Journal of Infrastructure, Policy and Development 2024, 8(15), 9984.
https://doi.org/10.24294/jipd9984

Review

Literature review on the evaluation of resilience in infrastructure projects

Ali Shoaei*, **Vitor Sousa, Carlos Oliveira Cruz**

CERIS, Instituto Superior Técnico, Universidade de Lisboa, 1049-001 Lisboa, Portugal
*** Corresponding author:** Ali Shoaei, ali.shoaei@tecnico.ulisboa.pt

CITATION

Shoaei A, Sousa V, Cruz CO. (2024). Literature review on the evaluation of resilience in infrastructure projects. Journal of Infrastructure, Policy and Development. 8(15): 9984. https://doi.org/10.24294/jipd9984

ARTICLE INFO

Received: 30 October 2024
Accepted: 19 November 2024
Available online: 16 December 2024

Abstract: Infrastructure decision-making has traditionally been focused on the use of cost-benefit analysis (CBA) and multicriteria decision analysis (MCDA). Nevertheless, there remains no consensus in the infrastructure sector regarding a favored approach that comprehensively integrates resilience principles with those tools. This review focuses on how resilience has been evaluated in infrastructure projects. Initially, 400 papers were sourced from Web of Science and Scopus. After a preliminary review, 103 papers were selected, and ultimately, the focus was narrowed down to 56 papers. The primary aim was to uncover limitations in both CBA and MCDA, exploring various strategies for amalgamating them and enhancing their potential to foster resilience, sustainability, and other infrastructure performance aspects. Results were classified based on different rationalities: i) objectivist, ii) conformist, iii) adjustive, and iv) reflexive. The analysis revealed that while both CBA and MCDA contribute to decision-making, their perceived strengths and weaknesses differ depending on the chosen rationality. Nonetheless, embracing a broader perspective, fostering participatory methods, and potentially integrating both approaches seem to offer more promising avenues for assessing the resilience of infrastructures. The goal of this research proposal is to devise an integrated approach for evaluating the long-term sustainability and resilience of infrastructure projects and constructed assets.

Keywords: cost-benefit; decision-support; evaluation; infrastructure; multi-criteria analysis; resilience

1. Introduction

Infrastructure assets like roads, bridges, and railways are vital to daily life but require significant investment, often made under uncertainty (Marlow et al., 2010). Decision-making in this area is challenging due to complex asset networks, limited resources, conflicting goals, and uncertainties (Chen and Bai, 2019). Cost-benefit analysis (CBA) and Multi-Criteria Decision Analysis (MCDA) are widely used tools for infrastructure investments.

CBA, mandatory for EU-funded projects (European Commission, 2014; Xu et al., 2015), provides a clear quantitative view of benefits and costs. However, it is complex, its adoption varies across Europe, and guidelines do not guarantee full acceptance (Andersson, 2018). MCDA, frequently applied in national projects, simplifies decision-making by reducing technical data complexity (Ha et al., 2019; Tripathy et al., 2019; Yannis et al., 2020).

CBA assesses projects based on economic efficiency, using Key Performance Indicators (KPIs) like Net Present Value (NPV) and Internal Rate of Return (IRR), while MCDA can incorporate both monetary and non-monetary impacts to align with stakeholder preferences (Florio et al., 2018). CBA provides a clear financial and economic justification, whereas MCDA offers transparency and broader stakeholder engagement (Dodgson et al., 2009). MCDA has evolved through various fields, allowing for diverse evaluations across criteria such as economic, social, and environmental factors (Bana e Costa et al., 2006). Institutions like the EIB and ADB recommend MCDA to complement CBA for more holistic evaluations (Bank, 2013; EC, 2015; Véron-Okamoto and Sakamoto, 2014). CBA evaluates infrastructure investments by weighing their forecasted costs against the anticipated benefits, aiding decision-making regarding resource allocation (Marleau Donais et al., 2019). On the other hand, MCDA provides a multi-dimensional approach, considering diverse criteria and objectives, essential in understanding infrastructure performance (Lohman et al., 2023).

Resilience assessments often use CBA or MCDA to evaluate infrastructure's ability to withstand and recover from disruptions (Yang et al., 2023). Resilience can be quantified using the resilience triangle approach to calculate NPV or through indicators in CBA (Bruneau et al., 2003; Wang et al., 2021). These methods help optimize infrastructure management and investment, enhancing operational safety and socioeconomic benefits (Zhang et al., 2017).

A few papers, using and comparing CBA and MCDA from the perspective of their respective fields, can be found in the literature on topics such as nature-based solutions (Teotónio et al., 2020), environmental risk management (Gamper and Turcanu, 2007), energy (Medjoudj et al., 2013), sustainable development (Brucker et al., 2004), water management (Brouwer and Van Ek, 2004), and transportation (Marleau Donais et al., 2019). However, such literature reviews in the field of infrastructure resilience are absent. This review highlights the importance of both tools in assessing infrastructure resilience, sustainability, and performance, enabling informed decision-making and effective resource allocation.

2. Methodology

2.1. Concept review

The primary focus of this review is to explore the literature on MCDA and CBA tools for assessing infrastructure performance, particularly in the context of resilience. To address this objective, each contribution was classified based on specific variables and systematically organized into three main categories aligned with the study's objectives: Assessment Dimensions (Resilience or other performance measures), Tools (CBA and MCDA), and Applications (Infrastructure or related fields). The following subchapters provide a detailed discussion of these categories.

2.1.1. Assessment dimension

The assessment dimensions in this review encompass resilience, sustainability, and other performance metrics. However, the primary focus of the study is an in-depth exploration of resilience. Resilience is understood differently across various fields, making it challenging to establish a universally accepted definition. Nevertheless, a comprehensive understanding of resilience, particularly relevant in the context of resilient infrastructure, is the "ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events" (Council, 2012).

Figure 1 illustrates the impact of functionality and recovery time on the resilience of an infrastructure system. Lost functionality, defined as the aggregate effect of damage on the system's ability to operate and achieve its designed function, is a key factor. The duration of recovery post-hazard event is typically influenced by the system's condition at the time of the event, which includes design criteria, level of degradation, and maintenance history (Lounis and McAllister, 2016).

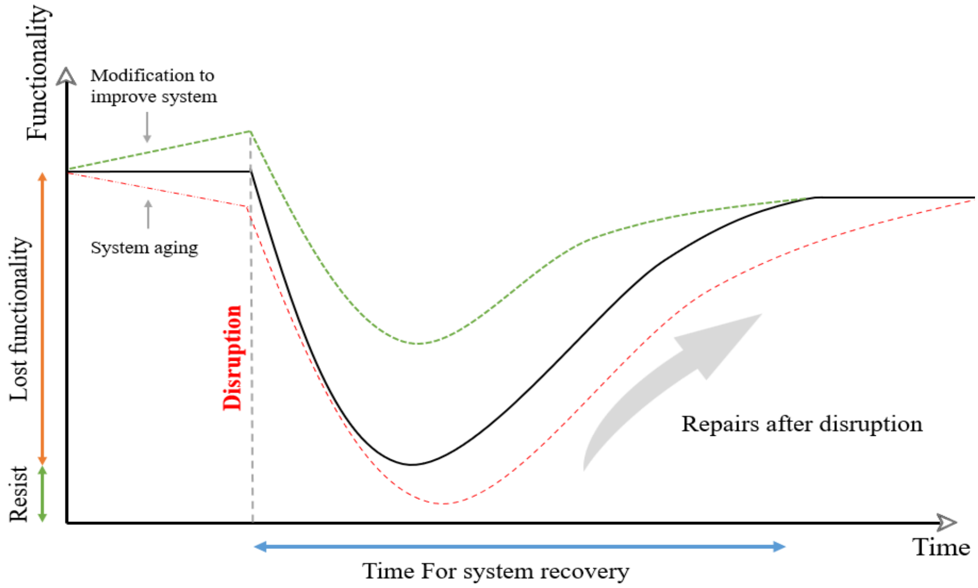


Figure 1. Effects of functionality and recovery time on system resilience.
(Adapted from Lounis and McAllister, 2016).

Biringer et al. (2013) divide resilience assessment methods into three major areas: structural (Berche et al., 2009; Janić, 2018), performance-based (Attoh-Okine et al., 2009; Chang and Shinozuka, 2004), and hybrid (Filippini and Silva, 2014; Reed et al., 2009). Structural methods assess the robustness of a system based on its structure or topology. Performance-based techniques measure the system's performance before and after an interruption to assess its resilience. Hybrid methods integrate structural and performance-based approaches. On the other hand, Hosseini et al. (2016) categorized resilience assessment into two primary approaches: qualitative and quantitative. The qualitative approach is further divided into (i) conceptual frameworks and (ii) semi-quantitative methods. The quantitative approach is segmented into (i) general models, which include probabilistic and deterministic methods, and (ii) structural-based models, encompassing optimization, simulation, and fuzzy logic techniques.

Alternatively, Wan et al. (2018) described resilience in 12 different terminologies in their review (**Figure 2**): Vulnerability (Blockley et al., 2012), Adaptability (Bhamra et al., 2011), Robustness (Faturechi and Miller-Hooks, 2015), Flexibility (Berle et al., 2013), Reliability (Barker et al., 2013), Recoverability (Baroud et al., 2015), Redundancy (Omer et al., 2012), Survivability (Baroud et al., 2014), Preparedness (Berle et al., 2011), Resourcefulness (Adams et al., 2012), Responsiveness (Ivanov et al., 2014), and Rapidity (Adams et al., 2012).

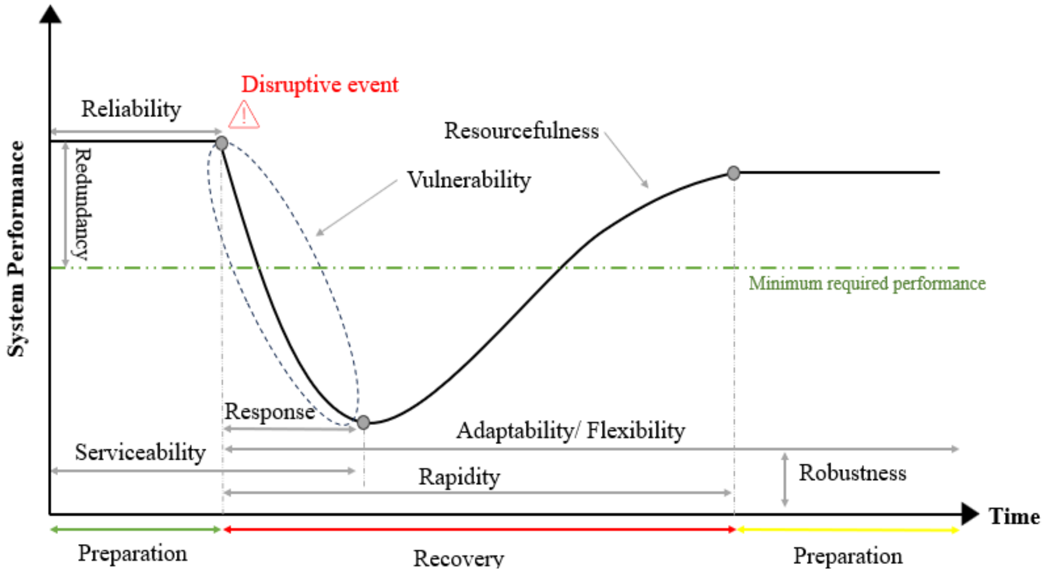


Figure 2. Schematic of performance of a resilient system.

