships established by concordance and discordance indices
DEMATEL	(Gabus & Fontela, 1972)	DEMATEL (Decision-Making Trial and Evaluation Laboratory) is a method for elucidating the interrelationships between criteria in MCDM, facilitating cause-effect linkages and structural modeling
COPRAS	(Zavadskas et al., 1994)	COPRAS (Complex Proportional Assessment) is an MCDM approach that ranks items by aggregating preferences and calculating the collective value of criteria
MOORA	(Brauers & Zavadskas, 2006)	MOORA (Multi-Objective Optimization based on Ratio Analysis) is a method for evaluating alternatives in MCDM by determining their relative superiority of alternatives using benefit and cost criteria
EDAS	(Ghorabaee et al., 2015)	EDAS (Evaluation based on Distance from Average Solution) is an MCDM approach that rates alternatives based on their closeness to the average solution, criterion significance, and performance
OPA	(Ataei et al., 2020)	OPA (Ordinal Priority Approach) is a decision-making strategy that uses a weighted average approach to integrate various criteria, with the weights arranged in order of significance
ITARA	(Hatefi, 2019)	ITARA (Indifference Threshold-Based Attribute Ratio Analysis) is a decision-making technique that builds on the AHP by including interval type-2 fuzzy sets, allowing uncertainty management in MCDM. It uses ratio analysis to establish the weights of criteria and alternatives, giving decision-makers a formal framework for evaluating and ranking options
ARAS	(Zavadskas & Turskis, 2010)	ARAS (Additive Ratio Assessment) is a method for ranking alternatives in MCDM based on their performance compared to the optimal option, considering both benefit and cost factors

Delgado-Rodríguez & Sillero-Arenas, 2018). This systematic review differentiates itself from prior studies by integrating a meticulous qualitative synthesis of MCDM frameworks with a comprehensive bibliometric mapping approach, revealing both overarching thematic patterns and detailed methodological insights that are frequently neglected. SLRs have demonstrated notable efficacy in pertinent fields; for instance, Francis and Thomas (2019) utilized an SLR to investigate the correlation between Lean Construction and environmental sustainability, whereas Chellappa and Ginda (2023) conducted a systematic review of MCDM techniques to improve construction safety, thereby promoting the implementation of more comprehensive risk management strategies. This study consolidates and analyzes extensive research results while using sophisticated bibliometric tools to identify emerging trends and highlight significant research gaps in sustainable building. Furthermore, mapping and assessing the relevant intellectual territory to specify a research question further develops a knowledge base. By ensuring that the review process is methodical, repeatable, and bias-free, this technique increases the validity and dependability of the results (Tranfield et al., 2003).

3.2. Data collection methodology

3.2.1. Selection of the database

One of the difficulties in the current investigation was selecting an appropriate database for document searches. Major scientific databases are available in the scientific community and may be utilized to find pertinent publications. These databases are Scopus, Web of Science (WoS), Google Scholar, EBCHOST, and others. However, selecting the most appropriate database considering its reputability and the clarity of the included articles is the most critical. For instance, due to severe limitations in the research interface, Google Scholar's relative recall and precision need to be improved for systematic scientific literature retrieval. Even though WoS offers subscription-based access to full texts of academic works, this differential access can create issues limiting reproducibility. Both major scientific databases (Google Scholar and WoS) have problems when benchmarking individual databases' research performance, with unequal distribution of research output and varying citation impact.

Considering the advantages and disadvantages of each scientific database, the Scopus database was used to perform the SLR. Access to more than 80 million records in a wide range of academic subjects is provided via Elsevier's Scopus abstract and citation database. Due to its broad coverage, which includes patents, book chapters, conference papers, peer-reviewed journals, and book chapters, scholars are guaranteed access to a vast range of credible academic material. By maintaining a database of top-notch content and using strict inclusion criteria, Scopus offers scholars reputable and trustworthy sources for their research projects. With the help of citation analysis tools, researchers may discover prominent works and authors, track citation metrics, and obtain insights into research trends and influence within their particular disciplines. Advanced search capabilities make it possible to retrieve pertinent material precisely.

3.2.2. Search strategy

The search technique aims to locate pertinent scholarly articles in the Scopus database. A search strategy locates relevant academic publications in the Scopus database. For this reason, a set of keywords was entered as a code to the database. This combination includes *TITLE-ABS-KEY (("sustainability" OR "construction" OR "construction industry") AND ("decision making" OR "decision model" OR "MCDM" OR "MADM") AND ("multiple criteria" OR "multi-criteria" OR "multiple attribute" OR "multi-attribute)).* The precise keyword set was developed via an iterative approach that included trial searches of major academic databases and talks with topic experts. First, several keyword combinations were examined to determine their relevancy and total retrieval rate. Next, keywords that produced too many irrelevant results (false positives) or failed to catch core literature (false negatives) were revised, changed, or removed.

3.2.3. Inclusion and exclusion criteria

The initial search query yielded 96 scientific documents, including journal articles, book chapters, and conference papers. This paper concentrated on original research and journal publications. Therefore, this study's findings did not include book chapters, and conference papers. Such an approach narrowed down the documents to be reviewed to 77. The research subject was considered while determining the investigation duration. It was crucial to choose a time frame near the present and begin the search in a year that saw many papers released. Therefore, the study considers only articles published between 2017 to 2023. The 2017–2023 timeframe captures the most recent and dynamic phase of methodological advancements and sustainability-focused initiatives in the AEC industry; in particular, during this period, scholars and practitioners have increasingly integrated novel MCDM techniques with sustainability goals, reflecting an increase in both the volume and diversity of relevant research that requires systematic examination. In such a way, the study narrowed down the number of documents to 49. The bibliometric analysis covers these 49 documents to identify the overall hotspots and trends in MCDM and MADM methods in different domains.

3.2.4. Screening and selection process

The screening and selection procedure was divided into several phases to guarantee the comprehensive identification of pertinent material. Duplicate records were first eliminated. The remaining publications' titles and abstracts were checked against the predetermined inclusion and exclusion criteria. To decide which of the remaining articles may be included in the review, a full-text evaluation was done on each. It resulted in 21 documents from the Scopus database for the final review. Additionally, 13 articles from reputed journals related to the research theme were analyzed. While the final review includes a small sample of 21 Scopus documents and 13 additional articles, this selection was made using deliberately stringent inclusion and exclusion criteria aimed at identifying high-quality studies that specifically focus on MCDM methods in sustainable construction. By emphasizing methodological rigor and relevance, the review guarantees that the body of literature included represents both established practices and developing trends, allowing for in-depth study of essential issues despite the restricted number of publications.

4. Bibliometric analysis

4.1. Primary information of documents

The fundamental purpose of this research is to find how to comprehend the evolution and state of MCDM applications for sustainability in the field of construction. This requires a methodical analysis and mapping of the academic landscape of MCDM approaches employed in the context of green construction. To do this, the authors used bibliometric tools to identify relevant trends, emerging subjects, and research needs. Because the subject is new and a gradual research tendency has evolved recently, a systematic bibliometric investigation is expected. Bibliometric analysis, often known as "scientometrics," is a well-known scientific method (Sethi et al., 2016). It is a quantitative analytical process that investigates the link between multiple variables in a certain location or field of research. This method is also utilized to explain or demonstrate the evolution of specific research over time (Noman et al., 2022). The bibliometric evaluation for studies was carried out using an open-source application known as VOS Viewer.

The significant growth in the number of documents published over the years indicates an increasing scholarly interest in the junction of MCDM applications towards achieving sustainability in the built environment. A consistent upward trend has been seen in the academic output of MCDM approaches for sustainable construction from 2017 to 2023. Three documents were released in 2017, five in 2018, and six in 2019. Five in 2020, eight in 2021, six in 2022, and a noteworthy increase to sixteen in 2023 were

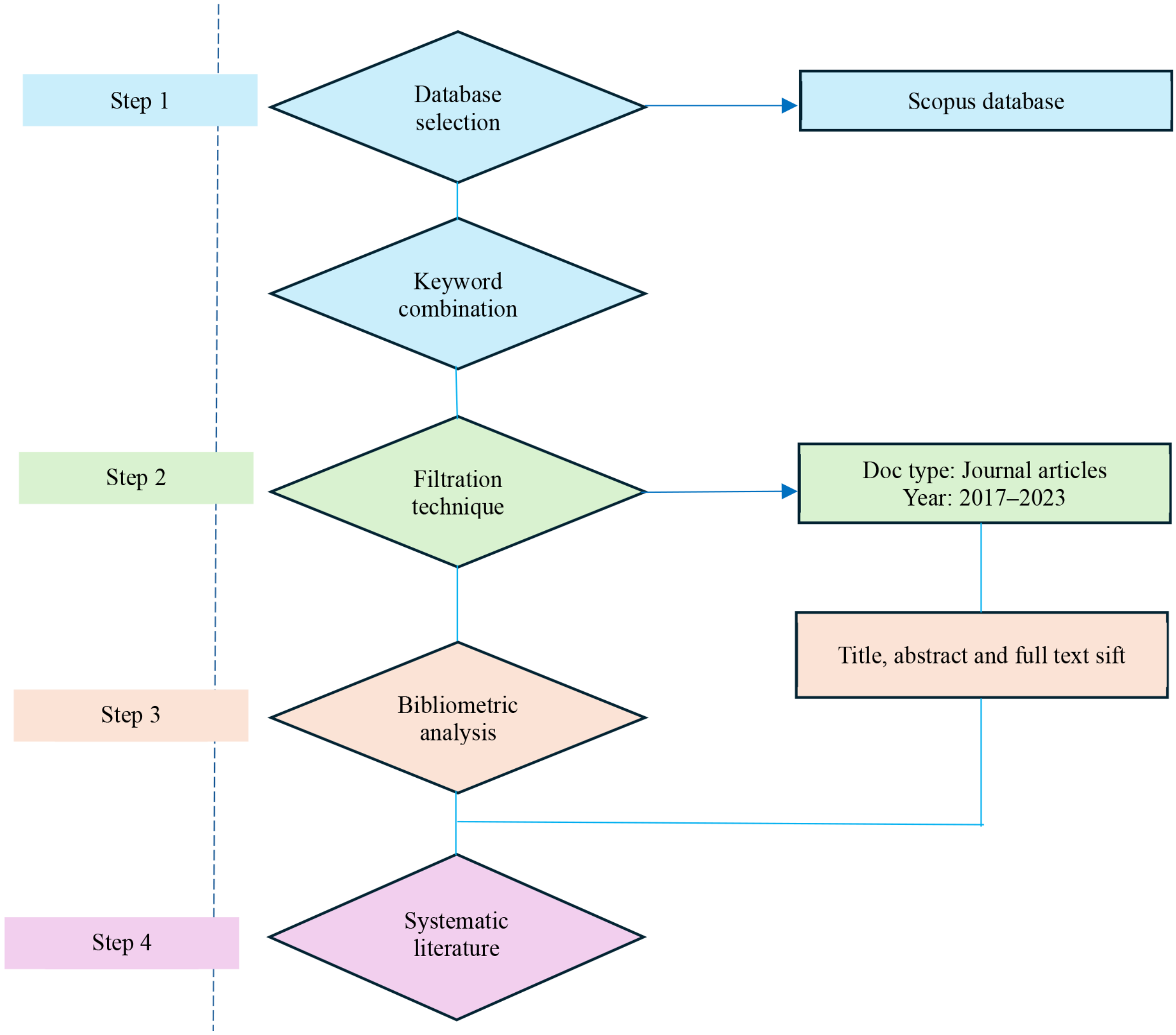

Figure 1. Methodical steps used in the SLR

the following publications in line with the trend. These figures show that the construction sector is becoming more interested in and involved in investigating MCDM techniques to address sustainability concerns. Figure 2 illustrates the documents that were published between 2017 to 2023.

