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URBAN FLOOD DISASTER RISK MANAGEMENT USING MULTI-CRITERIA DECISION-MAKING METHODS: A SCOPING REVIEW

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Abstract. Statistical data indicates a rising trend in the frequency and unpredictability of floods globally. Regions traditionally less affected by flooding are reportedly experiencing an increased impact, underscoring the widespread nature of this phenomenon. Over the past decade, the overall incidence of floods has significantly increased, affecting billions of people worldwide. If appropriate measures are not taken, floods driven by climate change, urbanization, and the consequences of human activities will continue to increase in frequency and intensity, leading to even greater economic, social, and environmental losses. Proper selection of management strategies and risk reduction measures is becoming particularly important for reducing flood risks. Multi-Criteria Decision Making (MCDM) methods are well-suited for addressing such complex, multi-criteria problems. Therefore, this study aims to explore the research fields of MCDM application in flood management and identify the most widely used methods. This is done to clarify their benefits and enhance their applicability. The Systematic Literature Review (SLR) revealed that the research field is broad and dynamic, evolving over the decades. However, the application of MCDM remains popular and, according to current trends, continues to gain popularity. New research fields are also emerging, such as "Identification and/or Mapping of Flood-Prone Areas" and "Sustainable Infrastructure Assessment", highlighting scientist growing concern about the importance of evaluating vulnerable areas and applying sustainable solutions to address flood management challenges. The findings are particularly relevant to real estate and property management, as they support the development of evidence-based frameworks for assessing property-level flood resilience and for guiding investment decisions to protect built assets.

Keywords: urban sustainability, infrastructure, flood disaster management, nature-based solutions, low impact development, multi-criteria decision-making (MCDM), geographic information systems (GIS).

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1. Introduction

One of humanity's greatest challenges is global warming and its resulting consequences, such as rising sea levels, floods, hurricanes, and biodiversity loss (Fabian et al., 2023; Holgate & Ruddy, 2023). Floods, droughts, hurricanes, and other disasters are becoming increasingly frequent and intense. This is supported by data from the Statista 2024. statistical database, which indicates that the number of natural disaster events worldwide has increased by approximately 15% since 2000. Floods accounted for the largest share of these disasters, with their frequency rising by as much as 20% over the same period. These floods have affected 1.661 billion people and caused more than €646.8 billion in economic losses.

The frequency and intensity of precipitation-induced floods are also influenced by urbanization and the increase in impervious surface areas (Huang et al., 2024; Idowu & Zhou, 2023; Liu et al., 2024). Surfaces such as asphalt, pavement, and concrete, along with the expansion of built-up areas, prevent rainwater from infiltrating the soil. Instead, water accumulates on the sur-face, inundating cities. Overloaded stormwater drainage systems, overwhelmed by in-creased rainfall, exacerbate the problem (Dang et al., 2025). Additionally, pump station failures can cause water blockages, resulting in network breakdowns and flooding of urban areas, streets, and buildings.

Floods driven by climate change and urbanization cause both direct and indirect impacts — from infrastructure damage and economic disruptions to negative effects on public health, education, and emergency services (Barredo et al., 2012; Cea & Costabile, 2022). According to Statista's 2024 data (Statista, n.d.-a), economic losses have not decreased over the past decade and are projected to grow with rising temperatures. The data presented in this analysis were sourced from the Statista platform, which is based on information prepared in 2020 by the United Kingdom, the European Union, and the Joint Research Centre. For example, if global temperatures increase by 3 °C, river-related economic losses alone could reach up to €48 billion annually (Figure 1) unless urgent measures are taken for flood prevention and management.

On April 17, 2024, the United Arab Emirates experienced the heaviest rainfall in Dubai since 1949 (Nyarko, 2024). In Dubai's hot-dominated climate (ten Bosch et al., 2024), where rainfall is typically minimal, the city lacks developed stormwater and drainage systems and has extensive impervious surfaces (Bibi et al., 2023). Consequently, sudden and intense rainstorms cause severe flooding, resulting in loss of life and substantial damage.

Another devastating flood occurred in Spain on October 31, 2024, after eastern Valencia experienced torrential rains on October 29–30. This disaster claimed over 220 lives and caused extensive economic losses (Beake & Mackintosh, 2024). These events highlight the urgent need for effective decision-making methods in flood management and risk reduction.

The global relevance of flood-related issues is highlighted by the United Nations Sustainable Development Goals (SDGs), political statements from various countries, and numerous scientific articles. Due to the importance of this problem worldwide, experts from various fields, including scientists, policymakers, water management, and technology specialists, are working to find the most suitable solutions. They propose diverse concepts for flood management and impact mitigation, such as Nature-Based Solutions (Guerrin et al., 2023), advanced technologies like Artificial Intelligence (AI), the Internet of Things (IoT), and AIoT (Samadi, 2022). Other approaches include the use of Geographic Information Systems (GIS), systems like Blue-Green Systems and Low Impact Development (LID) (Chiu et al., 2022), sentiment analysis (Guo et al., 2021), and other innovative methods.

To ensure long-term and effective flood management, it is essential to apply sustainability concepts. By addressing all three key dimensions, environmental, social, and economical, the best results can be achieved. Since the concept of sustainable urban development incorporates all these aspects (Hassan & Lee, 2015; Huang et al., 2015; Meijering et al., 2018; Tanguay et al., 2010) its application can significantly reduce flood-related damage and contribute to the achievement of the United Nations Sustainable Development Goals (SDGs).

Recent research shows that flood risk is not only a hydrological or engineering issue but also a significant concern for real estate and property management. Enhancing building resilience through measures such as floodproofing, drainage optimization, and planned maintenance is now central to sustainable property management (Amadi, 2024). Effective property-level flood resilience measures can significantly reduce flood damage and improve urban surface water management (Webber et al., 2021). These findings underscore the important role of property managers in turning technical solutions into practical asset protection. Developing decision-support systems to help property managers assess and prioritize flood management measures is essential for aligning flood resilience with long-term asset sustainability and informed investment planning. Multi-Criteria Decision-Making (MCDM) methods can significantly contribute to managing precipitation-induced floods in urbanized areas (De Brito & Evers, 2016). By applying MCDM, diverse criteria are utilized to structure and evaluate alternatives, enabling the selection of the most effective solutions (Voogd, 1982). The effectiveness of these methods is ensured by their adaptability in addressing complex problems and integrating the knowledge of various experts (De Brito & Evers, 2016; Yan et al., 2011; Zagonari & Rossi, 2013) across different fields (Esangbedo & Bai, 2019; Khiavi et al., 2023a; Nasiri Khiavi et al., 2023). MCDM methods also allow the use of mixed information and various data types, making them highly versatile for decision-making in complex scenarios.

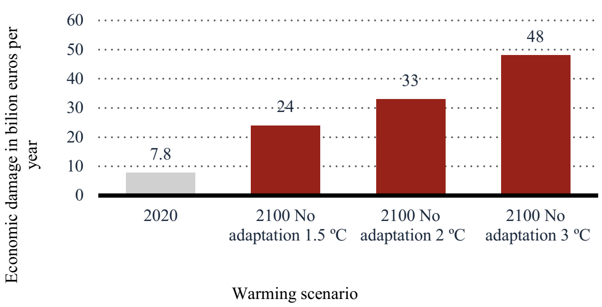

Figure 1. Economic loss due to river floods in the EU (2020–2100), prepared by the authors based on Statista 2024 data under a warming scenario

In the scientific literature on flood risk management, Multi-Criteria Decision-Making (MCDM) methods are frequently applied. However, to the best of our knowledge, between 2016 and November 2024, only one review article on this topic has been published in the Web of Science or Scopus databases.

A highly comprehensive study was published by De Brito and Evers (2016). Norėdami įvesti tekstą, spustelėkite arba bakstelėkite čia.In their review article, they provided an overview of the most widely applied MCDM methods for flood risk management.