(Adapted from Wan et al., 2018).

2.1.2. Tools

CBA is an economic tool aimed at identifying the most beneficial solution for a problem by evaluating the financial value of both positive (benefits) and negative (costs) socio-economic impacts over a project's lifecycle. However, the scope of these impacts is often limited by technical constraints (Marleau Donais et al., 2019). CBA determines the importance of pros and cons based on society's willingness to pay (Koopmans and Mouter, 2020) and compares different interventions or policies against a reference alternative, often doing nothing (Johansson and Kriström, 2015). The key metric in CBA is Net Present Value (NPV), which measures an option's overall economic profitability relative to a reference scenario. Since 1980, the U.S. has required CBA for regulations with significant economic impacts (Mishan and Quah, 2007).

Multi-criteria decision analysis (MCDA), is also known in the literature under the names of multiple criteria decision-making (MCDM), and multiple-criteria analysis (MCA), in this review MCDA will be referenced to highlight its role as a decision analysis tool. Decision-makers use decision-making approaches to prioritize crucial criteria, minimize uncertainty, and improve decision quality. MCDA techniques offer solutions for tackling diverse real-world problems (Mardani et al., 2016). For this need many tools and approaches have been developed, Simple Additive Weighting (SAW) method and the Multi-Attribute Utility Analysis (MAUA) (Keeney and Raiffa, 1993), Order of Preference by Similarity to Ideal Solution (TOPSIS) (Hwang and Yoon, 1981), VIseKriterijumska Optimizacija i Kompromisno Resenje (VIKOR) (Opricovic, 1998), Analytic Hierarchy Process (AHP) as pairwise comparisons (Saaty, 2003), and Elimination and Choice Expressing Reality (ELECTRE) (Roy, 1996). AHP and TOPSIS are still the mainstream ranking methods in decision support systems in infrastructure and related subjects (Yuan et al., 2022).

By considering numerous objectives and criteria, techniques like MCDA offer deeper insights into the essence of the issue compared to single-criterion methods like CBA (Barfod et al., 2011; Macharis and Bernardini, 2015; Ward et al., 2016). Additionally, MCDA methods enable the examination of diverse problem types and facilitate the handling of extensive data and information, whether it's quantitative or qualitative in nature (Barfod and Salling, 2015; Gühnemann et al., 2012).

The MCDA can be used to calculate a composite index of territorial resilience using a value tree technique to organize a set of indicators (Keeney, 1994). The SMARTER method (Barron, 1996) has been used as the weighting phase of the MCDA to deliver a set of weights for investigating the importance of the indicators and calculating a synthetic index of Territorial Resilience (TRI).

CBA, MCDA, or a blend of these approaches are commonly used in assessing and guiding the execution of infrastructure (Barfod et al., 2011; Brouwer and Van Ek, 2004; Salling and Pryn, 2015; Sjöstrand et al., 2018).

Earlier studies primarily emphasized merging CBA into MCDA within composite decision support systems. For instance, the EUNET project by the European Commission (EUNET, 2001), created a methodology that blends CBA and MCDA, treating investment criteria, like benefit-cost rates (B/C-rate), as essential elements within MCDA. The criteria chosen in this framework hinge on factors such as data reliability and preferences articulated by decision-makers or stakeholders involved in the decision process.

Gühnemann et al. (2012) highlighted four critical challenges in combining CBA and MCDA: First, existing procedures (CBA, MCDA, or both) cannot be disregarded, requiring the analyst to integrate both methods while ensuring compatibility. Second, maintaining compatibility with established assessment criteria, scales, and values from prior evaluations is essential. Third, there's notable uncertainty in impact levels and weights, without enough resources to model the full extent of uncertainty. Finally, decision-makers aim to comprehend the robustness of project rankings to defend against potential criticisms.

In the past century, CBA and MCDA were frequently depicted as distinctly opposing and competitive methodologies (Voogd, 1983). Nevertheless, currently, the vigor of the debate has lessened, and the discussion has, to some extent, transitioned toward recognizing potential synergies between the two assessment and evaluation methods (Barfod et al., 2011; Salling et al., 2005; Sijtsma, 2006; Teotónio et al., 2023).

In numerous countries, MCDA is viewed as a complement to CBA, utilized to encompass impacts that pose challenges when translated into monetary terms (Mackie et al., 2014). The European Conference of Ministers of Transport (ECMT, 2001) perceives CBA as fundamental in transport project evaluation but also acknowledges MCDA's potential in broadening the framework to incorporate other effects. Mackie et al. (2014) noted that, in the seven Western countries examined, including non-monetized benefits within a more comprehensive framework, such as Gühnemann et al. (2012) presented a novel approach to emphasize road infrastructure development guided by a combined CBA and MCDA approach, aligning investments with strategic transport policy goals in Ireland within the context of Ireland's National Secondary Road Network. Sijtsma (2006) discussed an amalgamation of CBA and MCDA, highlighting the pivotal role of stakeholders. Stakeholders, through consensus, determine which impacts are to be monetized in this approach.

There are some developed decision-making tools by integrating MCDA and CBA named COSIMA (Leleur et al., 2007; Sailing and Landex, 2006), and MAGICA (Teotónio et al., 2023). However, the studies have not focused on the emerging concern regarding resilience and the uncertainty assessment has been only partial. These two interconnected aspects need to be adequately dealt with.

2.1.3. Applications

This review focuses on decision support systems for large-scale linear infrastructure for instance roads, water, and energy networks. These systems, often public and capital-intensive, impact large populations and have long planning horizons (Chester et al., 2019; Sheng, 2017). Infrastructure is vital for achieving the UN's Sustainable Development Goals (SDGs), which require significant investment to provide essential services such as drinking water and electricity by 2030 (Oxford Economics, 2017; Thacker et al., 2019).

Historically, infrastructure projects have been driven by monetary assessments or subjective biases, but newer methods like Life Cycle Assessment (LCA) and Multi-Criteria Decision Analysis (MCDA) also consider social and environmental factors (Flyvbjerg, 2014). Recent research has expanded to include urban resilience, sustainability, and mobility, emphasizing infrastructure's role in urban development (Melkonyan et al., 2022). This study focuses on creating assessment tools that consider various performance dimensions across urban and infrastructure applications.

2.2. Literature collection and screening

This review method aligns closely with a systematic literature review. It follows a structured, methodical approach in defining search terms, selecting databases, and implementing rigorous inclusion and exclusion criteria. Key stages are:

- Database Selection and Structured Search Process: Using Web of Science and Scopus and defining keywords to filter the most relevant studies supports a systematic approach.
- Stepwise Filtering and Refinement: Papers were initially filtered based on language, availability, duplication, and thematic relevance. Further refining was conducted by reviewing titles and abstracts, a hallmark of systematic reviews.
- Criteria-Based Screening: Multiple criteria were applied to narrow down results, ensuring that the papers aligned specifically with resilience, infrastructure, cost-benefit analysis, and multi-criteria decision-making.
- Reproducibility: The method and criteria are described in detail, which enables reproducibility, a key feature of systematic reviews.

The initial search in Web of Science used keywords: cost-benefit, multi-criteria, resilience, infrastructure, evaluation, and decision-support. Using inclusion criteria, this search identified 157 papers (1 in French, 11 unavailable, 102 out of scope by title, and 16 less relevant by abstract), narrowing to 27 focused papers on resilience in decision-support tools. To refine further, a new search with "combining/combination" yielded 318 results but proved broad. Therefore, adjusting with a second keyword set: decision-support, cost-benefit, multi-criteria, and combining), resulted in 56 papers (1 in French, 1 duplicate with the first set of keywords, 2 unavailable, 32 out of scope, and 4 less relevant), with 16 highly relevant papers. In total, 213 papers from the Web of Science led to 63 selected for review (20 preliminary evaluations, 43 full reviews).

Scopus searches with the same keywords found 220 papers (10 duplicates with Web of Science, 2 in Chinese, 5 unavailable, 163 out of scope by title, and 27 less relevant by abstract), with 13 papers directly related to infrastructure resilience.

After screening, 400 papers were evaluated, 103 were selected (63 from Web of Science, 43 from Scopus), with 56 papers chosen for thorough review, as illustrated in **Figure 3**.

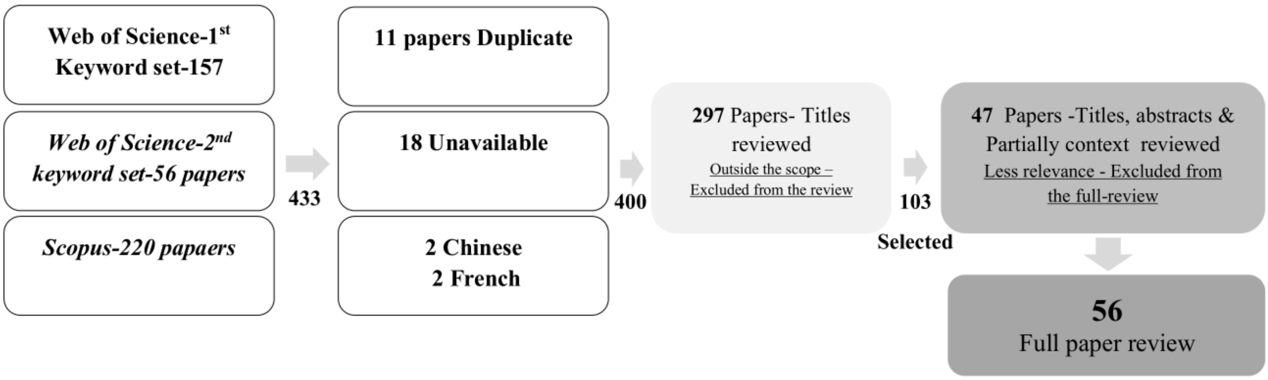


Figure 3. Flow diagram of the literature screening process.