Citation analysis (see Figure 3) of the papers under consideration for review shows a significant rise in academic influence over time, starting in 2020. The papers received 85 citations in 2020, indicating some initial interest from the scientific community. The citations then increased to 121 in 2021, indicating that the results are becoming more widely acknowledged. With citations almost doubling to 197 in 2022, the trend continued to rise, indicating growing significance and impact in the scholarly debate. Notably, in 2023, there was a notable spike in citations, with a total of 336, indicating the research results' strong influence and broad reach. The rising recognition and distribution of the research findings, together with the expanding significance and scholarly relevance of MCDM methodologies for sustainable building, are shown in these citation patterns.

The increasing quantity of citations indicates how highly esteemed the study is among the academic community and how crucial it is in influencing ongoing scholarly discussions. Although the study provides important quantitative data on document counts and citation frequencies, a more in-depth analytical perspective is required to understand how these patterns influence the overall development of MCDM and MADM in sustainable building. For example, an apparent increase in publications related to certain methodologies might reflect evolving legislative needs or new technical options, indicating areas where the discipline is converging on best practices. Periods of stagnant citation growth, on the other hand, may suggest the need for methodological development or highlight well-established methodologies that now serve as reference points for future innovation. By linking these bibliometric trends to real-world applications, shifting research agendas, and stakeholder interests, the study may provide more detailed insights into the maturity, directions, and urgent difficulties of MCDM and MADM techniques in the AEC sector.

The citation summary was further narrowed by identifying the top ten referenced articles. The 10 most cited papers are shown in Table 2 after this element was investigated based on the number of citations these articles received.

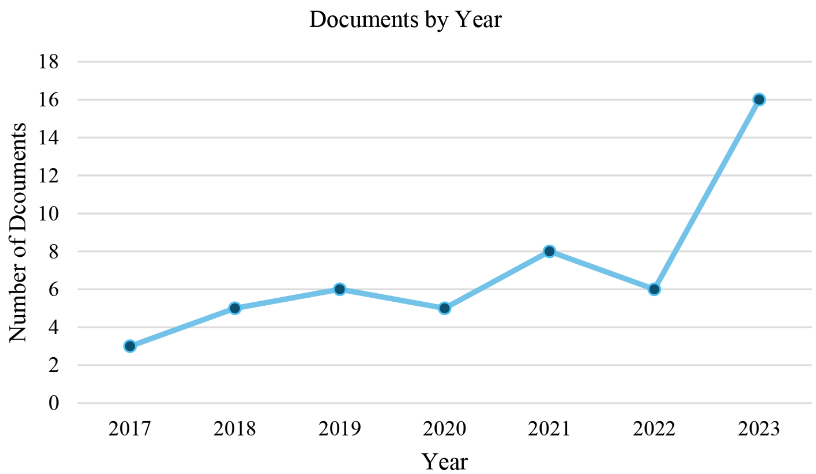

Figure 2. Number of documents published during 2017–2023

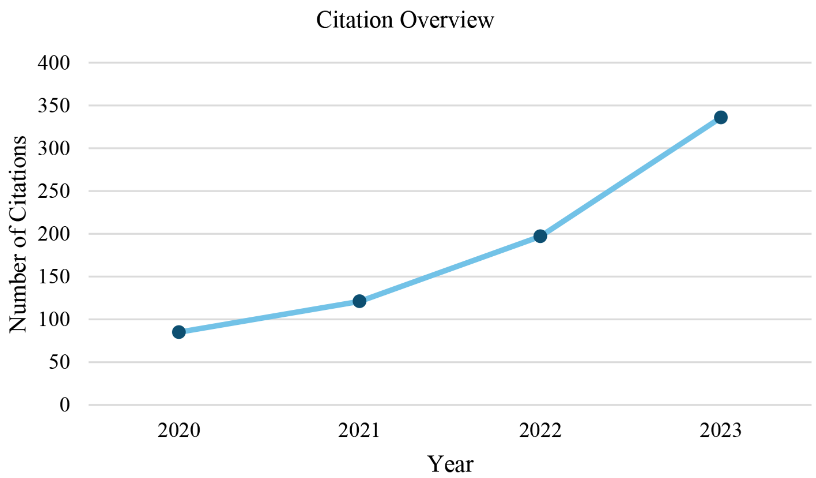

Figure 3. Citation overview of the documents

Table 2. Top 10 cited articles identified in the bibliometric analysis

No.	Article title	Author(s)	Year of publication	Citations received
01	Research on Construction Engineering Project Risk Assessment with Some 2-Tuple Linguistic Neutrosophic Hamy Mean Operators	Bag S.; Pretorius J. H. C.; Gupta S.; Dwivedi Y. K.	2018	120
02	Applications of AHP and VIKOR Methods Under Interval Type 2 Fuzzy Environment in Maritime Transportation	Soner O.; Celik E.; Akyuz E.	2017	90
03	A Novel Fuzzy Hybrid Neutrosophic Decision-making Approach for the Resilient Supplier Selection Problem	Pamučar D.; Yazdani M.; Obradovic R.; Kumar A.; Torres-Jiménez M.	2020	67
04	Adopting Distributed Ledger Technology for the Sustainable Construction Industry: Evaluating the Barriers Using Ordinal Priority Approach	Sadeghi M.; Mahmoudi A.; Deng X.	2021	57
05	Multi-Criteria Decision-Making for Sustainability and Value Assessment in Early PSS Design	Bertoni M.	2019	52
06	Sustainability Assessment of OPEC Countries: Application of A Multiple Attribute Decision-Making Tool	Ecer F.; Pamučar D.; Zolfani S. H.; Eshkalag M. H.	2019	49
07	Integrated Multiphase Sustainable Product Design with A Hybrid Quality Function Deployment – Multi-Attribute Decision-Making (QFD-MADM) Framework	Ocampo L. A.; Labrado J. J. T.; Jumao-as A. M. B.; Rama A. M. O.	2020	42
08	Extended Bipolar Fuzzy EDAS Approach for Multi-criteria Group Decision-making Process	Jana C.; Pal M.	2021	40
09	A Large Group Decision-Making Method and Its Application to The Evaluation of Property Perceived Service Quality	Wen-jin Z.; Deng-feng L.; Gao-feng Y.; Li-ping Z.	2019	27
10	Prioritizing Requirements for Implementing Blockchain Technology in Construction Supply Chain Based on Circular Economy: Fuzzy Ordinal Priority Approach	Sadeghi M.; Mahmoudi A.; Deng X.; Luo X.	2023	25

Table 3 shows the number of documents published in the five journals with the most publications.

Table 3. Top 05 journals that published the most articles identified from the bibliometric analysis

No.	Name of the journal	Number of documents published
01	Journal of Intelligent and Fuzzy Systems	06
02	Sustainability Switzerland	06
03	Journal of Cleaner Production	03
04	Agriculture Switzerland	02
05	Applied Soft Computing	02

These top 10 cited papers demonstrate how complex MCDM frameworks are being used in new ways across several aspects of sustainability and risk management in the construction and allied sectors. Bag et al. (2018) provide a two-tuple linguistic neutrosophic operator for risk assessment in building projects, while Soner et al. (2017) use AHP and VIKOR in a fuzzy environment to optimize marine transportation choices. Pamučar et al. (2020) utilize a hybrid fuzzy-neutrosophic framework to address resilient supplier selection, whereas Sadeghi et al. (2021) employ an ordinal priority method to assess hurdles to deploying blockchain for sustainable building. Similarly, Bertoni (2019) stresses value and sustainability in early product-service system (PSS) design, while Ecer et al. (2019) use various attribute decision-making methodologies to evaluate sustainability in OPEC member nations. Ocampo et al. (2020) provide a QFD-MADM hybrid for multistage sustainable product design, whereas Jana and Pal (2021) suggest an extended bipolar fuzzy EDAS technique for multi-criteria group decision-making. Zuo et al. (2019) widen the scope to large-group decision scenarios, concentrating on property service quality, while Sadeghi et al. (2023) emphasize the significance of blockchain-based supply chain solutions for circular economy objectives in building. Through these different applications, the papers highlight the adaptability and growing importance of MCDM methodologies in furthering sustainability, resilience, and creativity in the built environment.

The multidisciplinary character of research on MCDM methods for sustainable construction is reflected in the distribution of resources across subject areas (see Figure 4). With 19.6%, engineering is the most popular field. Computer science and environmental science are following, both at 14%. Energy makes up 11.2%, and mathematics makes up 12.1%. Agricultural & Biological Sciences, Business, Management & Accounting, and Social Sciences make up 18.6%. The lower numbers for medicine and nursing (2.8% and 1.9%) suggest that these fields are still developing. “Other,” which highlights varied contributions to sustainable construction research, comprises the remaining 5.6%. When taken as a whole, these topics demonstrate the multidisciplinary cooperation required to advance sustainability in the building industry.