The aim of this study is to conduct a systematic review of MCDM applications in flood management over the past decade. This review seeks to evaluate the latest trends in the use of MCDM for flood management and to identify the most critical areas within flood management practices.

The study is structured as follows: Section 2 describes the data and methods, Section 3 presents the results, Section 4 includes discussions and recommendations for future re-search, and Section 5 provides the conclusions.

2. Materials and methods

The Systematic Literature Review (SLR) is a structured and rigorous methodology used for a thorough evaluation of previous research in a specific field (Bolaños et al., 2024). For this review, data were collected from Scopus (www.scopus.com) and Web of Science (WoS) (www.webofscience.com) up to October 31, 2024. These databases were selected based on their status as two of the three most important multidisciplinary bibliographic data sources over the past 15 years (Visser et al., 2021). Scopus is one of the most comprehensive multidisciplinary scientific literature databases, covering a wide range of scientific journals, conference proceedings, books, and other scientific documents (Burnham, 2006; You et al., 2024). Similarly, WoS is known for its extensive and multidisciplinary coverage, categorizing scientific documents into 254 well-defined disciplines (Tian et al., 2024).

For this study, two primary terms, "flood" and "MCDM", were used to construct the query: "flood*" and „mcdm" OR „Multi Criteria Decision-making*" OR „Multi Criterion Decision Making*" OR „Multi-criteria Decision Making*".

The asterisk (*) was used in this study to cover as many studies as possible; for example, flood* ensures that the results include terms such as flood, floods, flooding, and similar variations. In the Scopus database, this symbol was not applied, as the database automatically performs searches for all keyword forms without the need for additional symbols. To avoid including irrelevant articles in the search results — such as those where the terms appeared only in the literature review or reference list — the term search in both databases was restricted to titles, abstracts, and keywords.

This study adopted a systematic review approach, following the guidelines of the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) method (Page et al., 2021), as shown in Figure 2. The initial search yielded 453 articles related to floods and MCDM. The query was then limited to the last decade (between 2016 and October 2024). The results were further refined by removing duplicates and selecting only early access articles and those published in scientific journals, including review articles. Additionally, the documents were narrowed to the field of engineering and limited to articles in English. After evaluating the abstracts of the remaining articles, 74 articles were selected for the study.

Since stormwater management is a critical task for addressing floods in urbanized areas (Dadrasajirlou et al., 2025), the SLR was limited to the field of engineering. Engineering researchers, through their focus on the built environment and the infrastructure of buildings and roads, can identify the most suitable solutions to reduce the economic and social impacts of floods, preserving not only property but also human lives. Properly selected engineering solutions can prevent flood-induced building collapses, accidents, and road damage or obstruction, ensuring that, during disasters, people can be safely evacuated, and the delivery of humanitarian or medical aid is not disrupted.

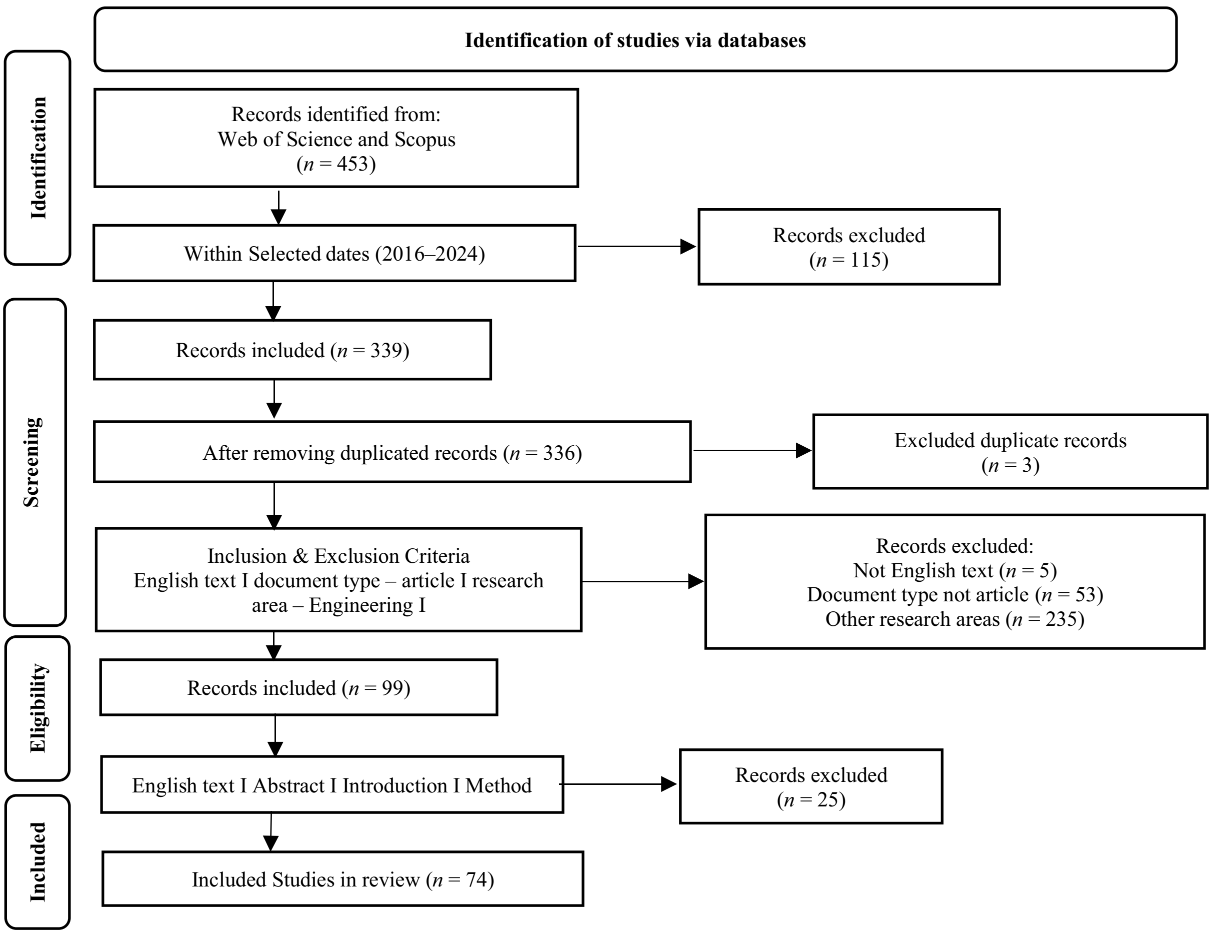

Figure 2. Stages of systematic literature review of MCDM in flood management (source: compiled by the authors using the PRISMA method)

3. Results

This section presents the SLR, covering scientific articles published between 2016 and October 2024. To clearly present the systematic results, the data will be displayed in tables and graphs.

3.1. Trends by year of publication

To analyse the trends in MCDM application in flood management, the articles were categorized by publication year, as shown in Figure 3. Over this decade, similar to the findings of De Brito and Evers (2016), the number of publications has consistently grown. In 2016, only 4 articles were published annually, but a significant increase was observed in 2022, with 9 articles. The number peaked in 2023, reaching 19 publications. As of October 2024, 18 articles have already been published. Since the data for 2024 is incomplete, it is likely that the total number of publications will further increase.

One of the reasons for the growth in this research field could be the adoption of the United Nations (UN) Sustainable Development Goals (SDGs) during the General Assembly session on September 25, 2015, aimed at improving the well-being of people and the planet (Lella et al., 2024). The increasing number of studies and growing attention to this topic may contribute to deeper mitigation of flood impacts and improved preparedness for extreme meteorological events in the future.

A second reason for the increase in publications could be the growing efforts of scientists to improve flood management in response to the intensifying impacts of climate change and natural conditions. Figure 3 also presents the number of floods up to 2023; data for 2024 is not yet available.

The number of floods fluctuated over the years, with a notable rise in 2019, followed by gradual growth until 2022. Based on these data, it is reasonable to support the hypothesis that the increase in the number of floods influenced the growing application of MCDM in flood management.