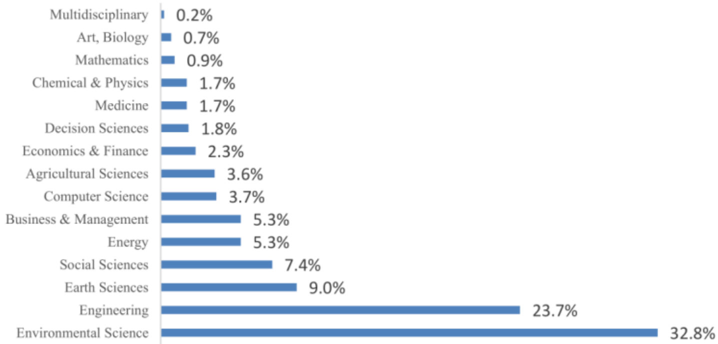
3. Analysis of the result

3.1. Trends analysis

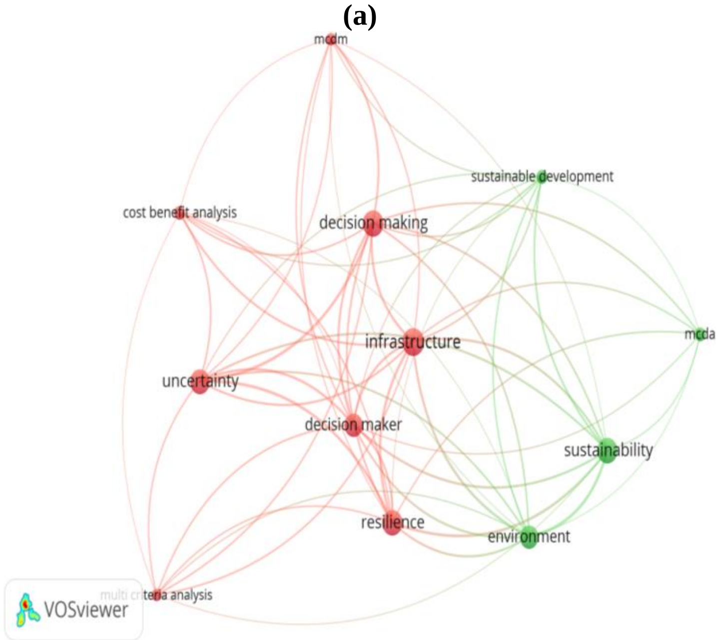
The reviewed literature was examined to identify trends in publication history, distribution across disciplines, key research themes, and geographical origins. This analysis highlights the evolution and context of research in the field. Details are presented in the following subheadings.

3.1.1. Scientific area

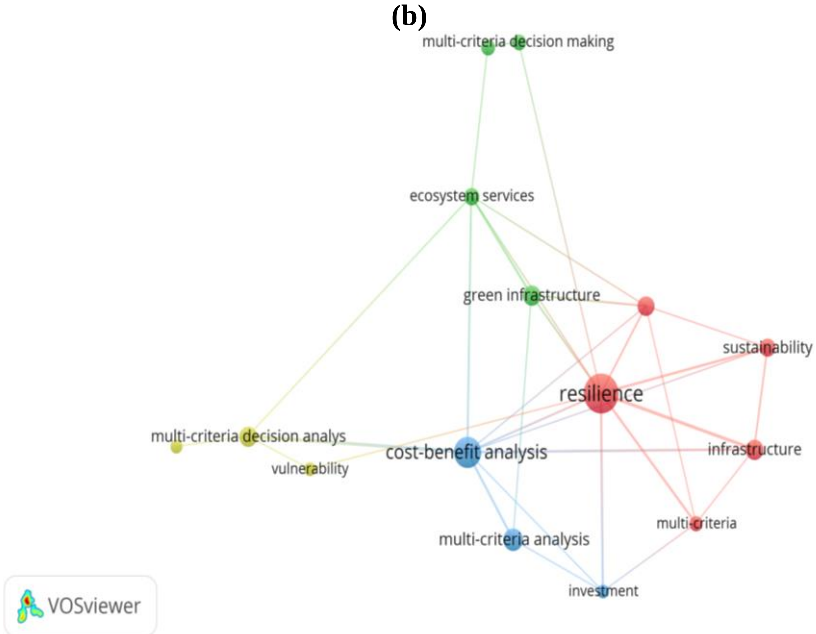
The reviewed papers spanned 15 research areas for all 433 papers (**Figure 4a**), with Environmental Sciences and Engineering having the most publications however, among the 56 fully reviewed papers, transportation (17 papers) surpassed environmental studies (10 papers) See **Table 1**. Keyword analysis using VOSviewer demonstrates the connections between assessment dimensions (Resilience), tools (CBA and MCDA), and Application (Infrastructure) topics (**Figure 4b**,**c**).



(a)



(b)

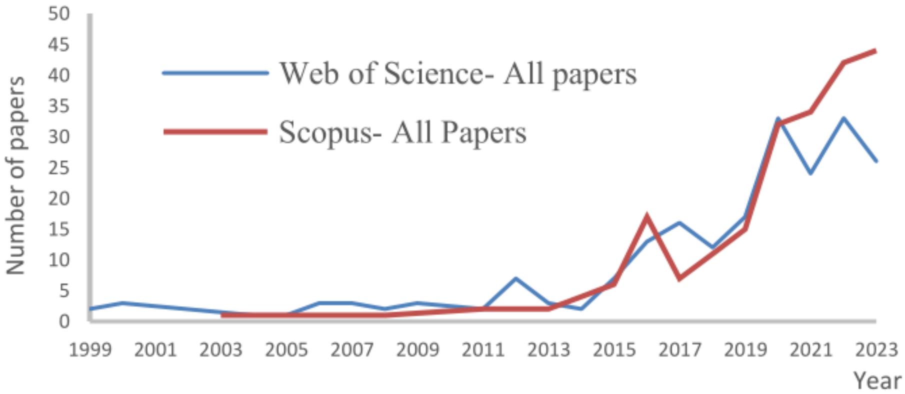


(c)

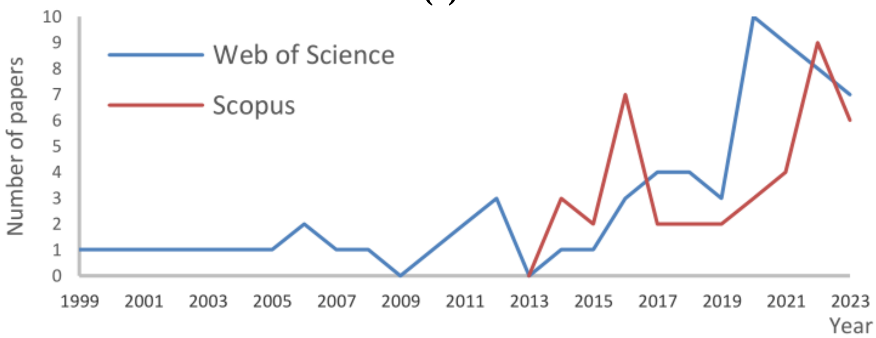
Figure 4. Area of published papers and Keyword occurrence in title and abstracts. **(a)** area of published papers categories-considering all 433 papers; **(b)** occurrence in title and abstracts; **(c)** author(s) keyword occurrence.

3.1.2. Historical trend

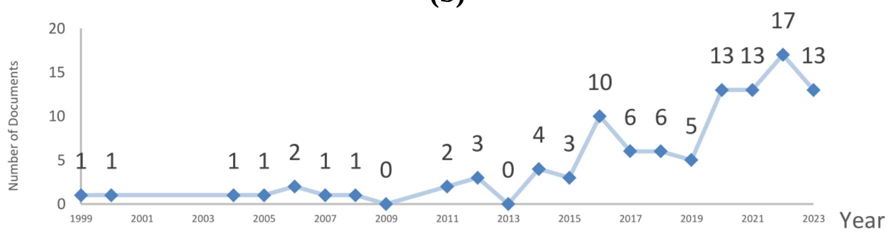
The historical trend for the second filtered set of 103 selected papers illustrates the number of papers focusing on the specified keywords has increased over time, with a noticeable surge in overall publications after 2007, as shown in **Figure 5a**. In **Figure 5b**, which covers 103 selected papers relevant to this review, there is a significant rise post-2014. The merged graph in **Figure 5c** further clarifies the trend, showing steady growth in published papers between 2016 and 2022, despite a slight dip from 2016 to 2020, which recovered by 2020.



(a)



(b)



(c)

Figure 5. The Trend of papers published in research area and keyword occurrence **(a)** trend of all 433 published papers; **(b)** trend of 103 selected; **(c)** trend of 103 selected published papers merged web of science with Scopus.

3.1.3. Topics of final selected papers

This analysis highlights 56 full-review papers, chosen from a pool of 103 selected papers, addressing key aspects of resilience and sustainability. Transportation with 17 papers focuses on infrastructure, roads, and urban planning. Environmental topics with 10 studies include green infrastructure and watershed management. 8 studies address urban resilience, and infrastructure resilience features in 7 papers. Building resilience appears in 4 studies, coastal and flood resilience each in 3, with themes of vulnerability and risk reduction. Water systems and general resilience each have 3 and 1 study, respectively. See **Table 1** for the topic references.

Table 1. Topics of research.

Research topic within 56 full-review papers	No.	References
Transportation resilience/sustainability/ critical infrastructure/roads/rout selection/management/cities	17	(Adey et al., 2021; Barfod et al., 2011; Belay et al., 2016; Cartes et al., 2021; Dojutrek et al., 2016; Donais et al., 2019; Gühnemann et al., 2012; Henke et al., 2020; Mardani et al., 2016; Martani et al., 2021; Oses et al., 2018; Sailing and Landex, 2006; Salling and Pryn, 2015; Shishegaran et al., 2020; Tischler, 2017; Tsamboulas and Mikroudis, 2000; Yang et al., 2023)
Environmental green infrastructure/environmental footprint/ecosystem/contaminated sediments/ river basin/watershed/agriculture/rural spatial	10	(Almohaimeed et al., 2021; Jia et al., 2022; Kaaviya and Devadas, 2021; Messner et al., 2006; Saarikoski et al., 2016; Sparrevik et al., 2012; Teotónio et al., 2020, 2023; Tiwari et al., 1999; Yuan et al., 2022)
Urban resilience/sustainability/climate adaptation/mobility/drainage	8	(Feofilovs and Romagnoli, 2020; Melkonyan et al., 2022; Pazzini et al., 2023; Rezvani et al., 2022; Rezvani et al., 2023; Silva et al., 2022; Uddin and Warnitchai, 2020; Yang and Zhang, 2021)
Infrastructure resilience/sustainability/management/critical infrastructure	7	(Arvin et al., 2023; Babar and Ali, 2022; Henn et al., 2016; Kabir et al., 2014; Shahtaheri et al., 2018; Singh et al., 2023; Zhu and Leibowicz, 2022)
Building resilience/sustainability/public building/prefabricated building	4	(Anwar et al., 2020; Asadi et al., 2020; Chauhan et al., 2022; Josa et al., 2020)
Coastal infrastructure coastal cities resilience/coastal infrastructure/vulnerability	3	(Barzehkar et al., 2021; Johnston et al., 2014; Rahat et al., 2023)
Flood flood resilience/reduce risks/control	3	(Alves et al., 2018; Brouwer and Van Ek, 2004; Li et al., 2019)
Water system supply sustainability/network resilience/wastewater	3	(Cunha et al., 2020; Karamouz et al., 2022; Sjöstrand et al., 2018)
General	1	(Lindfors, 2021)
Total	56	

3.1.4. Country and region

The study shows most papers come from the USA, UK, China, and several European countries, with Iran and India also contributing significantly. South America, Africa, and parts of Asia have limited research. Metadata discrepancies exist but likely don’t affect overall comparisons. See **Figure 6** for global distribution.