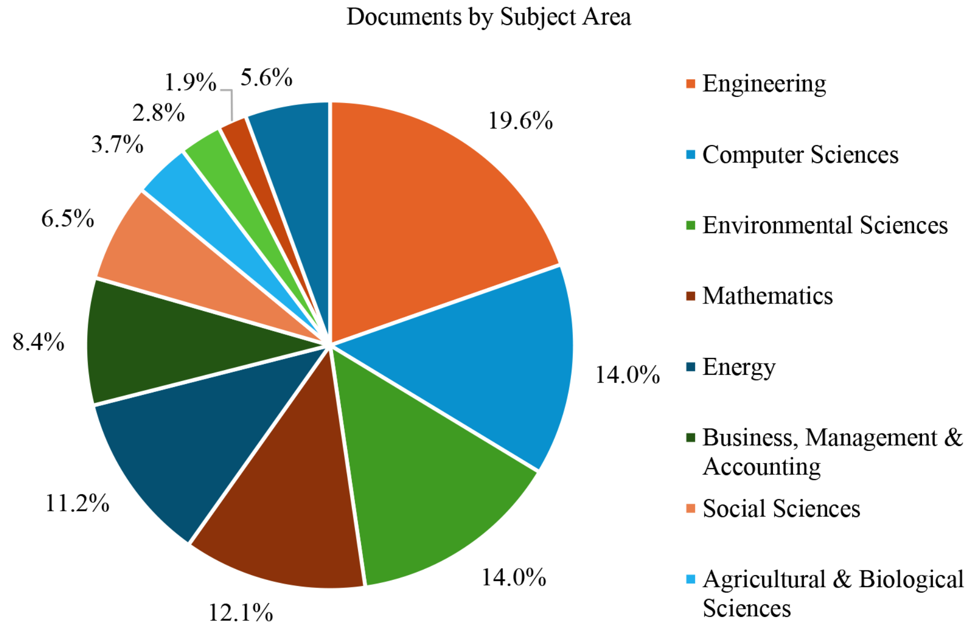

Figure 4. Documents according to subject area

4.2. Visual representation of the bibliometric analysis

Two of the most common network-based methodologies for examining the layout of data from science and technology are co-citation and keyword co-occurrences. A keyword co-occurrence examines the connections between keywords in the literature to understand the knowledge elements and framework of a scientific/technical field, whereas a co-citation analyzes the connections between references in the literature to study the structure of scientific discourse (Radhakrishnan et al., 2017). The VOS viewer application was used to determine the extent of keyword co-occurrence across all 49 publications.

Out of 599 keywords, 88 had a frequency ≥30. These 88 keywords were then subjected to a co-occurrence analysis, as seen in Figure 5.

The keyword's weight value determines the font size and node area. The more times the keyword occurs, and the larger the relevant node and font are, the higher the weight value. Thus, "decision making" is the most frequent term with 255 co-occurrences. "Construction industry" and "fuzzy sets" are next, with 159 and 93 co-occurrences, respectively.

Each node in Figure 6 represents a keyword, and when the surrounding keyword values change, so does the node's density. The node density is higher in the center,

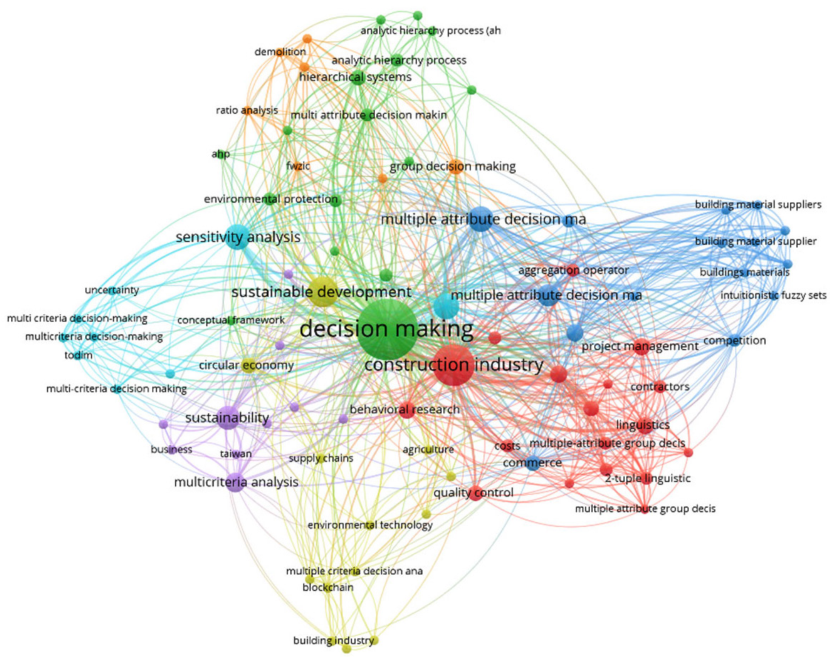

Figure 5. Keyword co-occurrence network

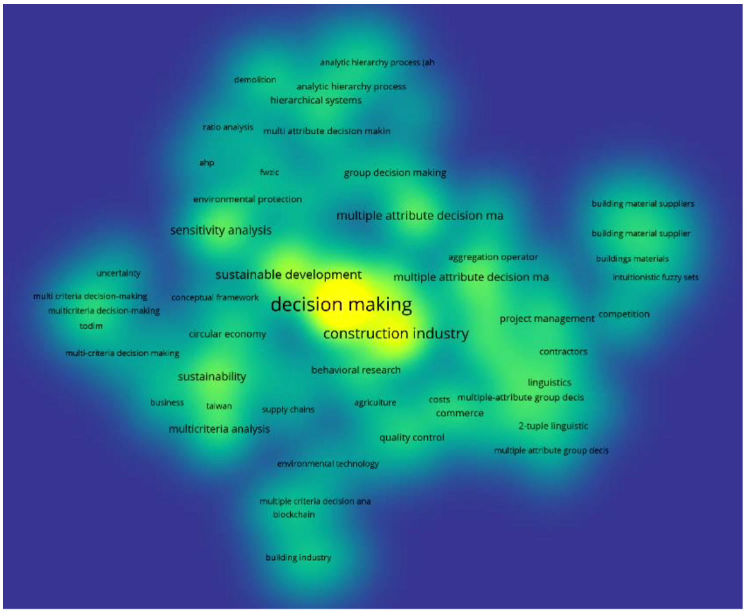

Figure 6. Density overlay of keyword co-occurrence network

and the research emphasis regions are brighter and deeper in color. The study subject is not hot if the nodes near the margins have colors closer to blue and lower density. Accordingly, the yellow area in the center represents the current research hotspot. The following research topics are linked to this hotspot: decision-making, the construction industry, sustainable development, fuzzy sets, multi-criteria analysis, sensitivity analysis, behavioral research, analytic hierarchy process, and multiple attribute decision-making. The research frontier is the blue area near the edge, and the following research areas include waste management, ratio analysis, project management, quality control, energy efficiency, and supply chain management.

Furthermore, VOSviewer was used to build a depiction of global collaboration. The thickness of the line connecting any two countries in the network visualization map indicates the degree of cooperation between those nations. The partnership between different developed and developing countries is depicted in Figure 7. The illustration shows several academic exchanges and collaborations in the field of MCDM research in construction across several nations, with China and the USA collaborating most frequently.

While the global collaboration map highlights the dominant role of countries such as China and the United States in shaping MCDM research for sustainable construction, more in-depth analysis can reveal underlying drivers such as significant governmental funding, robust research infrastructures, and strong academic-industry partnerships, all of which lead to increased publication output and collaborative networks. At the same time, poor participation from other areas might be due to budget limits, policy objectives, or insufficient institutional support. By recognizing these differences, the study may provide light on how larger, more diversified international collaborations–particularly with underrepresented regions–could enhance the global research agenda, promote information sharing, and increase the global effect of sustainable building programs.

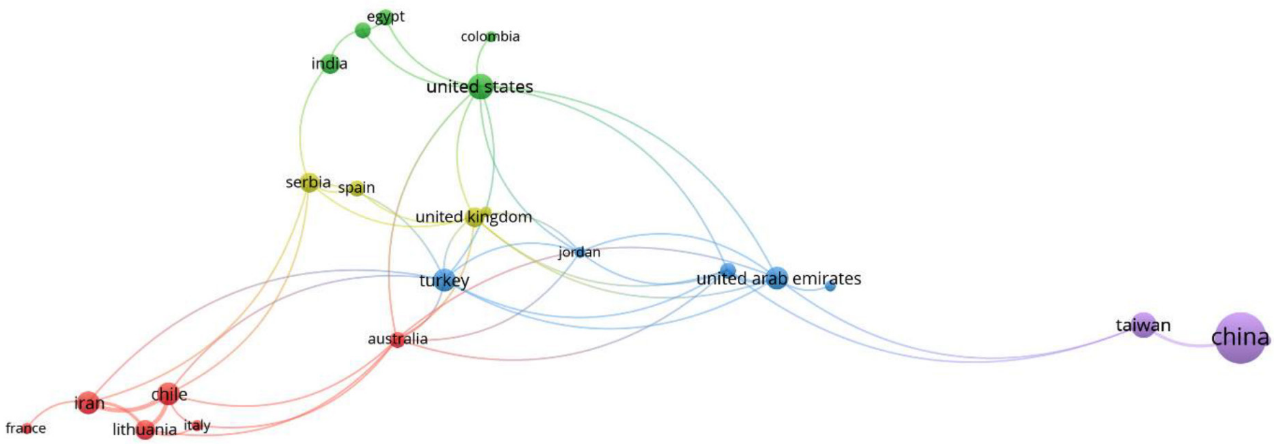

Figure 7. Country collaboration network

5. Discussion on MCDM applications for sustainable built environment

The results are discussed, and the evaluated journal articles are examined in this part. An overview of the examined articles is shown in Table 3, which also includes information about the author(s), year of publication, methodology (single or hybrid), methods used, and research problem.