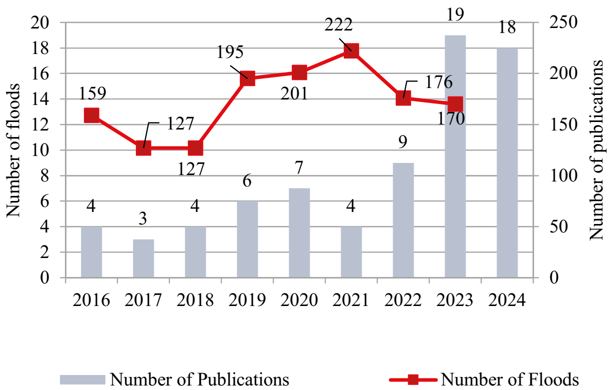

Figure 3. Number of papers on MCDM for flood management published over the period 2016–October 2024 and number of floods over the period 2016–2023 (source: compiled by the authors using Statista, n.d.-b).

3.2. Trends by area of application

An analysis of the selected articles by country (Figure 4) reveals that researchers from all continents have contributed to studies on flood management using MCDM. Asia ac-counted for the majority of publications (73.08%), followed by Europe and North America (7.69% each), Oceania (5.77%), Africa (3.85%), and South America, with the fewest contributions (0.96%). The 74 selected articles were authored by researchers from 104 countries. The countries with the highest number of publications on flood management using MCDM methods were Iran (25.96%), China (13.46%), and India (12.50%).

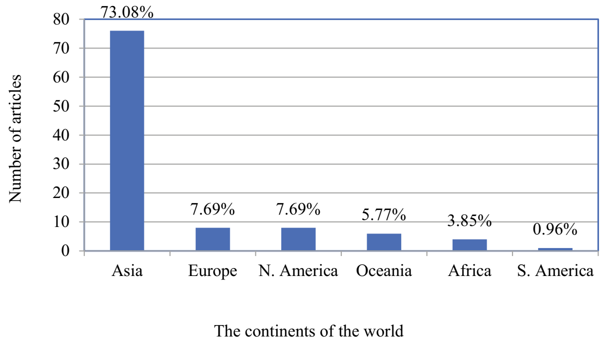

Figure 4. Distribution of MCDM flood management articles by continent

Compared to De Brito and Evers' earlier analysis (1995–2015), Asia remains the dominant contributor, reinforcing the region's leading role in flood management research using MCDM.

3.3. Bibliometric analysis of MCDM in flood management

Using co-occurrence analysis—a powerful text-mining technique that identifies re-search trends and relationships based on the frequency of keyword repetition in textual data (LiangYan et al., 2024) – this study analysed 74 scientific articles. The open-source software tool VOSviewer was employed, with the minimum co-occurrence frequency of keywords set to 2. After cleaning the keywords, a total of 118 unique keywords were identified.

As illustrated in Figure 5, the co-occurrence analysis identified five thematic clusters representing key research areas in the application of MCDM to flood management between 2016 and November 2024. These clusters encompass topics such as *water and urban management*, *climate change*, *disaster prevention*, *sustainability*, and *risk assessment*. The density of connections between terms reflects the frequency and strength of their co-occurrence, highlighting the multidimensional and interdisciplinary nature of the field. The top keywords with their Total Link Strength (TLS), which had at least 8 occurrences, are included in the Top 10 list (Table 1). The results indicate that the most frequently used keyword is *MCDM, followed by decision making, floods, and flood, with one country, Iran, appearing* in this top 10 list.

Table 1. Top 10 keywords in flood management research based on WoS and Scopus data

Rank	Keywords	Occurrences	TLS
1	MCDM	38	120
2	decision making	35	122
3	floods	33	113
4	flood management	23	82
5	risk assessment	14	51
6	AHP	13	55
7	GIS	12	38
8	flood hazards	9	36
9	fuzzy logic	8	34
10	Iran	8	33

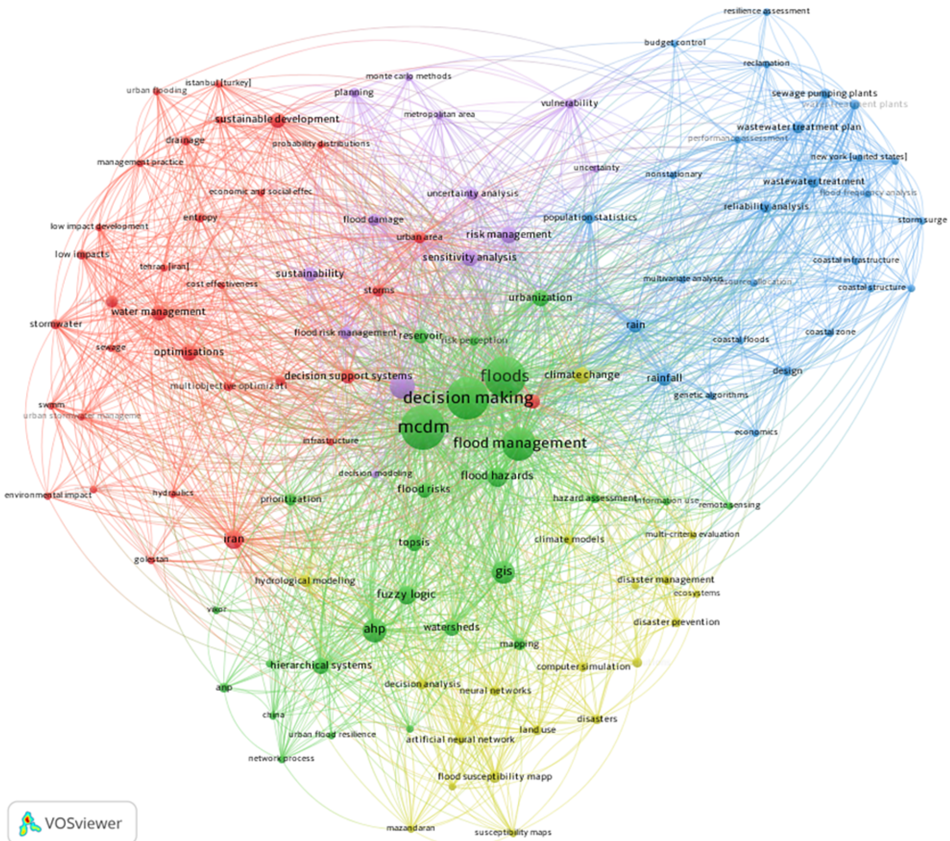

Figure 5. Keyword co-occurrence network for sustainable supply chain management in MCDM for flood management based on data from WoS and Scopus and visualized using VOSviewer

As shown in Figure 6, the results of the keyword co-occurrence visualization indicate that MCDM-related flood management research has evolved beyond purely technical and methodological approaches—such as the RUS framework and criteria correlation—towards a broader integration of socio-economic and environmental themes. These include uncertainty, financial and resource management, sustainability, and system reliability, reflecting the field's increasing interdisciplinarity and practical relevance.

The thematic scope now also encompasses keywords such as *MCDM*, *climate change*, *sustainable development*, *drainage*, *urban area*, *land use*, *flood susceptibility mapping*, *GIS*, *and disaster management*. Notably, the keyword MCDM began to emerge prominently around 2021, while Iran appeared only around 2023, indicating that the country has become one of the leading contributors to this research field in recent years.