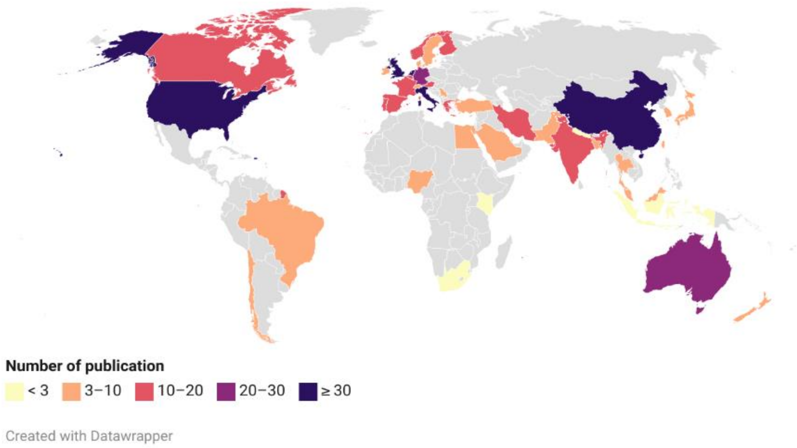


Figure 6. Distribution of publications based on country/area among all papers-countries with at least two papers are considered.

3.2. Content analysis

As detailed in the previous section, out of 400 papers, 297 were excluded based on irrelevant titles, leaving 103 for further consideration. After reviewing abstracts and context, the focus narrowed to 56 papers. These papers fall into three key subjects:

- Tools used, primarily MCDA or CBA techniques.
- Applications spanning infrastructure, buildings, urban spaces, and other assets.
- Assessment dimensions, focusing on resilience but also addressing sustainability and performance metrics.

Table 2 provides an overview of the 56 papers, categorized into three areas: i) resilience assessments using MCDA or CBA, ii) those using only MCDA, and iii) those combining MCDA and CBA.

Table 2. Summary of 56 papers review of method, tools, and areas.

Related to Subheading	No.	Scholar(s)/ year References	Tools		Application				Assessment dimension			Subject/area	Decision support tools	Assessment approach
			Multi-criteria	Cost-benefit	Infrastructure	Urban	Building	Other systems	Resilience	Sustainability	General performance			
Subheading 3.2.1	1	Yang et al. (2023)	✓		✓				✓			Transportation-Critical Infrastructures (CIs)	Multi-criteria framework (MCF)	Resilience Indicator
	2	Rahat et al. (2023)	✓		✓				✓			Coastal cities	MCDA AHP	Safe-to-Fail design (SF)
	3	Arvin et al. (2023)	✓		✓				✓			Infrastructure resilience	MCDA DEMATEL	Resilience indicator
	4	Singh et al. (2023)		✓	✓				✓			Infrastructure resilience	Traditional CBA NPV	Resilience Triangles (MRT)

Table 2. (*Continued*).

Related to Subheading	No.	Scholar(s)/ year References	Tools		Application				Assessment dimension			Subject/area	Decision support tools	Assessment approach
			Multi-criteria	Cost-benefit	Infrastructure	Urban	Building	Other systems	Resilience	Sustainability	General performance			
	5	Karamouz et al. (2023)	✓		✓				✓			Wastewater treatment infrastructure	Fuzzy multi-criteria decision-making (FMCDM)	Performance-based resilience
	6	Zhu and Leibowicz (2022)		✓	✓				✓			Infrastructure resilience	Traditional CBA	Markov decision process
	7	Babar and Ali (2022)	✓		✓				✓			Infrastructure resilience (CIs)	Fuzzy multi-criteria decision-making (FMCDM)	Expert-based FVIKOR
	8	Rezvani et al. (2022)	✓			✓			✓			Urban mobility	MCDA ARCDM	Resilience indicators set targets
	9	Anwar et al. (2020)	✓				✓		✓	✓	✓	Buildings under seismic	MCDA TOPSIS	Performance-based resilience
	10	Barzehkar et al. (2021)	✓		✓				✓	✓		Coastal cities	MCDA + GIS	General
	11	Kaaviya and Devadas (2021)	✓		✓				✓	✓		Watershed	MCDA + GIS	Data analysis
	12	Cartes et al. (2021)		✓	✓				✓			Transportation	Traditional CBA	Performance-based resilience
	13	Martani et al. (2021)		✓	✓				✓			Transportation	Monetizing the factors of service provided	Resilience indicator and set targets
	14	Adey et al. (2021)		✓	✓				✓			Transportation	Monetizing the factors of service provided	Resilience indicator and set targets
	15	Asadi et al. (2020)	✓		✓				✓	✓		Reinforced concrete buildings	MCDA AHP	Performance-based resilience
	16	Feofilovs and Romagnoli (2020)	✓			✓			✓	✓		Urban resilience	MCDA SD model	Resilience indicator
	17	Li et al. (2019)	✓			✓			✓			Urban flood resilience	MCDA VIKOR	Expert-based FVIKOR
	18	Dojutrek et al. (2016)	✓		✓				✓			Transportation (Bridge)	MCDA	Performance-based resilience
	19	Rezvani et al. (2023)	✓			✓			✓			Urban resilience	MCDA AHP	Resilience indicators set targets
	20	Belay et al. (2016)		✓	✓				✓			Transportation	Traditional CBA	Scenario-based

Table 2. (*Continued*).

Related to Subheading	No.	Scholar(s)/ year References	Tools: Multi-criteria	Tools: Cost-benefit	Application: Infrastructure	Application: Urban	Application: Building	Application: Other systems	Assessment dimension: Resilience	Assessment dimension: Sustainability	Assessment dimension: General performance	Subject/area	Decision support tools	Assessment approach
Subheading 3.2.2	21	Jia et al. (2022)	✓		✓						✓	Gray and green infrastructure	MCDA	Performance of infrastructure
	22	W. Yang and Zhang (2021)	✓		✓					✓		Urban resilience Drainage	MCDA AHP	Scenario-based/ alternatives SUDS
	23	Cunha et al. (2020)	✓		✓						✓	Water networks	MCDA PROMETHEE	Scenario-based/ alternatives
	24	Uddin and Warnitchai (2020)	✓			✓					✓	Urban system station location	MCDA AHP	Scenario-based/ alternative
	25	Josa et al. (2020)	✓				✓			✓		Building structural	MCDA MIVES	MIVES-scenario base/ alternative
	26	Alves et al. (2018)	✓			✓					✓	Reduce Flood Risk	MCDA MAUA	Performance of infrastructure
	27	Shahtaheri et al. (2018)	✓		✓					✓		Sustainable Infrastructure	MCDA	Triple bottom line TBL
	28	Johnston et al. (2014)	✓		✓					✓		Coastal infrastructure	MCDA GIS	Vulnerability
	29	Pazzini et al. (2023)	✓			✓				✓		Urban developments	MCDA ANP	ANP-BOCR
	30	Silva et al. (2022)	✓			✓					✓	Urban mobility	MCDA AHP	Scenario-based/ alternatives
	31	Melkonyan et al. (2022)	✓			✓				✓		Urban mobility	MCDA PROMETHEE	STEEP-scenario based/ alternative
	32	Yuan et al. (2022)	✓		✓					✓		Rural Spatial	MCDA	General
	33	Lindfors (2021)	✓		✓					✓		General	MCDA	General
	34	Shishegaran et al. (2020)	✓		✓					✓		Transportation	MCDA TOPSIS	Scenario base-Alternative-AECIEI
	35	Teotónio et al. (2020)	✓				✓			✓		Green roof	MCDA M-MACBETH	Scenario-based/ alternatives
	36	Oses et al. (2018)	✓			✓				✓		Transportation Urban area	MCDA MIVES	MIVES-Scenario based/ alternative
	37	Mardani et al. (2016)	✓		✓						✓	Transportation Systems	MCDA	General
	38	Kabir et al. (2014)	✓		✓						✓	Infrastructure management	MCDA	General

Table 2. (*Continued*).

Related to Subheading	No.	Scholar(s)/ year References	Tools		Application				Assessment dimension			Subject/area	Decision support tools	Assessment approach
			Multi-criteria	Cost-benefit	Infrastructure	Urban	Building	Other systems	Resilience	Sustainability	General performance			
Subheading 3.2.3	39	Teotónio et al. (2023)	✓	✓	✓					✓		Green roof	Combined MCDA and CBA-MAGICA	Scenario-based/ alternatives
	40	Chauhan et al. (2022)	✓	✓			✓				✓	Prefabrication industry	MCDA and CBA	Scenario-based/ alternatives
	41	Almohaimeed et al. (2021)	✓	✓				✓		✓		Energy-related emissions	MCDA and CBA	Demand side management (DSM)
	42	Henke et al. (2020)	✓	✓	✓					✓		Transportation	MCDA and CBA	Scenario base/ alternatives
	43	Sjöstrand et al. (2018)	✓	✓	✓					✓		Water supply	MCDA and CBA	Welfare economics theory
	44	Tischler (2017)	✓	✓	✓						✓	Transportation route selection	MCDA and CBA (CBA data in the weighted MCDA)	Scenario-based/ alternatives
	45	Saarikoski et al. (2016)	✓	✓				✓			✓	Ecosystem services	MCDA and CBA	General
	46	Salling and Pryn (2015)	✓	✓	✓					✓		Transportation	SUSTAIN-DSS CBA data in the weighted MCDA)	Scenario-based/ alternatives
	47	Gühnemann et al. (2012)	✓	✓	✓						✓	Road infrastructure	MCDA and CBA (CBA data in the weighted MCDA)	Scenario-based/ alternatives
	48	Sparrevik et al. (2012)	✓	✓				✓		✓		Contaminated Sediments	MCDA and CBA (CBA data in the weighted MCDA)	Scenario-based/ alternatives
	49	Barfod et al. (2011)	✓	✓	✓						✓	Transportation	Combined MCDA and CBA-COSIMA	Scenario-based/ alternatives
	50	Sailing and Landex (2006)	✓	✓	✓						✓	planned railway	Combined MCDA and CBA-COSIMA	Scenario-based/ alternatives
	51	Messner et al. (2006)	✓	✓							✓	River basin	MCDA and CBA IMA	Scenario-based/ alternatives

Table 2. (*Continued*).