Table 4 suggests hybrid approaches are more common than single approaches in the field of study on several facets of construction and sustainability. Analytic Hierarchy Process (AHP) is one of the most often used hybrid approaches; it is frequently coupled with methods like WASPAS, TOPSIS, DEMATEL, and others. These hybrid approaches are widely used to tackle challenging problems, including waste management,

Table 4. Summary of the review

No.	Reference	Type	Methodology	Problem
01	(Hasheminasab et al., 2022)	hybrid	AHP-ITARA-CoCoSo	Cleaner building industry
02	(Tao et al., 2022)	hybrid	TODIM-BWM	Site selection for underground construction
03	(Ecer et al., 2019)	hybrid	CoCoSo-WASPAS-MABAC-CODAS-VIKOR	Sustainable development in OPEC countries
04	(Ghailani et al., 2023)	single	MULTIMOORA-	Construction and demolition waste management
05	(Ocampo et al., 2020)	hybrid	QFD-AHP-ANP-DEMATEL	Sustainable product development
06	(Elshaboury & Marzouk, 2020)	hybrid	COPRAS-OCRA	Construction and demolition waste transportation
07	(İlçe & Özkaya, 2018)	hybrid	AHP -MOORA	Selecting the most appropriate construction material
08	(Hsueh et al., 2022)	hybrid	DELPHI-AHP	Appropriate curriculum to educate landscape designers
09	(Pamučar et al., 2020)	single	MABAC	Supply chain optimization
10	(Liu et al., 2023)	single	GRA	The inefficiency of the urban smart transportation system
11	(Gurmani et al., 2022)	single	TOPSIS	Selecting the most suitable construction company
12	(Sadeghi et al., 2023)	single	FOPA	Implement blockchain technology in the construction supply chain for a circular economy
13	(Wu et al., 2018)	hybrid	HM-WHM-DHM-WDHM	Assessing construction project risk
14	(Sadeghi et al., 2021)	single	OPA	Implementing distributed ledger technology for sustainable construction
15	(Bertoni, 2019)	single	CODA	Sustainability and value assessment in PSS design
16	(Zhang et al., 2018)	hybrid	DEMATEL-TOPSIS	Complexity in green contractor selection
17	(Yazdani et al., 2019)	hybrid	CoCoSo-DEMATEL-BWM	Qualified supplier selection
18	(Erdogan et al., 2019)	single	AHP	selecting a contractor
19	(Wang et al., 2023)	hybrid	DELPHI-ANP-TOPSIS	Role of AI in the construction industry
20	(Sánchez-Garrido et al., 2022)	hybrid	SAW-COPRAS-TOPSIS-VIKOR-MIVES	Life cycle performance in terms of sustainability in concrete structures
21	(Akhanova et al., 2020)	single	SWARA	Developing sustainability assessment framework for structures
22	(Yadegaridehkordi et al., 2020)	single	DEMATEL	Sustainability indicators for assessing green buildings
23	(Han et al., 2023)	single	AHP	Optimizing building performances for sustainable designs
24	(Ighravwe & Oke, 2019)	hybrid	SWARA-WASPAS-FAD-ARAS	Selecting a maintenance strategy for public buildings
25	(Josa et al., 2019)	single	MIVES	Sustainability assessment of building structural components
26	(Abadi & Moore, 2022)	single	AHP	Selecting circular proposals for building projects
27	(Zarghami et al., 2018)	single	AHP	Developing sustainability assessment tools for residential buildings
28	(Klumbytė et al., 2021)	hybrid	AHP-ARAS	Sustainable model for facility management
29	(Aghazadeh et al., 2022)	hybrid	DELPHI-SWARA-ARAS	Sustainable material selection
30	(Mayhoub et al., 2021)	single	AHP	Sustainable material selection for building facades
31	(Liu, 2023)	single	MABAC	Quality evaluation in construction
32	(Xu, 2023)	single	EDAS	Contractor selection
33	(Dai & Kang, 2023)	single	GRA	Risk assessment in construction procurement
34	(Song et al., 2020)	hybrid	TOPSIS-ELECTRE	Water resource management

material selection, sustainable development, and construction project performance optimization. Although single techniques are also used–of which AHP is the most frequent–they appear less widespread than hybrid approaches. Based on these findings, the significance of the above MCDM approaches is discussed as follows.

5.1. Material selection

Material selection is a critical issue in the construction and sustainability domains, as indicated by the research included in the table. Gurmani et al. (2022) and Aghazadeh et al. (2022) are among the authors who concentrate on material selection to determine which building materials are best suited for particular projects. These studies frequently use decision-making techniques such as AHP and TOPSIS to rank materials according to cost-effectiveness, availability, durability, and environmental impact, among other criteria.

Using a hybrid method that included QFD, AHP, ANP, and DEMATEL, Ocampo et al. (2020) investigated sustainable product development, which most likely involved material selection. this research provides guidelines for developing sustainable products by prioritizing stakeholder demands and parameter interdependencies. Furthermore, researchers suggest making software easy for remote input and output of design parameter rankings to increase acceptance in the construction industry. Furthermore, Sánchez-Garrido et al. (2022) used a hybrid method that included SAW, COPRAS, TOPSIS, VIKOR, and MIVES to investigate material selection to enhance sustainability in concrete structures. The study emphasizes how crucial it is to consider social, environmental, and economic factors to achieve sustainable building designs. Research by İlçe and Özkaya (2018) that combined the MOORA and AHP approaches found that using this innovative approach ensures that better materials are selected, ultimately raising customer satisfaction. It also increases the effectiveness of buying departments. Mayhoub et al. (2022) emphasize the significance of MCDM) while choosing materials for green building façades, including green rating systems, and determining various standards for thorough assessment. MCDM methods like AHP make thorough evaluation procedures easier. As a result, materials that optimize sustainability and earn more points toward green building certifications can be chosen by decision-makers who can now consider both green origin and performance factors. Aghazadeh et al. (2022) claim that the suggested framework solves the issue of experts' incapacity to offer precise quantitative assessments on complicated real-world challenges by using fuzzy hybrid techniques and triangular fuzzy numbers. This study clarifies essential aspects of sustainable material selection and ideal structural systems for mass-housing projects, demonstrating the stability and resilience of the chosen MCDM technique.

5.2. Contractor selection and supply chain optimization

MCDM is essential for maximizing supply chain management and contractor selection in the construction business.

Erdogan et al. (2019) emphasizes how vital MCDM is while dealing with construction management issues, especially when choosing the best contractor. The paper suggests a nine-step approach for making decisions, including selecting a decision process, defining objectives, identifying alternatives, and establishing criteria. Pamučar et al. (2020) researched supply chain optimization, emphasizing the need for effective logistical procedures to reduce risks and interruptions. Delays, overspending, and inefficient use of resources are all possible outcomes of supply chain interruptions in the construction sector. To create resilience and agility plans, Pamučar et al. (2020) use the MABAC approach to evaluate risks and disruptions in the supply chain. Sadeghi et al. (2023) used the FOPA approach in MCDM to use blockchain technology with the circular economy to improve the supply chain. The study skillfully tackled complicated decision-making processes by utilizing FOPA, highlighting the need to take intra-organizational factors, collaboration infrastructure, and technology requirements. This method helps stakeholders better grasp the characteristics of the circular economy and offers practical guidance on encouraging sustainable practices in the building industry's supply chain. Yazdani et al. (2019) have conducted research that provides construction companies with useful information for long-term planning and reducing vulnerability in their supply chains. The study presents a novel and all-inclusive methodology for addressing complex supplier selection issues in the construction industry. Furthermore, a technique known as 2-tuple linguistic Pythagorean fuzzy EDAS (2TLPF-EDAS) is presented by Xu (2023) to deal with the traditional multiple attribute group decision-making (MAGDM) problem of construction company contractor selection. Xu provides evidence of the suggested approach's efficacy, rationality, and precision in selecting low-cost and high-quality contractors for building projects within a competitive market setting though a case study and comparison analysis with alternative approaches.

5.3. Waste management and risk management

Ghailani et al. (2023) state that the study's primary conclusions emphasize several essential issues about CDW (construction and demolition waste) management solutions that employ MADM techniques. To be more precise, the q-ROPHFS–FWZIC approach efficiently ranked evaluation qualities for reuse distribution in CDW management plans, whereas the q-ROPHFS–FDOSM-based MULTIMOORA technique yielded consistent and trustworthy modelling outcomes. These results emphasize how crucial it is to take into account a variety of factors and use strong

MADM techniques when creating plans for the sustainable management of CDW. Energy was shown to be the most sensitive feature in waste transportation fleet optimization, followed by cost, length, and emissions, according to Elshaboury and Marzouk (2020). This study developed a thorough model that integrated the processes of evaluation, optimization, and decision-making. The model provided insightful information for waste management methods.

Furthermore, Zhang et al. (2018) introduced the IVD-HF_UUBLS technique to improve decision-making processes, which more correctly depicts choice reluctance when choosing an appropriate green contractor by addressing attribute interdependency. The MADM model was made flexible by using DEMATEL and creating generic operators. The approach's usefulness in producing more dependable answers for complex decision contexts is demonstrated by the study's findings, which have been confirmed through case studies and tests. A probabilistic hesitancy fuzzy GRA (PHF-GRA) approach is presented by Dai and Kang (2023) for the risk assessment of engineering procurement construction (EPC) projects. Dai and Kang illustrate the efficacy and relevance of PHF-GRA in resolving the difficulties of integrating and managing projects involving multiple construction parties within the EPC general contracting model in the quickly expanding Chinese construction industry through a realistic case study and comparative analysis.

Through its ability to support well-informed decision-making processes in the face of complex and unpredictable project contexts, MCDM provides invaluable tools for successful construction risk management. Wu et al. (2018) state that the study uses 2TLNNs to analyze MADM difficulties. They provide several 2TLNN-based Hamy mean aggregation operators and devise methods for resolving MADM issues, illustrated using a real-world case study involving risk assessment for construction engineering projects. Song et al. (2020) fill a significant research need in systematic and useful research, especially for diversion scheme selection, presenting a theoretical framework for choosing first-stage diversion schemes (FDSs) to enhance damming process control. In particular, the study addresses social attitudes and environmental considerations within the decision-making process, highlighting the industrial potential of the decision-making framework and mutual information in improving decision-making processes in the damming industry and contributing to overall water resources management.

5.4. Sustainability assessment tools

Ecer et al. (2019) thoroughly assessed OPEC nations' sustainability performances in considering the growing demand for hydrocarbon-based fuels worldwide and the necessity of finding more environmentally friendly energy sources. The UAE, followed by Qatar, Kuwait, and Iran, was found to be the most sustainable nation among OPEC members using the CoCoSo approach. According to the research, political, economic, and geopolitical issues majorly influence sustainability rankings, with nations facing more turmoil falling behind. The results of this study are essential to the construction sector because they provide information on how OPEC nations are doing in sustainability, which is important for guiding decision-making processes in construction initiatives and guaranteeing that they align with international sustainability objectives. Bertoni (2019) provides a systemic approach and tools for assessing circular product/service offerings, incorporating sustainability factors into the decision-making process. The construction industry may benefit from this study as it offers a framework for evaluating the value and sustainability of design solutions, making it easier to make well-informed decisions when working on projects incorporating circular economy and sustainable practices. Akhanova et al. (2020) offer a BIM (Building information modelling)-based methodology for assessing building sustainability adapted to Kazakhstan's environment and uses the SWARA approach to assign weights to evaluation criteria. The study attests to the accuracy and dependability of the framework, stressing its applicability to nearby nations with comparable climates and its usefulness as a resource for green construction developers. By integrating Kazakhstan-specific factors and treating important sustainability categories, the framework facilitates well-informed decision-making and automates green building certification procedures via BIM technology.