3.4. Classification scheme

This section presents an analysis of 74 scientific articles published between 2016 and November 2024. In addition to the previously mentioned criteria for selecting articles,

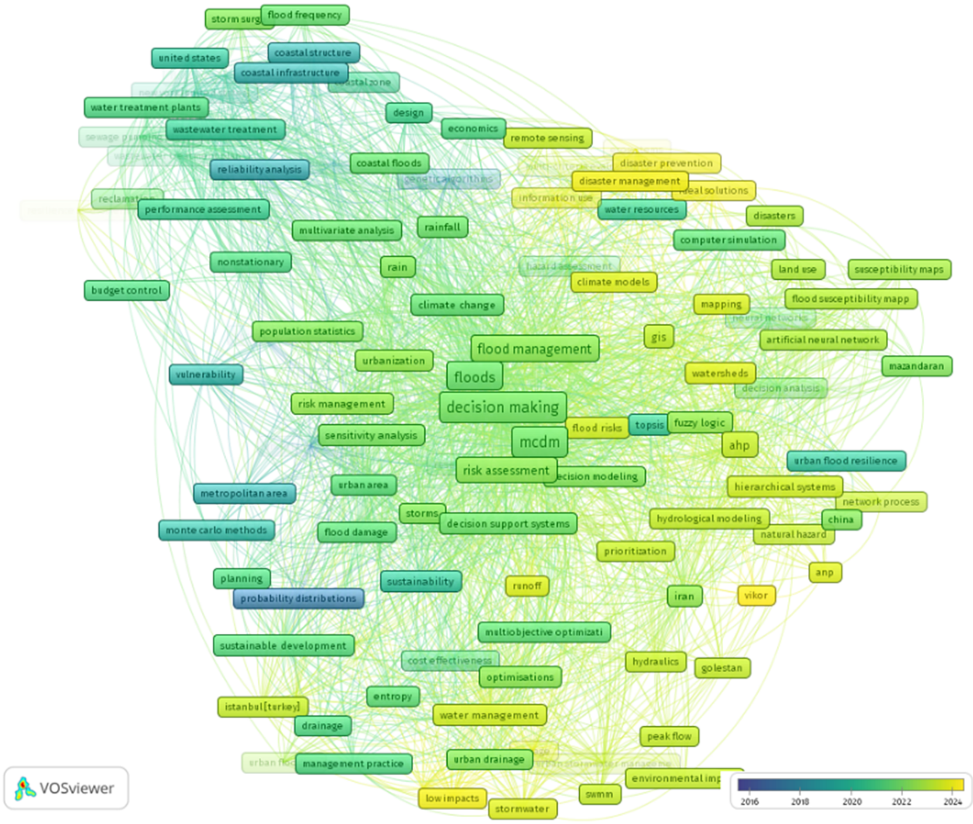

Figure 6. Overlay visualization of keyword co-occurrence in flood management research based on WoS and Scopus data and generated using VOSviewer (WoS, Scopus, VOSviewer)

Table 2. Objectives of the reviewed studies and MCDM methods applied

The aim of the study	MCDM method(s) applied*	The method based on stakeholder groups	Authors
Integrated dam site selection and reservoir flood control: it includes studies aimed at identifying potential dam construction sites to reduce water scarcity and flood risks	TOPSIS, MIF	–	Rane et al. (2023)
Ranking of alternatives and flood risk management: it includes studies that evaluated or examined all three or one of the three stages of flood disasters, namely preparedness, response, or recovery, in terms of organization, planning, and/or implementation (United Nations Office for Disaster Risk Reduction [UNDRR], n.d.)	VIKOR, TOPSIS, AHP5, FAHP, Fuzzy-VIKOR, NS-MAUT, SMAA-VIKOR, PROMETHEE, SCP, ANP, MV-CoCoSo, WSM, COPRAS, SMAA-2, ELECTRE, ELECTRE I, MABAC, TOPSIS, IVIF TOPSIS, FAHP-EW, CWMMD, AHP, EWM, DEMATEL, SMAA, SWARA, Shannon Entropy, FAHP, IEWM, ANP, AHP-EW	Questionnaires, Expert group interviews, Focus group Discussions, Interviews, Expert judgment, Stakeholder analysis, Principal Component Analysis, Group meetings, Voting (Borda method), Field surveys	Abdullah et al. (2020); Ahmadisharaf et al. (2016a); Akay and Baduna Kocyigit (2020); Banihabib et al. (2020); Bitarafan et al. (2023); da Silva et al., (2022); Ekmekcioğlu et al. (2022); Hamidifar et al. (2024); Jodhani et al. (2024); Lyu and Yin (2023); Mooselu et al. (2019); Nematollahi et al. (2022); Rahat et al. (2023); Shahiri Tabarestani and Afzalimehr (2021); Soebroto et al. (2024); Sun et al., (2020); Wei et al. (2024); Xu et al. (2023); Yang and Zhang (2021); Yang et al. (2019); Zhu et al. (2016, 2018, 2017a, 2017b)

End of Table 2

The aim of the study	MCDM method(s) applied*	The method based on stakeholder groups	Authors
Flood resilience assessment: it includes studies that analysed the ability of systems or societies to effectively and timely respond to floods and appropriately man-age their consequences (UNDRR, n.d.)	VIKOR, TOPSIS, AHP, FAHP-EW, AHP, SWM, DEMATEL, SMAA, FAHP, ANP, AHP-EW	Interviews, Delphi	Aldlbahi (2024); Moghadas et al. (2019); Song and Chung (2016); Zhu and Liu (2021)
Vulnerability assessment: it includes articles that assess conditions determined by physical, social, economic, and environmental factors or processes that increase the vulnerability of communities, assets, and systems to the impacts of floods (UNDRR, n.d.)	TOPSIS, WLC, PROMETHEE, AHP, FANP, COPRAS, EM, AHP, EM	Questionnaires, Interviews, Delphi technique, Principal Component Analysis	Aggarwal et al. (2024); Azizi et al. (2023); Boultif et al. (2024); Mladineo et al. (2022); Sutradhar (2023); Tabatabaee et al. (2022); Wang et al. (2019); Zewdu et al. (2024)
Identification and/or mapping of flood-prone areas: this includes identifying areas at risk of flooding and creating corresponding maps. Flood-prone area maps enable responsible authorities to better prepare for emergencies, implement appropriate protective measures, and reduce the damage caused by floods (Ullah et al., 2024)	TOPSI, VIKOR, CoCoSo, AHP, FAHP, CF, EM, FANP, EDAS, WASPAS, COPRAS, SAW, MABAC, Fuzzy-DEMATEL, Fuzzy Logic, FAHP-EW, BWM, AHP, SE, FAHP, EM, FAHP, ANP, FR, WOE, AHP-EW	Questionnaires	Abd-el-Kader et al. (2023); Ahmadisharaf et al. (2016b); Aloui et al. (2024); Balogun et al. (2022); Chandole et al. (2024); Debnath et al. (2023); Dutta and Deka (2024); Guerra and Abebe (2019); Khosravi et al. (2019); Leta and Adugna (2023); Mahmoodi et al. (2024); Moradian et al. (2024); Mudashiru et al. (2022); Negese et al. (2022); Roushan et al. (2024); Sahraei et al. (2023); Shaikh et al. (2024); Shahiri Tabarestani et al. (2023); Upadhyay and Patel (2022); Ziarh et al. (2021)
Sub-Watershed and Watershed Prioritization Effects: it includes studies that analysed the potential of sub-watersheds and watersheds to cause floods	VIKOR, TOPSIS, AHP, PROMETHEE, FANP, WM, FAHP, ANP, ELECTRE I, PSI, AHP, IRN-DEMATEL, ANP, FHAP, CRITIC	Questionnaires	Akay and Baduna Kocyigit (2020); Karamouz et al. (2023); Khiavi et al. (2023b); Mahmoodi et al. (2023); Naubi et al. (2017)
Sustainable infrastructure assessment: it includes studies that evaluated the planning and implementation potential of Low-Impact Development Systems (LID), sustainable urban drainage systems, Stormwater Green Infrastructure (SGI), and Nature-Based Solutions (NBS) in flood management	VIKOR, TOPSIS, PROMETHEE, TODIM, COPRAS, CP, AHP, Entropy, SE, FAHP	Focus group discussions, Delphi method, Questionnaires	Ashofteh and Pourali Dougaheh (2024); Birgani and Yazdandoost (2018); Dadrasajirlou et al. (2023); Ekmekcioğlu (2024); Hosseinzadeh et al. (2023); Mani et al. (2019); Nazari et al. (2023)
Wastewater treatment plant (WWTP) resilience evaluation: it includes studies that assessed the resilience of wastewater treatment plants in populated areas	PROMETHEE, TOPSIS, AHP, Bayesian inference	–	Karamouz et al. (2018, 2020); Karamouz and Farzaneh (2020); Karamouz and Hojjat-Ansari (2020)