Related to Subheading	No.	Scholar(s)/ year References	Tools		Application				Assessment dimension			Subject/area	Decision support tools	Assessment approach
			Multi-criteria	Cost-benefit	Infrastructure	Urban	Building	Other systems	Resilience	Sustainability	General performance			
	52	Brouwer and Van Ek (2004)	✓	✓	✓						✓	Flood control policies	Integrated CBA and MCDA	Scenario-based/ alternatives
	53	Tsamboulas and Mikroudis (2000)	✓	✓	✓						✓	Transportation	EFECT (CBA data in the weighted MCDA)	Scenario-based/ alternatives
	54	Tiwari et al. (1999)	✓	✓				✓		✓		Agriculture system	MCDA and CBA (CBA data in the weighted MCDA)	Scenario-based/ alternatives
	55	Henn et al. (2016)	✓	✓	✓						✓	Public infrastructure	MCDA and CBA (CBA data in the weighted MCDA)	Scenario-based/ alternatives
	56	Donais et al. (2019)	✓	✓	✓					✓		Transportation	Combined MCDA and CBA in Sustainability	General

3.2.1. Decision support framework on applications' resilience with MCDA or CBA approach

Resilience is an inherent quality in systems, reflecting their ability to endure and recover from disturbances. This section reviews 20 papers focused on resilience assessment using either Cost-Benefit Analysis (CBA) or Multi-Criteria Decision Analysis (MCDA). While CBA and MCDA were often applied separately, both are frequently combined in other assessments like sustainability and performance evaluations.

Frameworks within the MCDA approach to resilience assessment were identified, with five primary categories of resilience assessments emerging from the literature. These methods highlight various aspects of resilience, though some may not fit strictly within these categories (**Figure 7**):

i. Resilience indicators/Set targets development (Arvin et al., 2023),
ii. Performance-based (Karamouz et al., 2023),
iii. Resilience triangle-RT (Singh et al., 2023),
iv. Triple bottom line-TBL (Shahtaheri et al., 2018),
v. Safe to Fail-SF (Rahat et al., 2023).

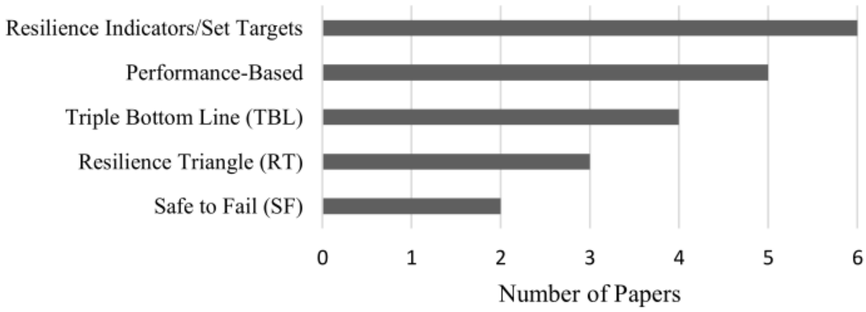


Figure 7. Trend in resilience approach in 20 papers.

Resilience assessments often overlook the use of explicit criteria, though translating capacities and characteristics into criteria can enhance clarity. Criteria serve as indicators to track progress in specific aspects, and their absence leaves operators without a clear guide to achieving desired outcomes (Yang et al., 2023). Yang et al. (2023) developed resilience criteria for critical infrastructure using a multi-criteria framework, while Arvin et al. (2023) employed the DEMATEL method to weight resilience indicators, addressing the limitations of AHP and BMW models (Rezaei, 2015). Feofilovs and Romagnoli (2020) created a dynamic Urban Resilience Index for flood risk in Latvia, simplifying complex resilience concepts into a single indicator for policymakers (Meerow et al., 2016). Rezvani et al. (2022, 2023) integrated ISO 31000 and 55000 principles into climate adaptation strategies, using the Urban Resilience Evaluation System (URES) to define key indicators for urban resilience.

Attribute-based assessments focus on preparedness but lack insight into system performance during disruptions. They are useful for resource allocation and resilience measurement through expert opinions (Karamouz et al., 2022). Key resilience attributes include “rapidity”, “robustness”, “resourcefulness”, and “redundancy” (Bruneau and Reinhorn, 2007). Performance-based methods, such as PROMETHEE, assess post-disruption resilience (Behzadian et al., 2010; Karamouz et al., 2023). Karamouz et al. (2022) developed resilience metrics for wastewater infrastructure, while Anwar et al. (2020) created a performance-based framework for seismic retrofits, emphasizing downtime and recovery. Asadi et al. (2020) used Risk-based Multi-Attribute Utility Theory and AHP to build an MCDA framework addressing economic, social, and environmental criteria in building design.

The resilience triangle approach is one method used within the infrastructure field to quantify resilience (Bruneau et al., 2003; Wang et al., 2021). This methodology, initially introduced by Bruneau et al. (2003), provided a visual depiction of a disruption’s impact on a system. In this approach, the y-axis represents the system’s functionality, while the x-axis denotes time. By considering the y-axis as the performance function, spanning from 0% to 100%, the calculation of resilience loss follows a specific formula (**Figure 8**).

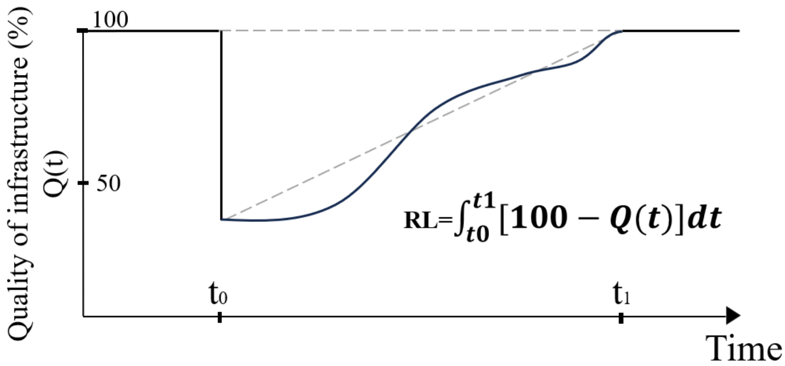


Figure 8. Resilience triangle.

(Adapted from Bruneau et al., 2003).

This approach functions as a framework for resilience assessment, encompassing financial, social, and environmental impacts. The Triple Bottom Line (TBL) evaluates three core dimensions: people, planet, and prosperity emphasizing a comprehensive view of sustainability. Evaluations using TBL measure an entity's resilience by analyzing its capacity to thrive economically, meet societal needs, and mitigate environmental impact (Janjua et al., 2020; Masood et al., 2023). Shahtaheri et al. (2018) developed the "SIMPLE-Design" framework, drawing from Triple Bottom Line (TBL) principles, integrating criteria development into a multi-criteria preference assessment for early design alternatives.

This assessment offers a flexible design approach that minimizes infrastructure damage while ensuring continuous functionality, focusing on resilience against disturbances (Kim et al., 2017). Rahat et al. (2023) prioritized Safe-to-Fail (SF) criteria and ranked flood mitigation strategies to enhance coastal resilience. They used the Analytic Hierarchy Process (AHP), which ranks alternatives by creating pairwise comparison matrices based on expert opinions gathered through a structured questionnaire, supporting multi-criteria decision-making.

Making decisions about resilience programs is challenging due to high costs and uncertainty, especially for rare, high-impact risks. While few studies address this, CBA remains a key method alongside cost-effectiveness, multicriteria, and robust decision-making approaches (Mechler et al., 2014). Zhu and Leibowicz (2022) proposed using the Markov decision process for resilience upgrades. Adey et al. (2021) and Martani et al. (2021) compared transportation infrastructure resilience, using weighted indicators and CBA to set resilience targets. Cartes et al. (2021) estimated economic losses from hazards and assessed cost-benefit ratios for road segments. (Belay et al., 2016) created a dynamic CBA framework for road projects, and Singh et al. (2023) introduced Modified Resilience Triangles (MRT) to evaluate long-term adaptive resilience and NPV under different scenarios.

3.2.2. Decision support framework on applications with MCDA approach

The studies within this section have devised an approach to assess constructed assets, focusing on their sustainability or performance through Multicriteria Analysis (MCDA). This MCDA approach can be categorized based on its utilization within their respective methodologies or frameworks. Scholars have developed various MCDA tools, such as AHP (Saaty, 1977), ANP (Saaty, 2006), TOPSIS (F. K. Hwang, 1979), PROMETHEE (Brans et al., 1986), VIKOR (Opricovic, 1998), MAUA (Bell et al., 1977), MACBETH (Bana e Costa and Chagas, 2004), and, integration with GIS.

Acknowledging the existence of various multi-criteria approaches such as SAW, ELECTRE, SMART, etc, and several other potential integrations that might not have been covered in articles related to the subject, it’s important to highlight that in this section, 18 papers have been classified based on their utilization of MCDA (**Figure 9**).

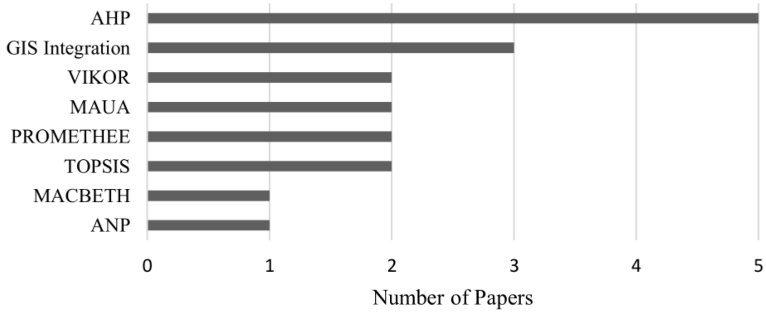


Figure 9. The trend of the MCDA approach in other assessment dimensions in 18 papers.