Using Malaysia's Green Building Index (GBI), Yadegaridehkordi et al. (2020) develop and rate sustainability parameters to meet the pressing demand for eco-efficiency methods in building fabrication. Using fuzzy DEMATEL analysis, the study highlights the significance of environmental quality and energy efficiency, offering valuable data for improving sustainable practices in the construction industry. Josa et al. (2019) provide a multi-criteria model that applies the MIVES method to evaluate the sustainability of the structural components for inaccessible sports hall roofs. This model provides perspectives on the sustainability and economic viability of several materials, including steel, concrete, and wood. This study helps the building industry by providing practitioners with useful recommendations for environmentally friendly structural design solutions.

Abadi and Moore (2022) provide a decision-making approach that incorporates circularity assessments (CAs) into front-end construction project alternatives to facilitate the selection of circular proposals. The model helps industry practitioners reach an agreement by facilitating systematic evaluations, detailed comparisons between options, and the use of the PLACIT framework and AHP. By directing stakeholders toward more sustainable and circular practices, this strategy helps the construction industry shift to a circular economy. By adapting foreign sustainability assessment instruments to Iranian sustainability concerns, Zarghami et al. (2018) developed the Iranian Sustainability Assessment Tool (ISAT) for residential structures. By incorporating regional concerns like water efficiency and global sustainability priorities, ISAT uses the fuzzy analytic hierarchy process (FAHP) to provide policy-makers and construction experts with a customized framework for implementing sustainable practices in residential construction. This tool helps the construction industry by offering a trustworthy manual for efficiently addressing regional sustainability issues, which promotes the adoption of sustainable building methods in Iran.

5.5. Technological advancements

MCDM is becoming increasingly important in driving technology in the construction sector by enabling decision-making among a complicated range of factors and choices. As technology develops, the transportation sector is gradually transitioning to smart transportation. The GRA-2TLNN for MADM was presented by Liu et al. (2023). To illustrate the efficacy of 2TLNN-GRA, they included an example of a thorough assessment for USTMS, along with comparisons with alternative techniques. In research on the application of AI technologies in the construction industry, Wang et al. (2023) use a hybrid MCDM concept in a fuzzy environment called Delphi-ANP-TOPSIS. The study emphasizes the value of applying the hybrid MCDM framework to assess and rank AI technologies according to many criteria, with practical implications for researchers, industry experts, and policy-makers. Stakeholders are encouraged to address technological, environmental, legal, ethical, and societal ramifications to maximize advantages and minimize dangers in deploying AI within the construction industry (Weerakoon et al., 2024). Sadeghi et al. (2021) highlight how DLT, or blockchain, revolutionizes project delivery and business models in the construction sector. Based on expert perspectives, the report rates 41 hurdles and evaluates 30 sustainable features. It highlights important issues such as the need for more innovative applications, infrastructure for data management, and client demand. Removing these obstacles in the building ecosystem, removing these obstacles significantly improves social, economic, and environmental sustainability, especially in supply chain management, openness, and fair competition.

5.6. Design and maintenance

Based on AHP, Han et al. (2023) suggested a novel MCDM model. This model allows architects to develop the best plans, advancing the building performance-based design's dependability and efficiency. Additionally, this approach enables the architect to actively participate in the optimization process instead of just obtaining the Pareto solution. It allows the optimal design process to transition between a forward and a traditional inverse design at any point. Furthermore, the optimal maintenance plan for public buildings was determined by Ighravwe and Oke (2019) using a variety of MCDM techniques, taking sustainability factors into account. Their study showed that corrective maintenance was the best course of action for long-term economic viability. The study considered preventive maintenance the least appropriate approach for public buildings in the case study region. In contrast, the research found corrective maintenance to be the most suitable strategy, combining FAD and ARAS methodologies with WASPAS.

Additionally, a system that streamlines building inventory and monitoring was presented by Klumbytė et al. (2021), allowing for a thorough assessment of real estate facilities. This method improves real estate management by decreasing the demand for new buildings, increasing efficiency, and lessening the environmental impact. The recommendations provide useful direction for municipal building management as they align with efficient management practices and public law principles. Providing a valuable tool for those involved in energy projects, Tao et al. (2022) give a decision framework for determining the best locations for underground pumped storage design. The framework improves choice flexibility and accuracy by using TODIM to account for varying risk preferences and TIFN to quantify assessment indices. The framework provides a balanced approach between empirical facts and subjective experience by incorporating BWM. Liu (2023) presents P2TLN-MABAC, a unique approach to the quality evaluation of building projects that combines the MABAC methodology with Pythagorean 2-tuple linguistic sets. Using a numerical example, the study illustrates the method's efficacy in supporting construction projects' high-quality and sustainable development by optimizing quality supervision and management systems.

Using DELPHI and AHP, Hsueh et al. (2022) developed a MADM model to improve landscape design education by identifying pertinent instructional courses. Their study emphasizes how important it is for students to acquire transdisciplinary knowledge and professional competencies. The study emphasizes the value of eco-friendly design, project practice, and collaborative design in landscape education by focusing on elements like professional skills, practice, and interdisciplinary collaboration. It aligns with industry demands for sustainability and multidisciplinary approaches. The study also highlights the value of hands-on design and industry partnerships in developing students' skills for sustainable landscape design, which is essential for fulfilling industry demands and advancing the creation of low-carbon and green cities.

6. Conclusions

The present systematic review offers significant knowledge into the use of MCDM and MADM methodologies in tackling diverse issues related to the construction sector and the sustainable built environment. After conducting a bibliometric analysis of 49 articles and reviewing over 34 relevant research papers, it is clear that MCDM techniques are essential for handling complex decision-making situations like selecting a material, selecting a contractor, managing waste, managing risk, evaluating sustainability, keeping up with technology, optimizing design, and organizing maintenance strategies.

The review's conclusions show how common hybrid MCDM approaches are, which blend many methods to successfully address complex problems. One of the most often utilized methods is the AHP, which is regularly combined with other strategies like WASPAS, TOPSIS, DEMATEL, and others to solve a variety of problems from supply chain optimization to material selection. The following are the key takeaways obtained from the SLR:

- Material selection is a crucial area of emphasis, with research using MCDM methodologies to rank materials according to affordability, availability, durability, and environmental impact;
- Effective supply chain management and contractor selection are made easier by MCDM, which also improves logistical processes, lowers risks, and boosts project performance;
- Hybrid approaches such as SWARA, WASPAS, ARAS, DELPHI, ANP, and TOPSIS show how effective it is to combine different techniques to handle difficult problems comprehensively.

It is evident that the MCDM approaches significantly contribute to sustainability objectives such as carbon footprint reduction and resource efficiency by including rigorous assessment criteria (e.g., greenhouse gas emissions, energy consumption, raw material utilization) into the decision-making process. By giving weights and scores to both economic and environmental factors, MCDM creates a balanced framework that emphasizes the long-term advantages of greener choices while guaranteeing that cost-effectiveness and project viability do not trump ecological concerns. This systematic trade-off analysis enables stakeholders to choose building materials, construction techniques, and operational strategies that reduce overall resource depletion and greenhouse gas emissions, thereby reinforcing a comprehensive approach that aligns project objectives with measurable sustainability targets.

Future study on MCDM approaches in the AEC sector should focus on particular gaps and underexplored areas. First, more robust methodologies are required for dealing with real-time data and ambiguity in decision-making, which is especially important in dynamic construction situations. Second, stakeholder-driven weighting systems and criterion selection methods need more examination to guarantee that varied viewpoints are adequately represented. Third, the integration of new digital technologies (such as Building Information Modeling, the Internet of Things, and AI-driven analytics) into MCDM frameworks is still in its early stages and requires additional investigation to improve both accuracy and efficiency. Finally, while hybrid approaches are becoming more popular, there is an urgent need to improve techniques for managing computational complexity, ensuring methodological consistency, and validating data quality, all of which have a direct impact on the practical applicability of MCDM methods in sustainable construction projects.

MCDM approaches may be used in real-world AEC projects by integrating them into current project management processes and digital platforms, such as BIM systems, to enable data-driven evaluations of design options. For example, project teams might employ software plugins or bespoke decision-support dashboards to include crucial variables such as energy use, cost, and stakeholder preferences into weighted scoring models. This allows for fast comparisons of multiple design or material possibilities, even in the face of uncertainty, by giving clear, quantitative outputs that direct stakeholder talks (for example, contractors, architects, and environmental experts). Furthermore, training and capacity-building activities are critical for helping practitioners effectively evaluate MCDM findings, resolve biases or data restrictions, and modify criteria as projects go. Organizations may gradually institutionalize MCDM techniques by developing established processes for data collection, criterion weighting, and model validation, ensuring they remain responsive to project-specific circumstances while still being consistent with larger sustainability objectives.

All things taken into account, the analysis highlights how important MCDM techniques are to assist well-informed decision-making processes, encouraging sustainability, and propelling technical advancements in the architecture, AEC industry. To address changing difficulties and advance the creation of more resilient and sustainable built environments, additional research and the implementation of MCDM methodologies are needed.