Note: * TOPSIS – Technique for Order Preference by Similarity to Ideal Solution; MIF – Multi Influencing Factor; VIKOR – VIseKriterijumska Optimizacija I Kompromisno Resenje; AHP – Analytic Hierarchy Process; FAHP – Fuzzy - Analytic Hierarchy Process; Fuzzy-VIKOR – Fuzzy-VIseKriterijumska Optimizacija I Kompromisno Resenje; NSMAUT – Non-Standard Multi-Attribute Utility Theory; SMAA-VIKOR – Stochastic Multi-criteria Acceptability Analysis - VIseKriterijumska Optimizacija I Kompromisno Resenje; PROMETHEE – Preference Ranking Organization Method for Enrichment Evaluation; SCP – Simplified Composite Programming; ANP – Analytic Network Process; MV-CoCoSo –Majority Voting COmbined COmpromise SOlution; WSM – Weighted Sum Method; COPRAS – Complex Proportional Assessment; SMAA-2 – Stochastic Multi-criteria Acceptability Analysis-2; ELECTRE – Elimination and Choice Translating Reality; MABAC – Multi-Attributive Border Approximation Area Comparison; IVIF-TOPSIS – Interval-Valued Intuitionistic Fuzzy Technique for Order of Preference by Similarity to Ideal Solution; FAHP-EW – Fuzzy-Analytic Hierarchy Process Entropy Weighting; CWMMD – Combined Weighting Method and Multi-criteria Decision-making; EWM – Entropy Weight Method; DEMATEL – Decision-Making Trial and Evaluation Laboratory; SMAA – Stochastic Multi-criteria Acceptability Analysis; SWARA – Step-wise Weight Assessment Ratio Analysis; IEWM – Improved Entropy Weight Method; AHP-EW – Analytic Hierarchy Process Entropy Weighting; SWM – Shannon Weighting Method; WLC – Weighted Linear Combination; EM – Entropy Method; CoCoSo – COmbined COmpromise SOlution; CF – Concordance and Discordance Filter; EDAS – Evaluation based on Distance from Average Solution; WASPAS – Weighted Aggregated Sum Product Assessment; SAW – Simple Additive Weighting; Fuzzy-DEMATEL – Fuzzy-Decision-Making Trial and Evaluation Laboratory; BWM – Best-Worst Method; SE – Shannon Entropy; FR – Fuzzy Ranking; WOE – Weight of Evidence; WM – Weighted Sum Method; PSI – Preference Selection Index; IRN-DEMATEL – Interval Rough Number-Decision-Making Trial and Evaluation Laboratory; CRITIC – Criteria Importance Through Intercriteria Correlation; TODIM – Technique for Order Preference by Similarity to Ideal Solution; CP – Compromise Programming.

they were evaluated based on the objectives of the studies conducted. Specifically, the analysis assessed whether the articles addressed flood management in one or more of its stages (preparation for floods, response during floods, and post-flood recovery) using MCDM methods.

The articles included in the SLR were classified into major research areas. A total of eight primary areas were identified. Table 2 provides information on the objectives for which the articles were selected and the MCDM methods applied to achieve these objectives.

An analysis of the data from Table 3 revealed that between 2016 and November 2024, the most extensively studied research areas were Flood Management, Identification and/or Mapping of Flood-Prone Areas, and Sustainable Infrastructure Assessment. The trends in research areas over the past decade partially align with those identified by De Brito and Evers (2016). However, this study found broader research areas. For instance, Vulnerability Assessment was combined with the Hazard Assessment area, which was examined separately in De Brito and Evers (2016), as these topics are closely related and were often analysed together in scientific articles. Similarly, Coping Capacity Assessment and Emergency Management were integrated into Flood Resilience Assessment in this study, as they are closely connected and are components of Flood Resilience.

Based on the research data, it can be inferred that over the years, studies have become more complex and have examined flood management in a broader scope.

3.5. Trends by area of application

Over the past decade, *Ranking of Alternatives and Flood Risk Management* emerged as the most prominent research topics, accounting for over 32.00% of all studies (Table 3). Closely following was the *Identification and/or Mapping of Flood-Prone Areas* research area, comprising 27.03% of all studies. In third place was *Flood Vulnerability Assessment*, which lagged behind the top two areas by more than half, accounting for only 13.51% of the total research. The least explored area was *Integrated Dam Site Selection* and *Reservoir Flood Control*, with only one study conducted on this topic, representing 1.35% of all research.

Table 3. Distribution of applications by flood risk management topic

Area of application	*N*	%
Ranking of alternatives and flood risk management	24	32.43
Identification and/or Mapping of flood-prone areas	20	27.03
Floods vulnerability assessment	8	10.81
Sustainable infrastructure assessment	7	9.46
Flood resilience assessment	5	6.76
Sub-watershed and watershed prioritization effects	5	6.76
Wastewater treatment plant (WWTP) resilience evaluation	4	5.41
Integrated dam site selection and reservoir flood control	1	1.35
Total	74	100

In the study conducted for the period 1995–June 2015, the most prominent flood management topics were Ranking of Alternatives for Flood Mitigation (22.78%), Risk Assessment (21.11%), and Vulnerability Assessment and Hazard Assessment (each 15.00%), while the least explored topic was Emergency Management (3.89%) (De Brito & Evers, 2016). These results indicate that the most widely studied topics differed only slightly between the two periods. However, the least-studied topics did not align, as since 2016, Emergency Management in flood management using MCDM has not been applied at all.

These topics have attracted significant attention from researchers because Flood Risk Management has become particularly important due to rapid urbanization in coastal zones. Urban engineering systems often prove inadequate in handling not only increased precipitation but also the overflow of water bodies (Shahiri Tabarestani et al., 2023), Urban planning, population behaviour, and even tourist flows can also influence flood risk levels (Romano et al., 2024). As a result, effective land use and planning increasingly involve the identification of risk zones, Mapping of Flood-Prone Areas, and proper assessment of Flood Vulnerability to minimize flood damage as efficiently as possible. Vulnerability includes social vulnerability (Adger, 2006; Ligon & Schechter, 2003; Mandal et al., 2024; Yoon, 2012), Economic Vulnerability (Briguglio et al., 2009; Mandal et al., 2024), Physical Vulnerability (Douglas, 2007; Mandal et al., 2024).

3.6. Trends by MCDM method

Scientists widely use various MCDM methods for identifying flood risk zones to address the precise assessment of flood hazards and vulnerabilities (Dutta & Deka, 2024). Methods such as AHP (Saaty, 1977), TOPSIS, and VIKOR (Edamo et al., 2022; Mitra & Das, 2023) are commonly applied because they each have unique theoretical foundations and lack clearly defined disadvantages when compared to one another (Yang & Zhang, 2021). This theory is also supported by this study. Table 4 provides data on the methods used for various flood management areas.

In scientific articles on the application of MCDM in flood management over the past decade, as in the previous two decades, the most frequently used method was AHP and its variations, such as FAHP and FAHP— accounting for 38.42% of cases. The SLR analysis revealed that this method was particularly common for calculating criteria weights. The second most frequently used method in the analysed studies was TOPSIS and its variations—12.11%, including SMMA-TOPSIS and IVIF TOPSIS. The third most commonly used method was ANP, along with fuzzy ANP and FANP, at 7.89%. The distribution of the remaining methods is provided in Table 5.