The Analytical Hierarchy Process (AHP), developed by Saaty (1977), is an intuitive MCDA method used to assign numerical values to qualitative attributes through trade-offs. Its flexibility and simplicity make it widely used in policy decisions (Elkarmi and Mustafa, 1993). AHP involves building a hierarchical structure of goals, criteria, and sub-criteria, followed by pairwise comparisons to determine their relative importance. Consistency checks ensure reliability, and results are synthesized to guide decision-making (Vaidya et al., 2006). Uddin and Warnitchai (2020) used AHP for fire station location planning, while W. Yang and Zhang (2021) applied it to sustainable urban drainage strategies. Silva et al. (2022) combined AHP with TOPSIS for urban mobility project selection.

The Analytic Network Process (ANP), developed by Saaty (2006), is a decision-support tool that helps structure complex decision problems by visualizing interconnected elements in a network (Pazzini et al., 2023). Unlike AHP, ANP considers interdependencies between groups, making it better suited for complex scenarios where criteria and alternatives influence each other (Fountzoula and Aravossis, 2022). Though AHP is favored for its simplicity, ANP provides a more detailed framework for intricate decisions. Pazzini et al. (2023) used ANP for urban regeneration decision-making.

The Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS), developed by Hwang and Yoon (1981), is an MCDA method that ranks alternatives by comparing their proximity to both ideal and negative ideal solutions (Paradowski et al., 2020). It helps identify the optimal choice based on this relative distance. Shishegaran et al. (2020) applied TOPSIS in a sustainability evaluation of highway interchanges in Iran.

The PROMETHEE method, developed by Brans et al. (1986), is favored for its simplicity and human-like decision-making process using pairwise comparisons. It handles diverse criteria without pre-normalization and works even with missing data

(Tscheikner-Gratl et al., 2017). Melkonyan et al. (2022) highlighted PROMETHEE's suitability for low-uncertainty data and clear communication of decision problems, using it alongside the STEEP method for sustainable urban mobility. PROMETHEE has also been applied in performance-based resilience assessments (Behzadian et al., 2010; Karamouz et al., 2023).

When choosing an MCDA method, consistency, transparency, and simplicity are crucial. Multi-Attribute Utility Theory (MAUT) is widely used for reliable decision-making, allowing criteria to be weighted based on user preferences (Riabacke et al., 2012). Alves et al. (2018) applied MAUT for flood risk infrastructure, and also some scholars employed "MIVES", a MAUT-based method, that supports sustainable decisions (Josa et al. 2020; Oses et al. 2018; San-José Lombera and Garrucho Aprea 2010).

Measuring Attractiveness by a Categorical Based Evaluation Technique is based on a pairwise comparison procedure to determine the value of the alternatives while applying a non-numerical questioning procedure to attribute numerical scores. This is the critical distinction between MACBETH and other MCDA methods that use a pairwise comparison procedure involving the attribution of numerical judgments and, sometimes, leading to mistakes (Bana e Costa et al., 2012). In one of the papers found, Teotónio et al. (2020) adopted the MACBETH method based on M-MACBETH software (Bana e Costa and Chagas, 2004) to develop a decision support system for green roof investments in residential buildings.

VIKOR is a multi-criteria decision-making technique that selects the best alternative by balancing conflicting criteria (Mardani et al., 2016). It offers a compromise between ideal and worst-case outcomes (Yazdani and Graeml, 2014). Khan Babar and Ali (2022) integrated Fuzzy AHP with FVIKOR to evaluate resilience strategies for critical infrastructure, fitting the complex decision-making needed for multiple policies (König and Wenzelburger, 2021). Li et al. (2019) applied VIKOR for flood resilience using hybrid fuzzy judgments, while Johnston et al. (2014) used MCDA and GIS to assess coastal infrastructure vulnerabilities under potential flooding scenarios.

Decision support systems often combine tools like GIS, MCDA, ANN, and Bayesian networks. AHP and GIS integration have been effective in studies on flooding, land use, and sustainability (Achu et al., 2020; Bocchini et al., 2014; Desalegn and Mulu, 2021; Ouyang et al., 2011; Sudha Rani et al., 2015; Zabihi et al., 2020). Barzehkar et al. (2021) used MCDA and ANN with GIS for coastal planning, while Kaaviya and Devadas (2021) applied AHP with GIS for water resilience. Moreover, Johnston et al. (2014) used GIS and MCDA to assess coastal infrastructure vulnerabilities under three potential flooding scenarios.

3.2.3. Decision support framework on applications utilizing tools separately or in a two-step process

Unlike the previous section's focus on specific sustainability or performance assessments, the papers here emphasize decision support tools combining Multi-Criteria Decision Analysis (MCDA) and Cost-Benefit Analysis (CBA). These 18 papers fall into three main categories: i) CBA as the primary method, ii) MCDA as the primary method, and iii) using the tools separately or in a two-step process. See the trend in **Figure 10**.

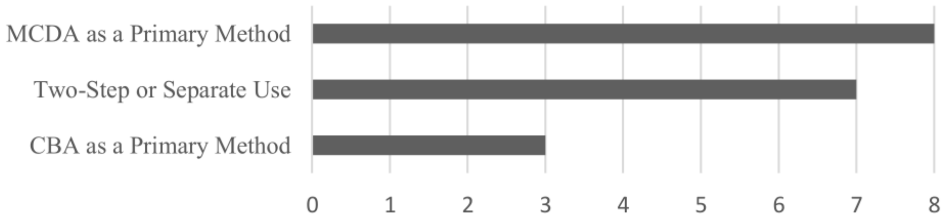


Figure 10. The trend of the composition approach in 18 papers.

Barfod et al. (2011) and Sailing and Landex (2006) introduced COSIMA (Composite Model of Assessment) for transportation decision support, which integrates Cost-Benefit Analysis (CBA) with Multi-Criteria Decision Analysis (MCDA). COSIMA uses the AHP technique and a calibration factor (α indicator) to weigh MCDA outcomes, typically 20%–30%, against CBA results. The first phase conducts traditional CBA to obtain metrics like net present value (NPV), internal rate of return (IRR), and benefit-cost ratio (BCR). The second phase evaluates non-monetary criteria through MCDA, presenting total value (TV) and total rate of return (TRR), Following Equation (1):

$$TRR\ (A_k) = \frac{TV(A_k)}{C_k} = \frac{1}{C_k} \cdot \left(\sum_{i=1}^{I} V_i(X_{ik}) + \alpha \cdot \left[\sum_{j=1}^{J} w_j \cdot VF_j(Y_{jk}) \right] \right) \tag{1}$$

where:

A_k is a project alternative *k*;

C_k is the total cost of alternative *k*;

$V_i\ (X_{ik})$ is the value in monetary units of CBA effect "*i*" for alternative *k*;

$VF_j\ (Y_{jk})$ is the value function score of alternative k for MCDA-criterion *j*;

W(*j*) is the weight that expresses the importance of criterion *j*;

α is the calibration factor that expresses the balance between the CBA and MCDA parts in the model.

In addition, Teotónio et al. (2023) built on the COSIMA model to create MAGICA, a tool for decision-making in green roof projects. MAGICA has three phases: Simple MAGICA operates like a multi-objective CBA, Two-step MAGICA integrates MCDA after CBA to address non-monetary factors, and Joint MAGICA merges CBA and MCDA results into a single attractiveness measure, similar to the COSIMA model.

The COSIMA approach translated MCDA results into CBA format using shadow prices, but practical challenges arose due to trade-offs between CBA and MCDA. The EUNET method (EUNET, 2001) integrated CBA as a criterion within MCDA for prioritizing transportation projects. Gühnemann et al. (2012) combined CBA and MCDA in a transportation project, while Barfod and Salling (2015) developed "SUSTAIN-DSS" for sustainability. Tsamboulas and Mikroudis (2000) introduced "EFECT" to convert CBA impacts into MCDA. Tiwari et al. (1999) used MCDA for agricultural sustainability, and Sparrevik et al. (2012) evaluated sediment management. Messner et al. (2006) and Brouwer and Van Ek (2004) integrated CBA and MCDA for water allocation and flood control policies, respectively.

Some authors present Cost-Benefit Analysis (CBA) and Multi-Criteria Decision Analysis (MCDA) results separately, viewing them as complementary rather than needing integration. This reflects the belief that each method provides distinct insights, offering unique perspectives and values, and allowing decision-makers to evaluate a broader range of criteria. For instance, Almohaimeed et al. (2021) analyzed the economic impact of MCDA options by examining each alternative's costs and benefits, calculating NPV, IRR, payback period, and BCR for each scenario, focusing on the "Demand Side Management" (DSM) effect on the environmental footprint. Henke et al. (2020) developed a sustainable assessment method for transportation investments by combining CBA, MCDA, and stakeholder input. Using AHP and Delphi methods, they compared CBA and MCDA outcomes to guide decisions, though MCDA focused mainly on monetary criteria. Eventually, in water supply sustainability, Sjöstrand et al. (2018) evaluated regional water supply sustainability using CBA for the economic domain and MCDA for environmental and social aspects. NPV was calculated, while social and environmental effects were rated through expert and stakeholder judgments.

4. Conclusion

This paper has explored the integration of Cost-Benefit Analysis (CBA) and Multi-Criteria Decision Analysis (MCDA) tools for assessing resilience and sustainability in infrastructure projects. Both methodologies play critical roles in decision-making, with their strengths and weaknesses varying depending on the underlying rationality applied. CBA provides clear quantitative metrics such as Net Present Value (NPV) and Internal Rate of Return (IRR), making it effective for monetizing resilience impacts and setting quantitative targets. Meanwhile, MCDA offers a versatile framework to evaluate diverse, often non-monetary criteria, allowing for the inclusion of qualitative and subjective factors such as social, environmental, and technical aspects.

Within resilience assessment, the leading approach that emerged focused on performance-based and resilience indicators for evaluating resilience. Multi-criteria decision Analysis (MCDA) gained significance because of its ability to thoroughly analyze various problem types and effectively handle extensive qualitative or quantitative data. Specifically, among MCDA methodologies, the Analytical Hierarchy Process (AHP) stood out as the primary approach due to its assessment proficiency. However, certain authors explored the use of a cost-benefit analysis suite to establish resilience targets to monetize the impact of resilience loss.

One of the findings is the increasing preference for integrating CBA within MCDA frameworks. This combined approach enables decision-makers to utilize the quantitative strengths of CBA while addressing the broader, qualitative considerations that MCDA excels at managing. Tools like COSIMA and MAGICA represent advanced solutions in this area, providing systematic frameworks that effectively integrate these methodologies. Their ability to incorporate both monetary and non-monetary criteria make them particularly suitable for sustainability assessments, offering a robust mechanism to align diverse stakeholder perspectives.