References

Abadi, M., & Moore, D. (2022). Selection of circular proposals in building projects: An MCDM model for lifecycle circularity assessments using AHP. *Buildings*, *12*(8), Article 1110. https://doi.org/10.3390/buildings12081110

Afshari, A. R., Nikolić, M., & Akbari, Z. (2017). Personnel selection using group fuzzy AHP and SAW methods. *Journal of Engineering Management and Competitiveness*, *7*(1), 3–10. https://doi.org/10.5937/jemc1701003A

Aghazadeh, E., Yildirim, H., & Kuruoglu, M. (2022). A hybrid fuzzy MCDM methodology for optimal structural system selection compatible with sustainable materials in mass-housing projects. *Sustainability*, *14*(20), Article 13559. https://doi.org/10.3390/su142013559

Ahmad, M., Zhao, Z., & Li, H. (2019). Revealing stylized empirical interactions among construction sector, urbanization, energy consumption, economic growth and CO_2 emissions in China. *Science of the Total Environment*, *657*, 1085–1098. https://doi.org/10.1016/j.scitotenv.2018.12.112

Akhanova, G., Nadeem, A., Kim, J. R., & Azhar, S. (2020). A multi-criteria decision-making framework for building sustainability assessment in Kazakhstan. *Sustainable Cities and Society*, *52*, Article 101842. https://doi.org/10.1016/j.scs.2019.101842

Alaloul, W. S., Musarat, M. A., Rabbani, M. B. A., Iqbal, Q., Maqsoom, A., & Farooq, W. (2021). Construction sector contribution to economic stability: Malaysian GDP distribution. *Sustainability*, *13*(9), Article 5012. https://doi.org/10.3390/su13095012

Amponsah, C. T. (2013). An integrated approach for prioritizing projects for implementation using AHP. *ISAHP Proceedings* (pp. 1–10). https://doi.org/10.13033/isahp.y2013.019

Ashtiani, M., & Azgomi, M. A. (2014). Trust modeling based on a combination of fuzzy analytic hierarchy process and fuzzy

VIKOR. *Soft Computing*, *20*(1), 399–421. https://doi.org/10.1007/s00500-014-1516-1

Ataei, Y., Mahmoudi, A., Feylizadeh, M. R., & Li, D.-F.(2020). Ordinal Priority Approach (OPA) in multiple attribute decision-making. *Applied Soft Computing*, *86*, Article 105893. https://doi.org/10.1016/j.asoc.2019.105893

Bai, C., & Sarkis, J. (2018). Integrating sustainability into supplier selection: A grey-based TOPSIS analysis. *Technological and Economic Development of Economy*, *24*(6), 2202–2224. https://doi.org/10.3846/tede.2018.5582

Becker, J., Becker, A., & Saabun, W. (2017). Construction and use of the ANP decision model taking into account the experts' competence. *Procedia Computer Science*, *112*, 2269–2279. https://doi.org/10.1016/j.procs.2017.08.145

Bertoni, M. (2019). Multi-criteria decision making for sustainability and value assessment in early PSS design. *Sustainability*, *11*(7), Article 1952. https://doi.org/10.3390/su11071952

Bolomope, M., Amidu, A., Ajayi, S., & Javed, A. (2022). Decision-making framework for construction clients in selecting appropriate procurement route. *Buildings*, *12*(12), Article 2192. https://doi.org/10.3390/buildings12122192

Brauers, W. K. M., & Zavadskas, E. K. (2010). Project management by MULTIMOORA as an instrument for transition economies. *Technological and Economic Development of Economy*, *16*(1), 5–24. https://doi.org/10.3846/tede.2010.01

Brauers, W. K., & Zavadskas, E. K. (2006). The MOORA method and its application to privatization in a transition economy. *Control and Cybernetics*, *35*(2), 445–469. https://eudml.org/doc/209425

Brauers, W. K., & Zavadskas, E. K. (2011). MULTIMOORA optimization used to decide on a bank loan to buy property. *Technological and Economic Development of Economy*, *17*(1), 174–188. https://doi.org/10.3846/13928619.2011.560632

Chakraborty, S., & Zavadskas, E. K. (2014). Applications of WASPAS method in manufacturing decision making. *Informatica*, *25*(1), 1–20. https://doi.org/10.15388/informatica.2014.01

Chellappa, V., & Ginda, G. (2023). Application of multiple-criteria decision making methods for construction safety research. *Proceedings of the Institution of Civil Engineers - Management Procurement and Law*, *177*(3), 127–136. https://doi.org/10.1680/jmapl.23.00006

Chen, C. (2019). A new multi-criteria assessment model combining GRA techniques with intuitionistic fuzzy entropy-based TOPSIS method for sustainable building materials supplier selection. *Sustainability*, *11*(8), Article 2265. https://doi.org/10.3390/su11082265

Dai, F., & Kang, Y. (2023). Methodology for risk assessment of engineering procurement construction project based on the probabilistic hesitant fuzzy multiple attributes group decision making. *Journal of Intelligent and Fuzzy Systems*, *45*(6), 12255–12266. https://doi.org/10.3233/jifs-231726

Dalkey, N. C., & Helmer, O. (1963). An experimental application of the DELPHI method to the use of experts. *Management Science*, *9*(3), 458–467. https://doi.org/10.1287/mnsc.9.3.458

Darko, A., Chan, A. P., Ameyaw, E. E., Owusu, E. K., Pärn, E., & Edwards, D. J. (2018). Review of application of analytic hierarchy process (AHP) in construction. *International Journal of Construction Management*, *19*(5), 436–452. https://doi.org/10.1080/15623599.2018.1452098

Dehdasht, G., Ferwati, M. S., Zin, R. M., & Abidin, N. Z. (2020). A hybrid approach using entropy and TOPSIS to select key drivers for a successful and sustainable lean construction implementation. *PloS One*, *15*(2), Article e0228746. https://doi.org/10.1371/journal.pone.0228746

Delgado-Rodríguez, M., & Sillero-Arenas, M. (2018). Systematic review and meta-analysis. *Medicina Intensiva*, *42*(7), 444–453. https://doi.org/10.1016/j.medin.2017.10.003

Ecer, F., Pamučar, D., Zolfani, S. H., & Eshkalag, M. K. (2019). Sustainability assessment of OPEC countries: Application of a multiple attribute decision making tool. *Journal of Cleaner Production*, *241*, Article 118324. https://doi.org/10.1016/j.jclepro.2019.118324

Elshaboury, N., & Marzouk, M. (2020). Optimizing construction and demolition waste transportation for sustainable construction projects. *Engineering, Construction and Architectural Management*, *28*(9), 2411–2425. https://doi.org/10.1108/ecam-08-2020-0636

Enginoğlu, S., Memiş, S., & Karaaslan, F. (2019). A new approach to group decision-making method based on TOPSIS under fuzzy soft environment. *Journal of New Results in Science*, *8*, 42–52.

Erdogan, S. A., Šaparauskas, J., & Turskis, Z. (2019). A multi-criteria decision-making model to choose the best option for sustainable construction management. *Sustainability*, *11*(8), Article 2239. https://doi.org/10.3390/su11082239

Fei, W., Opoku, A., Agyekum, K., Oppon, J. A., Ahmed, V., Chen, C., & Lok, K. L. (2021). The critical role of the construction industry in achieving the Sustainable Development Goals (SDGs): Delivering projects for the common good. *Sustainability*, *13*(16), Article 9112. https://doi.org/10.3390/su13169112

Ferreira, M., Morgado, C. D. R. V., & Lins, M. P. E. (2024). Organizations and stakeholders' roles and influence on implementing sustainability requirements in construction projects. *Heliyon*, *10*(1), Article e23762. https://doi.org/10.1016/j.heliyon.2023.e23762

Francis, A., & Thomas, A. (2019). Exploring the relationship between lean construction and environmental sustainability: A review of existing literature to decipher broader dimensions. *Journal of Cleaner Production*, *252*, Article 119913. https://doi.org/10.1016/j.jclepro.2019.119913

Freire-Guerrero, A., Alba-Rodríguez, M. D., & Marrero, M. (2019). A budget for the ecological footprint of buildings is possible: A case study using the dwelling construction cost database of Andalusia. *Sustainable Cities and Society*, *51*, Article 101737. https://doi.org/10.1016/j.scs.2019.101737

Ghailani, H., Zaidan, A. A., Qahtan, S., Alsattar, H. A., Al-Emran, M., Deveci, M., & Delen, D. (2023). Developing sustainable management strategies in construction and demolition wastes using a q-rung orthopair probabilistic hesitant fuzzy set-based decision modelling approach. *Applied Soft Computing*, *145*, Article 110606. https://doi.org/10.1016/j.asoc.2023.110606

Ghorabaee, M. K., Zavadskas, E. K., Olfat, L., & Turskis, Z. (2015). Multi-criteria inventory classification using a new method of evaluation based on distance from average solution (EDAS). *Informatica*, *26*(3), 435–451. https://doi.org/10.15388/informatica.2015.57

Ghorabaee, M. K., Zavadskas, E. K., Turskis, Z., & Antuchevičienė, J. (2016). A new combinative distance-based assessment (CODAS) method for multi-criteria decision-making. *Economic Computation and Economic Cybernetics Studies and Research*, *50*(3), 25–44. https://EconPapers.repec.org/RePEc:cys:ecocyb:v:50:y:2016:i:3:p:25-44

Goh, C. S., Ting, J. N., & Bajracharya, A. (2023). Exploring social sustainability in the built environment. *Advances in Environmental and Engineering Research*, *4*(01), 1–16. https://doi.org/10.21926/aeer.2301010

Gomes, L. F. A. M., & Lima, M. M. P. P. (1991). TODIMI: Basics and application to multicriteria ranking. *Foundations of Computing and Decision Sciences*, *16*(2), 113–127.

Gurmani, S. H., Chen, H., & Bai, Y. (2022). Multi-attribute group decision-making model for selecting the most suitable construction company using the linguistic interval-valued T-spherical fuzzy TOPSIS method. *Applied Intelligence*, *53*(10), 11768–11785. https://doi.org/10.1007/s10489-022-04103-0

Han, Z., Li, X., Sun, J., Wang, M., & Liu, G. (2023). An interactive multi-criteria decision-making method for building performance design. *Energy and Buildings*, *282*, Article 112793. https://doi.org/10.1016/j.enbuild.2023.112793

Hariram, N. P., Mekha, K. B., Suganthan, V., & Sudhakar, K. (2023). Sustainalism: An integrated Socio-Economic-Environmental model to address sustainable development and sustainability. *Sustainability*, *15*(13), Article 10682. https://doi.org/10.3390/su151310682

Hasheminasab, H., Zolfani, S. H., Kharrazi, M., & Štreimikienė, D. (2022). Combination of sustainability and circular economy to develop a cleaner building industry. *Energy and Buildings*, *258*, Article 111838. https://doi.org/10.1016/j.enbuild.2022.111838

Hatefi, M. A. (2019). Indifference threshold-based attribute ratio analysis: A method for assigning the weights to the attributes in multiple attribute decision making. *Applied Soft Computing*, *74*, 643–651. https://doi.org/10.1016/j.asoc.2018.10.050

Hossain, M. U., & Ng, S. T. (2019). Influence of waste materials on buildings' life cycle environmental impacts: Adopting resource recovery principle. *Resources, Conservation and Recycling*, *142*, 10–23. https://doi.org/10.1016/j.resconrec.2018.11.010

Hsueh, S., Sun, Y., Gao, M., Hu, X., & Meen, T. (2022). Delphi and Analytical Hierarchy Process Fuzzy model for auxiliary decision-making for cross-field learning in landscape design. *Sensors and Materials*, *34*(5), Article 1707. https://doi.org/10.18494/SAM3817

Huang, Y., & Jiang, W. (2017). Extension of TOPSIS method and its application in investment. *Arabian Journal for Science and Engineering*, *43*(2), 693–705. https://doi.org/10.1007/s13369-017-2736-3