Table 4. Distribution of applications by MCDM method and area of application

The aim of the study	AHP, FAHP, FAHP-EW	Others (CoCoSo, EWM, SCP, etc.)	TOPSIS, SMMA-TOPSIS, IVIF TOPSIS	ANP, FANP	VIKOR, Fuzzy-VIKOR, ASAA-VIKOR	PROMETHEE	SE, SEM	EM	DEMATEL, Fuzzy-DEMATEL, IRN-DEMATEL	ELECTRE, ELECTRE I	COPRAS	SMAA, SMAA-2
Ranking of alternatives and flood risk management	22	11	9	4	7	3	3	0	1	3	1	2
Identification and/or Mapping of flood-prone areas	27	11	5	3	2	0	1	2	2	0	1	0
Floods vulnerability assessment	8	3	1	1	0	1	0	2	0	0	0	0
Sustainable infrastructure assessment	2	2	3	0	1	1	1	1	0	0	1	0
Flood resilience assessment	8	1	1	1	1	0	1	0	1	0	0	1
Sub-watershed and watershed prioritization effects	4	3	1	6	1	2	0	0	1	1	0	0
Wastewater treatment plant (WWTP) resilience evaluation	2	3	1	0	0	3	0	0	0	0	0	0
Integrated dam site selection and reservoir flood control	0	1	1	0	0	0	0	0	0	0	0	0
Total	73	35	22	15	12	10	6	5	4	4	3	3

Table 5. Frequency distribution of MCDM methods used in flood management studies

MCDM method	*N*	%
AHP, FAHP, FAHP-EW	73	38.42
Others (CoCoSo, EWM, SCP, etc.)	32	16.84
TOPSIS, SMMA-TOPSIS, IVIF TOPSIS	23	12.11
ANP, FANP	15	7.89
VIKOR, Fuzzy-VIKOR, ASAA-VIKOR	12	6.32
SE, SWM, EM	11	7.79
PROMETHEE	10	5.78
DEMATEL, Fuzzy-DEMATEL, IRN-DEMATEL	4	2.11
ELECTRE, ELECTRE I	4	2.11
COPRAS	3	1.58
Total	190	100

As seen from the data in Tables 5 and 6, 18.23% of studies support the theory that decision-makers individually select MCDM methods based on their understandability and applicability to the specific research context. Similarly, in this decade's research, as in the study by De Brito and Evers (2016) Norėdami įvesti tekstą, spustelėkite arba bakstelėkite čia.covering the previous two decades, the number of MCDM methods used did not match the number of studies. This discrepancy arises because researchers often used multiple methods within a single study, applying different methods for tasks such as calculating criteria weights and obtaining results.

Decision-makers, aiming to avoid confusion-prone approaches and conduct research more efficiently, often select various software tools that enable quick and straightforward result generation Table 6. This reliance on software tools can also influence their choice of MCDM methods for flood management.

Table 6. Software tools supporting MCDM methods in flood risk management

Software tools	MCDM methods
Super decisions (https://superdecisions.com/)	AHP, ANP
D-Sight (https://www.d-sight.com/)	AHP, PROMETHEE, Multi-Attribute Utility Theory (MAUT)
OnlineOutput (https://onlineoutput.com/)	AHP, FAHP, Data envelopment analysis (DEA), DEMATEL, fuzzy DEMATEL, VIKOR, fuzzy VIKOR, TOPSIS, fuzzy TOPSIS, SAW, fuzzy SAW, PROMETHEE, ANP, fuzzy ANP, SWARA, WASPAS
Web-HIPRE (https://hipre.aalto.fi/)	AHP, Simple Multi-Attribute Rating Technique, Pairwise Comparisons
Decision radar (https://decision-radar.com/topsis)	TOPSIS, ELECTRE, SAW
MCDMaker (https://mcdmaker-software.web.app/)	AHP, CoCoSo, COPRAS, DEMATEL, ELECTRE, ENTROPY, VIKOR, TOPSIS, WASPAS, etc.

Table 6 also reveals a narrow range of reported software tools, which may reflect not only actual preferences but also limitations in reporting or tool accessibility. While AI and ML-based decision support tools are being increasingly discussed, their use in this domain remains largely experimental. Until these technologies are validated for flood risk MCDM applications, it is essential to improve current expert-based methods. Since human judgment is prone to subjectivity, bias, and inconsistency, enhancing methods with tools like consistency checks, fuzzy logic, and probabilistic weighting can increase reliability and reduce error.

3.7. Comparative analysis and recommendations for MCDM method selection

The diversity of MCDM methods applied in flood risk management reflects the analytical complexity and varying decision contexts within this domain. While some methods are often selected due to their simplicity or the availability of software, the choice should ultimately be guided by methodological suitability rather than popularity. Table 7 provides a comparative analysis of the most frequently used MCDM methods, summarising their strengths, limitations, and contexts in which they are most appropriate.

While software availability contributes to the popularity of certain MCDM methods, methodological appropriateness should be determined by the decision context. As summarised in Table 7, methods such as AHP and TOPSIS are often chosen for their simplicity, intuitive logic, and ease of implementation when data are well-structured and rapid decision-making is required (Chaube et al., 2024). However, these methods may be insufficient in complex or uncertain contexts involving conflicting objectives or interdependent criteria. In such cases, more technically demanding approaches such as PROMETHEE and ELECTRE provide non-compensatory logic and enable more nuanced preference modelling. VIKOR is particularly useful

Table 7. Comparison of commonly used MCDM methods in flood risk management

Method	Strengths	Limitations	Best suited when	Authors
AHP	Structured hierarchical framework; integrates qualitative expert judgement with quantitative data; supports transparent and systematic weighting; easily combined with GIS-based spatial analysis, widely supported by software	Subjectivity in pairwise comparisons; sensitive to inconsistency; methodological variability may reduce result	Criteria are well-defined; expert knowledge is available; decision problem can be structured hierarchically; GIS-based spatial integration is required	Thammaboribal et al. (2025); Nungula et al. (2024)
TOPSIS	Simple and intuitive ranking method based on distance from ideal solutions; computationally efficient; provides clear logic for decision-makers	Sensitive to data normalization; assumes criteria independence; less appropriate for problems with high uncertainty or qualitative variables	Criteria are quantitative and well-structured; decision-makers require fast and transparent results; inter-criteria dependencies are minimal	Akbulut Basar (2024)
ANP	Captures interdependencies and feedback between decision elements; integrates both qualitative and quantitative data; suitable for complex and dynamic systems; enables comprehensive prioritization; adaptable for SWOT, BOCR, and dynamic extensions	Requires extensive expert input; time-consuming; complex pairwise comparisons; sensitive to inconsistency; high cognitive demand in large-scale problems	Criteria are interdependent; decision elements influence one another; problem structure is complex; both qualitative and quantitative factors are involved; expert-based decision-making is feasible	Balaji et al. (2021)
VIKOR	Designed to identify compromise solutions among conflicting criteria; incorporates both group utility and individual regret; applicable in group decision-making settings	Sensitive to weight assignment and normalization; limited transparency in logic for some users; less effective when alternatives are closely ranked	Conflicting criteria must be balanced; group decision-making is required; a compromise solution is preferred over strict optimization	Yu and Ye (2025)
PROMETHEE	Algorithmically simple; enables full ranking of alternatives; flexible for both quantitative and qualitative criteria; supports dynamic (time-based) evaluation; allows integration of variability metrics (e.g., Gini coefficient); well-suited for multi-dimensional sustainability analysis; enhanced PROMETHEE supports temporal aggregation and trend analysis	Classical PROMETHEE is static – requires enhancements to handle time-dynamic scenarios; may rely on subjective weighting unless objective techniques (e.g., CRITIC) are applied; limited transparency in stakeholder preference explanation	Alternatives need to be ranked over time; criteria are diverse and multi-dimensional; both qualitative and quantitative data are involved; decision-making requires integration of temporal trends and performance variability	Mutambik (2024)

End of Table 7

Method	Strengths	Limitations	Best suited when	Authors
ELECTRE	Designed to handle multiple and often conflicting criteria; provides a structured and transparent decision-making process; suitable for both qualitative and quantitative data; supports outranking logic; flexible across domains such as urban planning, public policy, and technology selection	Requires precise definition of weights and criteria; performance depends on expert input; may oversimplify complex decisions if not properly parameterized; less intuitive than scoring/ranking methods for non-expert users	When decision-making involves conflicting criteria; multiple alternatives must be compared; the goal is to identify dominant options rather than compute exact scores; applicable in smart city technology selection and infrastructure prioritization	Mariane et al. (2024)
Fuzzy variants (e.g., fuzzy AHP, fuzzy TOPSIS, fuzzy VIKOR)	Incorporate vagueness and uncertainty; robust under imprecise input data	Increased modelling complexity; requires advanced understanding	Scenarios involving subjectivity, incomplete data, or qualitative expert evaluations	Das and De (2023)

when compromise solutions are needed among competing alternatives, while fuzzy MCDM variants increase robustness in the presence of ambiguity, imprecision, or subjectivity. Therefore, method selection should be context-driven, considering problem complexity, data availability, stakeholder involvement, and the degree of uncertainty.