Tools such as COSIMA and MAGICA have shown considerable potential in addressing both sustainability and resilience by facilitating criteria-based evaluations and managing financial and socio-economic aspects. Incorporating structured inputs from reliable decision-makers, along with resilience-specific criteria, could enhance their reliability and provide more actionable outcomes. However, this review highlights that most resilience assessments have primarily utilized either MCDA or CBA independently, rather than adopting a composite model that integrates both approaches.

The review process has several limitations, including potential biases stemming from the authors' perspectives, variations in keyword selection, and a reliance on English-language databases, which may limit the scope of the findings. Additionally, the limited focus on risk and uncertainty management represents a gap in the current research. Moreover, it is crucial to emphasize that this paper specifically addresses the resilience of infrastructure projects, with a focus on assets and planning in decision-making, rather than exploring organizational or management-related resilience. While these areas warrant further investigation, integrating project resilience (managerial dimensions) with asset resilience (engineering dimensions) could offer a comprehensive approach, tailored to stakeholder priorities and decision-making objectives.

Future research should focus on addressing these gaps by developing methodologies that explicitly integrate resilience indicators into CBA-MCDA frameworks and prioritize uncertainty quantification. Comparative evaluations of integrated assessment methods across various contexts would provide valuable insights into their effectiveness and limitations. Longitudinal case studies of infrastructure projects utilizing these tools could further reveal practical challenges and inform their refinement.

In conclusion, while significant progress has been made in leveraging CBA and MCDA for infrastructure decision-making, there is a need for continued innovation to enhance these frameworks. By advancing integration methodologies, incorporating resilience-specific criteria, and addressing uncertainties more systematically, the field can move toward more comprehensive and reliable evaluation systems. This will not only improve infrastructure decision-making but also ensure that investments are resilient, sustainable, and aligned with long-term societal goals.

Funding: This research was funded by Fundação para a Ciência e a Tecnologia (FCT), grant number "2023.03421.BDAN" supporting the PhD studies of the first author at the Instituto Superior Técnico (IST).

Acknowledgments: This work is part of the research activity carried out at the Civil Engineering Research and Innovation for Sustainability (CERIS) at the Instituto Superior Técnico (IST).

Conflict of interest: The authors declare no conflict of interest.

References

Achu, A. L., Thomas, J., & Reghunath, R. (2020). Multi-criteria decision analysis for delineation of groundwater potential zones in a tropical river basin using remote sensing, GIS and analytical hierarchy process (AHP). Groundwater for Sustainable

Development, 10, 100365. https://doi.org/https://doi.org/10.1016/j.gsd.2020.100365

Adams, T. M., Bekkem, K. R., & Toledo-Durán, E. J. (2012). Freight Resilience Measures. Journal of Transportation Engineering, 138(11), 1403–1409. https://doi.org/10.1061/(asce)te.1943-5436.0000415

Adey, B. T., Martani, C., Kielhauser, C., Robles, I. U., Papathanasiou, N., Burkhalter, M., Beltran-Hernando, I., & Garcia-Sanchez, D. (2021). Estimating, and setting targets for, the resilience of transport infrastructure. Infrastructure Asset Management, 8(4), 167–190. https://doi.org/10.1680/jinam.20.00011

Almohaimeed, S. A., Suryanarayanan, S., & O'neill, P. (2021). Simulation studies to quantify the impact of demand side management on environmental footprint. Sustainability (Switzerland), 13(17). https://doi.org/10.3390/su13179504

Alves, A., Gersonius, B., Sanchez, A., Vojinovic, Z., & Kapelan, Z. (2018). Multi-criteria Approach for Selection of Green and Grey Infrastructure to Reduce Flood Risk and Increase CO-benefits. Water Resources Management, 32(7), 2505–2522. https://doi.org/10.1007/s11269-018-1943-3

Andersson, H. (2018). Application of BCA in Europe-Experiences and Challenges. Journal of Benefit-Cost Analysis, 9(1), 84–96. https://doi.org/10.1017/bca.2018.5

Anwar, G. A., Dong, Y., & Li, Y. (2020). Performance-based decision-making of buildings under seismic hazard considering long-term loss, sustainability, and resilience. Structure and Infrastructure Engineering, 17(4), 454–470. https://doi.org/10.1080/15732479.2020.1845751

Arvin, M., Beiki, P., Hejazi, S. J., Sharifi, A., & Atashafrooz, N. (2023). Assessment of infrastructure resilience in multi-hazard regions: A case study of Khuzestan Province. International Journal of Disaster Risk Reduction, 88(December 2022), 103601. https://doi.org/10.1016/j.ijdrr.2023.103601

Asadi, E., Shen, Z., Zhou, H., Salman, A., & Li, Y. (2020). Risk-informed multi-criteria decision framework for resilience, sustainability and energy analysis of reinforced concrete buildings. Journal of Building Performance Simulation, 13(6), 804–823. https://doi.org/10.1080/19401493.2020.1824016

Attoh-Okine, N. O., Cooper, A. T., & Mensah, S. A. (2009). Formulation of Resilience Index of Urban Infrastructure Using Belief Functions. {IEEE} Systems Journal, 3(2), 147–153. https://doi.org/10.1109/jsyst.2009.2019148

Bana e Costa, C. A., & Chagas, M. P. (2004). A career choice problem: An example of how to use MACBETH to build a quantitative value model based on qualitative value judgments. European Journal of Operational Research, 153(2), 323–331. https://doi.org/https://doi.org/10.1016/S0377-2217(03)00155-3

BANA E COSTA, C. A., DE CORTE, J.-M., & VANSNICK, J.-C. (2012). MACBETH. International Journal of Information Technology & Decision Making, 11(02), 359–387. https://doi.org/10.1142/s0219622012400068

Bank, E. I. (2013). The economic appraisal of investment projects at the EIB. European Investment Bank Luxembourg.

Barfod, M. B., & Salling, K. B. (2015). A new composite decision support framework for strategic and sustainable transport appraisals. Transportation Research Part A: Policy and Practice, 72, 1–15. https://doi.org/10.1016/j.tra.2014.12.001

Barfod, M. B., Salling, K. B., & Leleur, S. (2011). Composite decision support by combining cost-benefit and multi-criteria decision analysis. Decision Support Systems, 51(1), 167–175. https://doi.org/10.1016/j.dss.2010.12.005

Barker, K., Ramirez-Marquez, J. E., & Rocco, C. M. (2013). Resilience-based network component importance measures. Reliability Engineering & System Safety, 117, 89–97. https://doi.org/https://doi.org/10.1016/j.ress.2013.03.012

Baroud, H., Barker, K., Ramirez-Marquez, J. E., & Rocco, C. M. (2015). Inherent Costs and Interdependent Impacts of Infrastructure Network Resilience. Risk Analysis, 35(4), 642–662. https://doi.org/10.1111/risa.12223

Baroud, H., Barker, K., Ramirez-Marquez, J. E., & Rocco S., C. M. (2014). Importance measures for inland waterway network resilience. Transportation Research Part E: Logistics and Transportation Review, 62, 55–67. https://doi.org/https://doi.org/10.1016/j.tre.2013.11.010

Barzehkar, M., Parnell, K. E., Soomere, T., Dragovich, D., & Engström, J. (2021). Decision support tools, systems and indices for sustainable coastal planning and management: A review. Ocean and Coastal Management, 212(June). https://doi.org/10.1016/j.ocecoaman.2021.105813

Behzadian, M., Kazemzadeh, R. B., Albadvi, A., & Aghdasi, M. (2010). PROMETHEE: A comprehensive literature review on methodologies and applications. European Journal of Operational Research, 200(1), 198–215. https://doi.org/https://doi.org/10.1016/j.ejor.2009.01.021

Belay, A. M., Torp, O., Thodesen, C., & Odeck, J. (2016). A framework for Organizing a Resilient Cost Benefit Analysis for Construction Projects. Procedia Engineering, 145(1877), 1169–1176. https://doi.org/10.1016/j.proeng.2016.04.151

Bell, D. E., Keeney, R. L., & Raiffa, H. (1977). Conflicting objectives in decisions. John Wiley \& Sons.

Berche, B., von Ferber, C., Holovatch, T., & Holovatch, Y. (2009). Resilience of public transport networks against attacks. The European Physical Journal B, 71(1), 125–137. https://doi.org/10.1140/epjb/e2009-00291-3

Berle, Ø., Norstad, I., & Asbjørnslett, B. E. (2013). Optimization, risk assessment and resilience in LNG transportation systems. Supply Chain Management: An International Journal, 18(3), 253–264. https://doi.org/10.1108/SCM-03-2012-0109

Berle, Ø., Rice Jr., J. B., & Asbjørnslett, B. E. (2011). Failure modes in the maritime transportation system: a functional approach to throughput vulnerability. Maritime Policy & Management, 38(6), 605–632. https://doi.org/10.1080/03088839.2011.615870

Bhamra, R., Dani, S., & Burnard, K. (2011). Resilience: the concept, a literature review and future directions. International Journal of Production Research, 49(18), 5375–5393. https://doi.org/10.1080/00207543.2011.563826

Biringer, B., Vugrin, E., & Warren, D. (2013). Critical Infrastructure System Security and Resiliency. {CRC} Press. https://doi.org/10.1201/b14566

Blockley, D., Agarwal, J., & Godfrey, P. (2012). Infrastructure Resilience for High-Impact Low Chance Risks. ICE Proceedings Civil Engineering, 165, 13–19. https://doi.org/10.1680/cien.11.00046

Bocchini, P., Frangopol, D. M., Ummenhofer, T., & Zinke, T. (2014). Resilience and Sustainability of Civil Infrastructure: Toward a Unified Approach. Journal of Infrastructure Systems, 20(2), 1–16. https://doi.org/10.1061/(asce)is.1943-555x.0000177

Brans, J. P., Vincke, P., & Mareschal, B. (1986). How to select and how to rank projects: The Promethee method. European Journal of Operational Research, 24(2), 228–238. https://doi.org/https://doi.org/10.1016/0377-2217(86)90044-5

Brouwer, R., & Van Ek, R. (2004). Integrated ecological, economic and social impact assessment of alternative flood control policies in the Netherlands. Ecological Economics, 50(1–2), 1–21. https://doi.org/10.1016/j.ecolecon.2004.01.020

Brucker, K. De, Verbeke, A., & Macharis, C. (2004). The applicability of multicriteria-analysis to the evaluation of intelligent transport systems (its). Research in Transportation Economics, 8, 151–179. https://doi.org/https://doi.org/10.1016/S0739-8859(04)08008-4

Bruneau et al. (2003). A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities. Earthquake Spectra, 19(4), 733–752. https://doi.org/10.1193/1.1623497

Bruneau, M., & Reinhorn, A. (2007). Exploring the Concept of Seismic Resilience for Acute Care Facilities. Earthquake Spectra, 23(1), 41–62. https://doi.org/10.1193/1.2431396

Cartes, P. C., Echaveguren Navarro, T., Giné, A. C., & Binet, E. A. (2021). A cost-benefit approach to recover the performance of roads affected by natural disasters. International Journal of Disaster Risk Reduction, 53(November 2020). https://doi.org/10.1016/j.ijdrr.2020.102014

Chang, S. E., & Shinozuka, M. (2004). Measuring Improvements in the Disaster Resilience of Communities. Earthquake Spectra, 20(3), 739–755. https://doi.org/10.1193/1.1775796

Chauhan, K., Peltokorpi, A., Lavikka, R., & Seppänen, O. (2022). To prefabricate or not? A method for evaluating the impact of prefabrication in building construction. Construction Innovation. https://doi.org/10.1108/CI-11-2021-0205

Chen, L., & Bai, Q. (2019). Optimization in decision making in infrastructure asset management: A review. Applied Sciences (Switzerland), 9(7). https://doi.org/10.3390/app9071380

Chester, M. V, Markolf, S., & Allenby, B. (2019). Infrastructure and the environment in the Anthropocene. Journal of Industrial Ecology, 23(5), 1006–1015. https://doi.org/10.1111/jiec.12848

Council, N. R. (2012). Disaster resilience: A national imperative.