Hwang, C., & Yoon, K. (1981). Methods for multiple attribute decision making. In *Lecture notes in economics and mathematical systems* (pp. 58–191). https://doi.org/10.1007/978-3-642-48318-9_3

Ighravwe, D. E., & Oke, S. A. (2019). A multi-criteria decision-making framework for selecting a suitable maintenance strategy for public buildings using sustainability criteria. *Journal of Building Engineering*, *24*, Article 100753. https://doi.org/10.1016/j.jobe.2019.100753

İlçe, A. C., & Özkaya, K. (2018). An integrated intelligent system for construction industry: A case study of raised floor material. *Technological and Economic Development of Economy*, *24*(5), 1866–1884. https://doi.org/10.3846/20294913.2017.1334242

Jana, C., & Pal, M. (2021). Extended bipolar fuzzy EDAS approach for multi-criteria group decision-making process. *Computational and Applied Mathematics*, *40*(1), Article 9. https://doi.org/10.1007/s40314-020-01403-4

Janković, A., & Popović, M. (2019). Methods for assigning weights to decision makers in group AHP decision-making. *Decision Making*, *2*(1), 147–165. https://doi.org/10.31181/dmame1901147j

Jato-Espino, D., Castillo-López, E., Rodríguez-Hernández, J., & Canteras-Jordana, J. C. (2014). A review of application of multi-criteria decision making methods in construction. *Automation in Construction*, *45*, 151–162. https://doi.org/10.1016/j.autcon.2014.05.013

Josa, I., Pons, O., De La Fuente, A., & Aguado, A. (2019). Multi-criteria decision-making model to assess the sustainability of girders and trusses: Case study for roofs of sports halls. *Journal of Cleaner Production*, *249*, Article 119312. https://doi.org/10.1016/j.jclepro.2019.119312

Jovanović, S., Savić, S., Jovičić, N., Bošković, G., & Djordjević, N. (2016). Using multi-criteria decision making for selection of the optimal strategy for municipal solid waste management. *Waste Management & Research*, *34*(9), 884–895. https://doi.org/10.1177/0734242x16654753

Kabassi, K., & Virvou, M. (2004). Personalised adult e-training on computer use based on multiple attribute decision making. *Interacting With Computers*, *16*(1), 115–132. https://doi.org/10.1016/j.intcom.2003.11.006

Karabašević, D., Stanujkić, D., Brzaković, M., & Karabašević, D. (2019). A multiple-criteria decision-making model for the selection of a hotel location. *Land Use Policy*, *84*, 49–58. https://doi.org/10.1016/j.landusepol.2019.03.001

Keršulienė, V., Zavadskas, E. K., & Turskis, Z. (2010). Selection of rational dispute resolution method by applying new step-wise weight assessment ratio analysis (SWARA). *Journal of Business Economics and Management*, *11*(2), 243–258. https://doi.org/10.3846/jbem.2010.12

Klinsky, S., & Mavrogianni, A. (2020). Climate justice and the built environment. *Buildings & Cities*, *1*(1), 412–428. https://doi.org/10.5334/bc.65

Klumbytė, E., Bliūdžius, R., Medineckienė, M., & Fokaides, P. A. (2021). An MCDM model for sustainable decision-making in municipal residential buildings facilities management. *Sustainability*, *13*(5), Article 2820. https://doi.org/10.3390/su13052820

Ley, A., & Lina, A. (2020). Designing software application decision with multi criteria Android-based Analytic Network Process algorithm. *IAIC Transactions on Sustainable Digital Innovation (ITSDI)*, *2*(1), 23–31. https://doi.org/10.34306/itsdi.v2i1.349

Lima, L. R. R., Da Trindade, E. L. G., Alencar, L. H., Alencar, M. H., & Silva, L. (2021). Sustainability in the construction industry: A systematic review of the literature. *Journal of Cleaner Production*, *289*, Article 125730. https://doi.org/10.1016/j.jclepro.2020.125730

Liu, L. (2023). Enhanced MABAC method for Pythagorean 2-tuple linguistic MAGDM and their applications to quality evaluation of construction project. *Journal of Intelligent and Fuzzy Systems*, *45*(1), 593–602. https://doi.org/10.3233/jifs-230963

Liu, Y., Wang, H., Liu, D., & Hou, Y. (2023). Method for comprehensive evaluation of urban smart traffic management system based on the 2-tuple linguistic neutrosophic numbers. *Neutrosophic Sets and Systems*, *53*, 75–96. https://doi.org/10.5281/zenodo.7535963

Liu, Z., Pypłacz, P., Ermakova, M., & Konev, P. (2020). Sustainable construction as a competitive advantage. *Sustainability*, *12*(15), Article 5946. https://doi.org/10.3390/su12155946

MacCrimmon, K. R. (1968). *Decisionmaking among multiple-attribute alternatives: A survey and consolidated approach*. RAND Corporation. https://apps.dtic.mil/sti/pdfs/AD0681005.pdf

Marcher, C., Giusti, A., & Matt, D. T. (2020). Decision support in building construction: A Systematic review of methods and application areas. *Buildings*, *10*(10), Article 170. https://doi.org/10.3390/buildings10100170

Mayhoub, M., Sayad, Z. E., Ali, A., & Ibrahim, M. (2021). Assessment of green building materials' attributes to achieve sustainable building façades using AHP. *Buildings*, *11*(10), Article 474. https://doi.org/10.3390/buildings11100474

Medineckienė, M., Zavadskas, E. K., Björk, F., & Turskis, Z. (2015). Multi-criteria decision-making system for sustainable building assessment/certification. *Archives of Civil and Mechanical Engineering*, *15*(1), 11–18. https://doi.org/10.1016/j.acme.2014.09.001

Moallemi, E. A., Malekpour, S., Hadjikakou, M., Raven, R., Szetey, K., Ningrum, D., Dhiaulhaq, A., & Bryan, B. A. (2020). Achieving the sustainable development goals requires transdisciplinary innovation at the local scale. *One Earth*, *3*(3), 300–313. https://doi.org/10.1016/j.oneear.2020.08.006

Mukhametzyanov, I. Z., & Pamučar, D. (2018). A sensitivity analysis in MCDM problems: A statistical approach. *Decision Making*, *1*(2), 51–80. https://doi.org/10.31181/dmame1802050m

Musarat, M. A., Alaloul, W. S., & Liew, M. S. (2021). Impact of inflation rate on construction projects budget: A review. *Ain Shams Engineering Journal*, *12*(1), 407–414. https://doi.org/10.1016/j.asej.2020.04.009

Musonda, I., & Okoro, C. (2021). Assessment of current and future critical skills in the South African construction industry. *Higher Education, Skills and Work-based Learning*, *11*(5), 1055–1067. https://doi.org/10.1108/heswbl-08-2020-0177

Niederberger, M., & Spranger, J. (2020). Delphi technique in health sciences: A map. *Frontiers in Public Health*, *8*, Article 457. https://doi.org/10.3389/fpubh.2020.00457

Noman, A. A., Akter, U. H., Pranto, T. H., & Haque, A. B. (2022). Machine learning and artificial intelligence in circular economy: A bibliometric analysis and systematic literature review. *Annals of Emerging Technologies in Computing*, *6*(2), 13–40. https://doi.org/10.33166/aetic.2022.02.002

Ocampo, L., Labrador, J. J. T., Jumao-As, A. M. B., & Rama, A. M. O. (2020). Integrated multiphase sustainable product design with a hybrid quality function deployment – multi-attribute decision-making (QFD-MADM) framework. *Sustainable Production and Consumption*, *24*, 62–78. https://doi.org/10.1016/j.spc.2020.06.013

Opricovic, S. (1998). *Multicriteria optimization of civil engineering systems* [PhD thesis]. Faculty of Civil Engineering of the University of Belgrade.

Páez, A. (2017). Grey literature: An important resource in systematic reviews. *Journal of Evidence-Based Medicine*, *10*(3), 233–240. https://doi.org/10.1111/jebm.12265

Pamučar, D., & Ćirović, G. (2015). The selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation Area Comparison (MABAC). *Expert Systems with Applications*, *42*(6), 3016–3028. https://doi.org/10.1016/j.eswa.2014.11.057

Pamučar, D., Yazdani, M., Obradović, R., Kumar, A., & Jiménez, M. T. (2020). A novel fuzzy hybrid neutrosophic decision-making approach for the resilient supplier selection problem. *International Journal of Intelligent Systems*, *35*(12), 1934–1986. https://doi.org/10.1002/int.22279

Patel, P. V., & Patel, A. (2021). Use of sustainable green materials in construction of green buildings for sustainable development. *IOP Conference Series: Earth and Environmental Science*, *785*(1), Article 012009. https://doi.org/10.1088/1755-1315/785/1/012009

Penadés-Plà, V., García-Segura, T., Martí, J. V., & Piqueras, V. Y. (2016). A review of Multi-Criteria Decision-Making Methods applied to the sustainable bridge design. *Sustainability*, *8*(12), Article 1295. https://doi.org/10.3390/su8121295

Peng, X., & Huang, H. (2020). Fuzzy decision making method based on CoCoSo with CRITIC for financial risk evaluation. *Technological and Economic Development of Economy*, *26*(4), 695–724. https://doi.org/10.3846/tede.2020.11920

Pomè, A. P., Tagliaro, C., & Ciaramella, G. (2021). A proposal for measuring in-use buildings' impact through the ecological footprint approach. *Sustainability*, *13*(1), Article 355. https://doi.org/10.3390/su13010355

Radhakrishnan, S., Erbis, S., Isaacs, J. A., & Kamarthi, S. (2017). Novel keyword co-occurrence network-based methods to foster systematic reviews of scientific literature. *PloS ONE*, *12*(3), Article e0172778. https://doi.org/10.1371/journal.pone.0172778

Rezaei, J. (2015). Best-worst multi-criteria decision-making method. *Omega*, *53*, 49–57. https://doi.org/10.1016/j.omega.2014.11.009

Roy, B. (1990). The outranking approach and the foundations of ELECTRE methods. In C. A. Bana e Costa (Ed.), *Readings in multiple criteria decision aid* (pp. 155–183). Springer. https://doi.org/10.1007/978-3-642-75935-2_8

Saaty, T. L. (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology, 15*(3), 234–281. https://doi.org/10.1016/0022-2496(77)90033-5

Saaty, T. L. (1990). How to make a decision: The analytic hierarchy process. *European Journal of Operational Research*, *48*(1), 9–26. https://doi.org/10.1016/0377-2217(90)90057-I

Saaty, T. L. (1996). *Decision making with dependence and feedback: The analytic network process*. RWS Publications.