Therefore, method selection should be context-driven, considering problem complexity, data availability, stakeholder involvement, and the degree of uncertainty. This comparative analysis directly addresses the need for clarity regarding the strengths and limitations of the most common MCDM approaches, as highlighted by reviewers.

3.8. Trends regarding stakeholders' involvement

Although stakeholder involvement in research can facilitate the development of flood risk management programs (Bakhtiari et al., 2024), it is often excluded. This is supported by the findings of the SLR, which showed that out of 74 studies, only 15 flood management studies included and described stakeholders (Figure 7). The decision-making techniques applied to engage stakeholders included questionnaires, interviews, the Delphi technique, focus group discussions, group meetings, and stakeholder analysis.

Stakeholder involvement in decision-making has become less prominent compared to the findings of De Brito and Evers (2016). When comparing this decade with the previous one, the inclusion of stakeholders has significantly declined. In the study conducted during the period 1992–June 2016, out of 65 studies, 43 involved stakeholders and applied a broader range of methods. In addition to the already mentioned techniques, methods such as workshops, web-based platforms, and narrative analysis were also utilized.

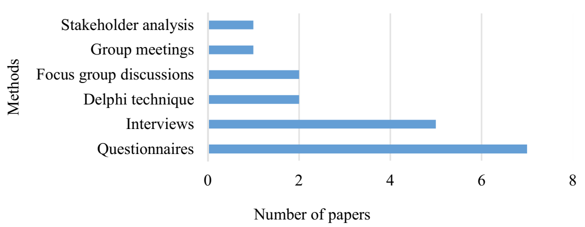

Figure 7. Methods for integrating multiple stakeholders' perspectives in flood management decision-making

The reduced involvement of stakeholders can be attributed to various reasons, such as:

1. Use of standardized and generalized models: decision-makers can rely on their experience, knowledge, and expertise to standardize or create generalized models that can be applied to MCDM methods. This approach makes research more efficient, saving time and resources in the process of selecting and ranking alternatives (Butturi et al., 2025; Khan et al., 2019; Velasquez & Hester, 2013).
2. Stakeholder coordination and competing interests: coordinating stakeholders and managing competing interests can pose significant challenges (Dordi et al., 2022). For instance, differing perspectives between communities and municipalities on land use can create conflicts. Additionally, public procurement processes, designed to ensure transparency, equality, and non-discrimination, can hinder the swift acquisition of new technologies (Directive 2014/24, n.d.).
3. Impact of misinformation: stakeholders, such as government agencies, water management companies, and even communities, influenced by misinformation, may develop incorrect beliefs, leading to poor decisions in flood management (Anderau, 2023). For instance, municipal authorities allocating budgets for infrastructure development or reconstruction may make inappropriate decisions due to inaccurate information about the actual condition of the infrastructure.
4. The application of advanced technologies, such as sensitivity analysis, can aid governmental institutions in efficiently allocating humanitarian aid. However,

the presence of misinformation or false data in systems used to collect information, such as Twitter, can result in improper distribution of humanitarian aid.

5. Use of AIoT: in real-time, IoT devices collect and record various data, such as rainfall measurements, while AI tools process the data and can autonomously perform certain actions (Samadi, 2022). For example, AIoT systems can automatically close or open floodgates to redirect floodwaters. Since such technological solutions can make decisions faster than human experts, the involvement of stakeholders in flood management processes has decreased.

Given these constraints, alternative solutions for supporting participatory decision-making are needed. In this context, artificial intelligence (AI) and machine learning (ML) methods offer promising supplementary pathways. While still at an early stage of adoption in flood-related MCDM applications, such tools can simulate stakeholder behaviour, extract preferences from historical data, or generate synthetic expert input in cases where direct engagement is impractical. Although these technologies are not a substitute for authentic participation, they may help improve inclusivity, transparency, and continuity in data-scarce or expert-limited environments. Future research should explore how AI-driven approaches can complement—not replace—traditional stakeholder engagement processes.

For these reasons, stakeholder involvement may no longer be as effective and beneficial as it was prior to 2016. Consequently, the inclusion of stakeholders in decision-making processes using MCDM for flood management may continue to decline in the future.

4. Discussion

Due to increasing climate change, urbanization, and human activities, humanity is increasingly facing more frequent and unpredictable floods, which are causing greater ecological, economic, and social damage worldwide. The most affected are residents of countries with lower Gross Domestic Product (GDP) (Padli et al., 2010; Zorn, 2018). In low-GDP regions, deforestation exacerbates the impact of floods, often triggering landslides that result in loss of life and destruction of property. In addition to the harm suffered by residents, cities themselves are also severely impacted, with infrastructure being destroyed. Economically developed countries are not immune to the effects of floods either, as exemplified by the 2024 floods in the United Arab Emirates and Spain.

Therefore, it is essential for all countries worldwide to adopt sustainable urban infra-structure development and constructively address the environmental, economic, and social challenges of flood risk management. Sustainable urban and infrastructure development should incorporate solutions such as green infrastructure, which integrates networks of natural and semi-engineered systems (Webber & Samaras, 2022), NBS including permeable surfaces, water collectors, and infiltration trenches, among others (Chiu et al., 2022). These sustainability-focused solutions can significantly contribute to reducing flood risks.

In addition to preventive measures, effective flood management strategies during and after disasters are crucial. These can benefit significantly from the application of advanced technologies such as AI and IoT (Samadi, 2022), AIoT, drones (He et al., 2024) and sentiment analysis (Bryan-Smith et al., 2023; Lu et al., 2023; Ma et al., 2023; Qin et al., 2024; Wang et al., 2024; Zander et al., 2023).

The emergence of trends in the application of new technologies is confirmed by the Co-Occurrence study. During this research, an analysis of the frequency and occurrence trends of key terms such as "GIS", "urban flood resilience", "climate models", and "decision analysis" revealed that from 2018 to 2024, scientists primarily focused on modern technologies, such as the application of GIS and the development of artificial neural networks. Additionally, significant conceptual topics, such as urban flood resilience, were widely explored. In earlier years (2016–2018), dominant keywords (e.g., "flood frequency", "storm surge", "wastewater treatment", "reliability analysis") indicated that more attention was previously given to technical aspects related to the reliability of flood infrastructure or wastewater treatment.

Based on newly identified trends, future researchers could conduct more in-depth interdisciplinary studies integrating technological solutions while considering societal needs. This approach would encompass engineering, social, climatological, and political aspects, enabling more effective and sustainable urban flood management. Such a holistic method could not only enhance cities' resilience to extreme natural events but also ensure the long-term sustainability of their development.

Since solutions to flood management challenges are multifaceted and must address technological, economic, environmental, and social aspects across all stages of flood management MCDM methods are highly effective for evaluating and selecting the most suitable and efficient alternatives. This is confirmed by the SLR, which showed a consistent increase in the number of studies applying MCDM methods in flood management. Decision-makers selected methods individually for their studies, with AHP being the most commonly chosen method over the past three decades.

Integrating analytical decision-support methods such as MCDM into property management can significantly enhance resilience-focused urban planning. The fuzzy-AHP model by Adebimpe et al. (2021) shows that combining quantitative and qualitative factors, such as physical vulnerability, economic exposure, and stakeholder preferences, effectively assesses flood resilience at the property level. Private property rights and spatial planning instruments are also essential for managing flood risk, as they balance public safety with property value (Sheehan & Brown, 2021). Aligning property-level decision-making tools with the work of real estate developers and asset managers supports comprehensive flood management strategies that are technically sound and socially and economically sustainable.

In the SLR analysis, a new trend was also observed: the decreasing involvement of stakeholders when using MCDM. As a result, there is a need for thorough investigation and evaluation of the benefits and drawbacks of decisions made without stakeholder involvement. This aims to achieve the greatest possible benefits for urban areas.

The patterns observed in the literature reflect deeper structural and methodological challenges. The limited stakeholder involvement may be attributed to logistical constraints, difficulty in accessing affected populations, or the absence of standardized frameworks for participation. Similarly, the widespread use of methods such as AHP and TOPSIS is likely driven by their ease of implementation and integration into popular decision-support tools, rather than intrinsic methodological superiority. Uneven data availability across regions and limited interdisciplinary collaboration further encourage reliance on expert-driven models, often at the expense of inclusivity and contextual relevance. These underlying causes point to the need for more robust, flexible, and participatory decision-making frameworks in future flood risk management efforts.

When interpreting the results of this study, it is important to consider that the quality of the articles was not assessed. The articles were selected from databases that include peer-reviewed journal articles. Similar to De Brito and Evers (2016) (Tanguay et al., 2010), the definitions of flood management application areas were subjective, as there are no clear agreements on these terms in the scientific literature. Consequently, these terms may be interpreted and defined differently by various researchers, even within the same countries.

Firstly, although this review allowed for the identification of research trends in this field, it did not address the gaps in the application of MCDM methods. Since researchers typically select methods that they find clearly understandable (Yang & Zhang, 2021), the study did not analyse differences between flood management alternatives when evaluated using different methods.

Secondly, the SLR results indicate that stakeholders are increasingly excluded from research, as advancements in technology, the emergence of AI tools integrated with databases, and the use of standardized and generalized models have reduced the effectiveness of the human factor in urgent decision-making processes. Therefore, further studies should compare the outcomes of decision-making involving experts and stakeholders with those that incorporate AI. These studies should also identify the opportunities, risks, and threats associated with using one approach over another.

As highlighted in the bibliometric and regional analysis (see Figures 4–5 and Table 2), several research gaps remain evident in the application of MCDM to flood management. First, there is a pronounced geographical imbalance: more than 73% of the reviewed studies originate from Asia, whereas contributions from Africa (3.85%) and South America (0.96%) are minimal. This asymmetry limits the generalizability of findings and underscores the need for more region-specific investigations in underrepresented contexts, particularly in countries with high exposure to flooding but limited research visibility. Second, the thematic scope of existing studies remains concentrated on flood-risk ranking and mapping, while fewer works address long-term resilience of infrastructure, wastewater treatment facilities, or post-flood recovery and adaptation strategies. Third, although methods such as AHP and TOPSIS dominate (Table 2), more flexible and uncertainty-oriented approaches—such as PROMETHEE, ELECTRE, or fuzzy-based MCDM—are rarely applied, despite their suitability for complex and multi-dimensional decision problems. Finally, while emerging technologies such as artificial intelligence and machine learning appear in the keyword network (Figure 5), their integration into MCDM frameworks is still at an early stage. Future research should therefore explore systematic ways to embed AI/ML into flood management decision-making, enhancing predictive capacity, risk mapping, and real-time responses, while also ensuring inclusiveness and methodological diversity.

5. Conclusions, limitations and future directions

This study aimed to assess the application of MCDM methods in flood management through an SLR covering the period from 2016 to October 2024. A total of 114 peer-reviewed articles were analyzed based on predefined selection criteria. The findings revealed a clear correlation between the frequency of flood events and the number of related publications. Research activity increased significantly from 2016 to 2021, slightly declined afterward, and rose again in 2023. This trend may be associated with several factors, including the growing impacts of climate change, increased population density and urbanization in flood-prone regions, and the rising demand for structured decision-support tools to address complex challenges.

The majority of the analyzed studies (73%) were conducted in Asia, continuing the trend observed from 1995 to 2015 (85%). This regional concentration highlights the sustained relevance of flood-related decision-making tools in areas most exposed to hydrological risks. Although MCDM methods were applied consistently throughout the decade, keyword co-occurrence analysis indicates that the term "MCDM" only gained significant visibility in the field after 2021.

The review identified eight main application domains: alternative ranking, flood risk management, flood-prone area mapping, vulnerability assessment, infrastructure sustainability, flood resilience, watershed prioritization, and WWTP or dam site selection. These domains reflect the adaptability of MCDM techniques to a broad spectrum of complex multi-criteria decisions. The usefulness of MCDM was confirmed by mapping specific methods to decision contexts (see Table 5), demonstrating the suitability of particular tools to different levels of complexity and uncertainty.

Despite these strengths, the review also revealed notable limitations. Only 20% of recent studies reported stakeholder involvement, compared to approximately 50% in the 1995–2015 period. This decline may be due to an increasing reliance on standardized models, challenges in coordinating stakeholder input, the influence of misinformation, and the growing adoption of AIoT technologies. Additionally, the range of reported software tools remains narrow (Table 6), and methodological transparency is limited—suggesting broader structural constraints within MCDM-based flood research.

To address these challenges, future work should promote more inclusive, participatory, and adaptive decision-making frameworks. Approaches such as fuzzy logic, probabilistic modelling, and AI-assisted simulations can enhance both data quality and stakeholder engagement. Continued research should also track how MCDM usage evolves in response to climate dynamics, technological advancements, and changes in governance. Ensuring that method selection aligns with the complexity of decision contexts remains essential: AHP and TOPSIS are better suited for structured, well-defined problems, while PROMETHEE, ELECTRE methods offer greater flexibility for complex, uncertain scenarios involving qualitative inputs or conflicting objectives. Ambiguity in decision contexts highlights the usefulness of fuzzy-based MCDM methods, which explicitly accommodate vagueness and imprecision in expert judgments.

In summary, MCDM is becoming increasingly prominent in flood management research. To fully realize its potential, ongoing efforts must focus on improving methodological clarity, transparency, and inclusiveness in the decision-making process.

While this review has highlighted key trends and methodological advances in the application of MCDM to flood management, it is equally important to recognize where research remains limited. Several critical gaps can be identified. Geographically, the literature is strongly concentrated in Asia, whereas Africa and South America remain underrepresented, which constrains the global transferability of findings. Thematically, studies continue to focus on risk ranking and mapping, with considerably fewer works addressing infrastructure resilience, wastewater treatment systems, and long-term recovery or adaptation strategies. Methodologically, AHP and TOPSIS dominate, while more flexible approaches such as PROMETHEE, ELECTRE, or fuzzy-based MCDM are rarely applied, despite their suitability for uncertain and multi-dimensional decision contexts. Finally, although artificial intelligence and machine learning are emerging in the field, their systematic integration into MCDM frameworks is still in its early stages. Addressing these gaps would not only broaden the relevance of MCDM for diverse regions and flood stages but also strengthen its capacity to combine methodological rigor with stakeholder engagement and real-time decision support.

Future studies could further enhance MCDM-based flood management by incorporating emerging technologies such as the Internet of Things (IoT) and sentiment analysis. IoT-enabled sensors can provide real-time hydrological and infrastructural data, thereby strengthening the evidence base for timely and adaptive decision-making. In parallel, sentiment analysis of social media and community-generated content could capture evolving public perceptions, risk awareness, and behavioural responses during flood events. The integration of these approaches with MCDM would not only enrich data diversity but also foster more responsive, participatory, and context-sensitive decision-support systems. such integration opens promising avenues for future research, ensuring that MCDM frameworks evolve in step with technological progress and societal transformations.

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