Saaty, T. L. (2005). *Theory and applications of the analytic network process: Decision making with benefits, opportunities, costs, and risks*. https://ci.nii.ac.jp/ncid/BA84752512

Sadeghi, M., Mahmoudi, A., & Deng, X. (2021). Adopting distributed ledger technology for the sustainable construction industry: Evaluating the barriers using Ordinal Priority Approach. *Environmental Science and Pollution Research*, *29*(7), 10495–10520. https://doi.org/10.1007/s11356-021-16376-y

Sadeghi, M., Mahmoudi, A., Deng, X., & Luo, X. (2023). Prioritizing requirements for implementing blockchain technology in construction supply chain based on circular economy: Fuzzy Ordinal Priority Approach. *International Journal of Environmental Science and Technology*, *20*(5), 4991–5012. https://doi.org/10.1007/s13762-022-04298-2

Sánchez-Garrido, A. J., Navarro, I. J., & Piqueras, V. Y. (2022). Multi-criteria decision-making applied to the sustainability of building structures based on Modern Methods of Construction. *Journal of Cleaner Production*, *330*, Article 129724. https://doi.org/10.1016/j.jclepro.2021.129724

Schmidt, K., Aumann, I., Hollander, I., Damm, K., & Von Der Schulenburg, J. G. (2015). Applying the Analytic Hierarchy Process in healthcare research: A systematic literature review and evaluation of reporting. *BMC Medical Informatics and Decision Making*, *15*(1), Article 112. https://doi.org/10.1186/s12911-015-0234-7

Sethi, B. B., Maharana, B., & Mohanty, B. K. (2016). Periodical literature bibliometric analysis: A case study of four international journals. *Library Philosophy and Practice*, 1. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=3699&context=libphilprac

Song, Z., Liu, Q., & Hu, Z. (2020). Decision-making framework, enhanced by mutual inspection for first-stage dam construction diversion scheme selection. *Water Resources Management*, *34*(2), 563–577. https://doi.org/10.1007/s11269-019-02461-y

Stojčić, M., Zavadskas, E. K., Pamučar, D., Stević, Ž., & Mardani, A. (2019). Application of MCDM methods in sustainability engineering: A literature review 2008–2018. *Symmetry*, *11*(3), Article 350. https://doi.org/10.3390/sym11030350

Tan, T., Mills, G., Papadonikolaki, E., & Liu, Z. (2021). Combining multi-criteria decision making (MCDM) methods with building information modelling (BIM): A review. *Automation in Construction*, *121*, Article 103451. https://doi.org/10.1016/j.autcon.2020.103451

Tao, Y., Luo, X., Zhou, J., Wu, Y., Zhang, L., & Liu, Y. (2022). Site selection for underground pumped storage plant using abandoned coal mine through a hybrid multi-criteria decision-making framework under the fuzzy environment: A case in China. *Journal of Energy Storage*, *56*, Article 105957. https://doi.org/10.1016/j.est.2022.105957

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing Evidence-Informed management knowledge by means of systematic review. *British Journal of Management*, *14*(3), 207–222. https://doi.org/10.1111/1467-8551.00375

Udomsap, A. D., & Hallinger, P. (2020). A bibliometric review of research on sustainable construction, 1994–2018. *Journal of Cleaner Production*, *254*, Article 120073. https://doi.org/10.1016/j.jclepro.2020.120073

Uzair, M., & Kazmi, S. A. A. (2023). A multi-criteria decision model to support sustainable building energy management system with intelligent automation. *Energy and Buildings*, *301*, Article 113687. https://doi.org/10.1016/j.enbuild.2023.113687

Vakili, S., Ölçer, A. I., & Schönborn, A. (2021). Identification of Shipyard priorities in a multi-criteria decision-making environment through a transdisciplinary energy management framework: A real case study for a Turkish Shipyard. *Journal of Marine Science and Engineering*, *9*(10), Article 1132. https://doi.org/10.3390/jmse9101132

Vasilca, I., Nen, M., Chivu, O. R., Radu, V., Simion, C., & Marinescu, N. (2021). The management of environmental resources in the construction sector: An empirical model. *Energies*, *14*(9), Article 2489. https://doi.org/10.3390/en14092489

Wang, K., Zhang, Y., Goswami, S. S., Yin, Y., & Zhao, Y. (2023). Investigating the role of artificial intelligence technologies in the construction industry using a Delphi-ANP-TOPSIS hybrid MCDM concept under a fuzzy environment. *Sustainability*, *15*(15), Article 11848. https://doi.org/10.3390/su151511848

Weerakoon, T. G., Šliogerienė, J., & Turskis, Z. (2024). Assessing the impact of ai integration on advancing circular practices in construction. *Mokslas – Lietuvos ateitis*, *16*, 1–7. https://doi.org/10.3846/mla.2024.21029

Weerakoon, T. G., Wimalasena, S., & Zvirgzdiņš, J. (2023). Assessment of implementation of circular economy framework in the Sri Lankan construction sector. *Baltic Journal of Real Estate Economics and Construction Management*, *11*(1), 133–152. https://doi.org/10.2478/bjreecm-2023-0009

Wei, L., Tam, V. W., Chen, H., & Du, L. (2020). A holistic review of research on carbon emissions of green building construction industry. *Engineering Construction and Architectural Management*, *27*(5), 1065–1092. https://doi.org/10.1108/ecam-06-2019-0283

Wu, S., Wang, J., Wei, G., & Wei, Y. (2018). Research on construction engineering project risk assessment with some 2-tuple linguistic neutrosophic hamy mean operators. *Sustainability*, *10*(5), Article 1536. https://doi.org/10.3390/su10051536

Wu, W. Y., Shih, H., & Chan, H. (2009). The analytic network process for partner selection criteria in strategic alliances. *Expert Systems with Applications*, *36*(3), 4646–4653. https://doi.org/10.1016/j.eswa.2008.06.049

Xu, C. (2023). An integrated fuzzy group decision-making model for construction enterprise contractor selection based on EDAS method and Information entropy. *Journal of Intelligent and Fuzzy Systems*, *45*(2), 3233–3245. https://doi.org/10.3233/jifs-231063

Yadegaridehkordi, E., Hourmand, M., Nilashi, M., Alsolami, E., Samad, S., Mahmoud, M., Alarood, A. A., Zainol, A., Majeed, H. D., & Shuib, L. (2020). Assessment of sustainability indicators for green building manufacturing using fuzzy multi-criteria decision making approach. *Journal of Cleaner Production*, *277*, Article 122905. https://doi.org/10.1016/j.jclepro.2020.122905

Yazdani, M., Wen, Z., Liao, H., Banaitis, A., & Turskis, Z. (2019). A grey combined compromise solution (CoCoSo-G) method for supplier selection in construction management. *Journal of Civil Engineering and Management*, *25*(8), 858–874. https://doi.org/10.3846/jcem.2019.11309

Yazdani, M., Zaraté, P., Zavadskas, E. K., & Turskis, Z. (2018). A combined compromise solution (COCOSO) method for multi-criteria decision-making problems. *Management Decision*, *57*(9), 2501–2519. https://doi.org/10.1108/md-05-2017-0458

Zarghami, E., Azemati, H., Fatourehchi, D., & Karamloo, M. (2018). Customizing well-known sustainability assessment tools for Iranian residential buildings using Fuzzy Analytic Hierarchy Process. *Building and Environment*, *128*, 107–128. https://doi.org/10.1016/j.buildenv.2017.11.032

Zavadskas, E. K., & Turskis, Z. (2010). A new additive ratio assessment (ARAS) method in multicriteria decision-making. *Technological and Economic Development of Economy*, *16*(2), 159–172. https://doi.org/10.3846/tede.2010.10

Zavadskas, E. K., Antuchevičienė, J., Hosseini, M. R., & Martek, I. (2021). Sustainable construction engineering and management. *Sustainability*, *13*(23), Article 13028. https://doi.org/10.3390/su132313028

Zavadskas, E. K., Antuchevičienė, J., Vilutienė, T., & Adeli, H. (2017). Sustainable decision-making in civil engineering, construction and building technology. *Sustainability*, *10*(2), Article 14. https://doi.org/10.3390/su10010014

Zavadskas, E. K., Kaklauskas, A., & Sarka, V. (1994). The new method of multi-criteria complex proportional assessment of projects. *Technological and Economic Development of Economy*, *3*, 131–139.

Zavadskas, E. K., Turskis, Z., & Kildienė, S. (2014). State of art surveys of overviews on MCDM/MADM methods. *Technological and Economic Development of Economy*, *20*(1), 165–179. https://doi.org/10.3846/20294913.2014.892037

Zhang, J., Qi, X., & Liang, C. (2018). Tackling complexity in green contractor selection for mega infrastructure projects: A hesitant fuzzy linguistic MADM approach with considering group attitudinal character and attributes' interdependency. *Complexity*, *2018*, 1–31. https://doi.org/10.1155/2018/4903572

Zhou, J., Xiahou, T., & Liu, Y. (2021). Multi-objective optimization-based TOPSIS method for sustainable product design under epistemic uncertainty. *Applied Soft Computing*, *98*, Article 106850. https://doi.org/10.1016/j.asoc.2020.106850

Zhu, L. (2020). Research and application of AHP-fuzzy comprehensive evaluation model. *Evolutionary Intelligence*, *15*(4), 2403–2409. https://doi.org/10.1007/s12065-020-00415-7

Zhu, R., Hu, X., Li, V., & Liu, C. (2021a). Investigating economic roles of multinational construction industries: A super-efficiency DEA approach. *Applied Economics*, *53*(41), 4810–4822. https://doi.org/10.1080/00036846.2021.1910133

Zhu, X., Meng, X., & Zhang, M. (2021b). Application of multiple criteria decision making methods in construction: A systematic literature review. *Journal of Civil Engineering and Management*, *27*(6), 372–403. https://doi.org/10.3846/jcem.2021.15260

Zuo, W., Li, D., Yu, G., & Zhang, L. (2019). A large group decision-making method and its application to the evaluation of property perceived service quality. *Journal of Intelligent & Fuzzy Systems*, *37*(1), 1513–1527. https://doi.org/10.3233/JIFS-182934

Zvirgzdiņš, J., Plotka, K., & Geipele, S. (2018). Eco-economics in cities and rural areas. *Baltic Journal of Real Estate Economics and Construction Management*, *6*(1), 88–99. https://doi.org/10.2478/bjreecm-2018-0007

Zvirgzdiņš, J., Plotka, K., & Geipele, S. (2019). Circular economy in built environment and real estate industry. *Modern Building Materials, Structures and Techniques*. https://doi.org/10.3846/mbmst.2019.046