Cunha, M., Marques, J., & Savić, D. (2020). A Flexible Approach for the Reinforcement of Water Networks Using Multi-Criteria Decision Analysis. Water Resources Management, 34(14), 4469–4490. https://doi.org/10.1007/s11269-020-02655-9

Desalegn, H., & Mulu, A. (2021). Flood vulnerability assessment using GIS at Fetam watershed, upper Abbay basin, Ethiopia. Heliyon, 7(1), e05865. https://doi.org/https://doi.org/10.1016/j.heliyon.2020.e05865

Dodgson, J. S., Spackman, M., Pearman, A., & Phillips, L. D. (2009). Multi-criteria analysis : a manual. In Appraisal (Vol. 11, Issues 1–3). https://doi.org/10.1002/mcda.399

Dojutrek, M. S., Labi, S., & Dietz, J. E. (2016). A multi-criteria methodology for measuring the resilience of transportation assets. International Journal of Disaster Resilience in the Built Environment, 7(3), 290–301. https://doi.org/10.1108/IJDRBE-07-2014-0053

EC. (2015). Economic Appraisal Tool fo Cohesion Policy 2014-2020: Guide to Cost-Benefit Analysis of Investment Projects. European Commission, December 2014. https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf

ECMT. (2001). Assessing the benefits of transport. European Conference of Ministers of Transport.

Elkarmi, F., & Mustafa, I. (1993). Increasing the utilization of solar energy technologies (SET) in Jordan: Analytic hierarchy process. Energy Policy, 21(9), 978–984. https://doi.org/https://doi.org/10.1016/0301-4215(93)90186-J

EUNET, 2001. (2001). Final Report – Executive Summary, 4th RTD Framework Programme of the European Commission. EUNET/SASI, Final Report – Executive Summary, 4th RTD Framework Programme of the European Commission, , 2001., 11.

European Commission. (2014). Guide to Cost-benefit Analysis of Investment Projects: Economic appraisal tool for Cohesion Policy 2014-2020. In Publications Office of the European Union (Issue December). https://doi.org/10.2776/97516

F. Hutton Barron, B. E. B. (1996). The efficacy of SMARTER - Simple Multi-Attribute Rating Technique Extended to Ranking. Acta Psychologica, 93(1–3), 23–36. https://doi.org/10.1016/0001-6918(96)00010-8

Faturechi, R., & Miller-Hooks, E. (2015). Measuring the Performance of Transportation Infrastructure Systems in Disasters: A Comprehensive Review. Journal of Infrastructure Systems, 21, 4014025. https://doi.org/10.1061/(ASCE)IS.1943-555X.0000212

Feofilovs, M., & Romagnoli, F. (2020). Assessment of Urban Resilience to Natural Disasters with a System Dynamics Tool: Case Study of Latvian Municipality. Environmental and Climate Technologies, 24(3), 249–264. https://doi.org/10.2478/rtuect-2020-0101

Filippini, R., & Silva, A. (2014). A modeling framework for the resilience analysis of networked systems-of-systems based on functional dependencies. Reliability Engineering {\&} System Safety, 125, 82–91. https://doi.org/10.1016/j.ress.2013.09.010

Florio, M., Morretta, V., & Willak, W. (2018). Cost-Benefit Analysis and European Union Cohesion Policy: Economic Versus Financial Returns in Investment Project Appraisal. Journal of Benefit-Cost Analysis, 9(1), 147–180. https://doi.org/10.1017/bca.2018.4

Flyvbjerg, B. (2014). What you Should Know about Megaprojects and Why: An Overview. Project Management Journal, 45(2), 6–19. https://doi.org/10.1002/pmj.21409

Fountzoula, C., & Aravossis, K. (2022). Decision-Making Methods in the Public Sector during 2010–2020: A Systematic Review. Advances in Operations Research, 2022, 1750672. https://doi.org/10.1155/2022/1750672

Gamper, C. D., & Turcanu, C. (2007). On the governmental use of multi-criteria analysis. Ecological Economics, 62(2), 298–307. https://doi.org/https://doi.org/10.1016/j.ecolecon.2007.01.010

Gühnemann, A., Laird, J. J., & Pearman, A. D. (2012). Combining cost-benefit and multi-criteria analysis to prioritise a national road infrastructure programme. Transport Policy, 23, 15–24. https://doi.org/10.1016/j.tranpol.2012.05.005

Ha, M.-H., Yang, Z., & Lam, J. S. L. (2019). Port performance in container transport logistics: A multi-stakeholder perspective. Transport Policy, 73, 25–40. https://doi.org/10.1016/j.tranpol.2018.09.021

Henke, I., Cartenì, A., & Di Francesco, L. (2020). A sustainable evaluation processes for investments in the transport sector: A combined multi-criteria and cost–benefit analysis for a new highway in italy. Sustainability (Switzerland), 12(23), 1–27. https://doi.org/10.3390/su12239854

Henn, L., Sloan, K., Charles, M. B., & Douglas, N. (2016). An appraisal framework for evaluating financing approaches for public infrastructure. Public Money and Management, 36(4), 273–280. https://doi.org/10.1080/09540962.2016.1162595

Hosseini, S., Barker, K., & Ramirez-Marquez, J. E. (2016). A review of definitions and measures of system resilience. Reliability Engineering and System Safety, 145, 47–61. https://doi.org/10.1016/j.ress.2015.08.006

Hwang, C.-L., & Yoon, K. (1981). Methods for Multiple Attribute Decision Making. In Lecture Notes in Economics and Mathematical Systems (pp. 58–191). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-48318-9_3

Hwang, C. L., & Yoon, K. P. (1981). Multiple attribute decision making: methods and applications, a state-of-the-art survey. SpringerVerlang.

Hwang, F. K. (1979). An O (n log n) algorithm for rectilinear minimal spanning trees. Journal of the ACM (JACM), 26(2), 177–182.

Ivanov, D., Sokolov, B., & Dolgui, A. (2014). The Ripple effect in supply chains: trade-off 'efficiency-flexibility-resilience' in disruption management. International Journal of Production Research, 52(7), 2154–2172. https://doi.org/10.1080/00207543.2013.858836

Janić, M. (2018). Modelling the resilience of rail passenger transport networks affected by large-scale disruptive events: the case of {HSR} (high speed rail). Transportation, 45(4), 1101–1137. https://doi.org/10.1007/s11116-018-9875-6

Janjua, S. Y., Sarker, P. K., & Biswas, W. K. (2020). Development of triple bottom line indicators for life cycle sustainability assessment of residential bulidings. Journal of Environmental Management, 264, 110476. https://doi.org/https://doi.org/10.1016/j.jenvman.2020.110476

Jia, H., Liu, Z., Xu, C., Chen, Z., Zhang, X., Xia, J., & Yu, S. L. (2022). Adaptive pressure-driven multi-criteria spatial decision-making for a targeted placement of green and grey runoff control infrastructures. Water Research, 212(September 2021), 118126. https://doi.org/10.1016/j.watres.2022.118126

Johansson, P.-O., & Kriström, B. (2015). Cost-benefit analysis for project appraisal. Cambridge University Press. https://doi.org/https://doi.org/10.1017/CBO9781316392751

Johnston, A., Slovinsky, P., & Yates, K. L. (2014). Assessing the vulnerability of coastal infrastructure to sea level rise using multi-criteria analysis in Scarborough, Maine (USA). Ocean and Coastal Management, 95, 176–188. https://doi.org/10.1016/j.ocecoaman.2014.04.016

Josa, I., Pons, O., Fuente, A. de la, & Aguado, A. (2020). 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, 119312. https://doi.org/10.1016/j.jclepro.2019.119312

Kaaviya, R., & Devadas, V. (2021). Water resilience mapping of Chennai, India using analytical hierarchy process. Ecological Processes, 10(1), 1–22. https://doi.org/10.1186/s13717-021-00341-1

Kabir, G., Sadiq, R., & Tesfamariam, S. (2014). A review of multi-criteria decision-making methods for infrastructure management. In Structure and Infrastructure Engineering (Vol. 10, Issue 9, pp. 1176–1210). Taylor & Francis. https://doi.org/10.1080/15732479.2013.795978

Karamouz, M., Movahhed, M., & Elyasi, A. H. (2023). Financial allocation and network recovery for interdependent wastewater treatment infrastructure: development of resilience metrics. Sustainable and Resilient Infrastructure, 8(sup1), 262–288. https://doi.org/10.1080/23789689.2022.2148447

Karamouz, M., Zoghi, A., & Mahmoudi, S. (2022). Flood Modeling in Coastal Cities and Flow through Vegetated BMPs: Conceptual Design. Journal of Hydrologic Engineering, 27(10). https://doi.org/10.1061/(asce)he.1943-5584.0002206

Keeney, R. (1994). R.L. Keeney, H. Raiffa: Decisions with multiple objectives{\textendash}preferences and value tradeoffs, Cambridge University Press, Cambridge {\&} New York, 1993, 569 pages, {ISBN} 0-521-44185-4 (hardback), 0-521-43883-7 (paperback). Behavioral Science, 39(2), 169–170. https://doi.org/10.1002/bs.3830390206

Keeney, R. L., & Raiffa, H. (1993). Decisions with multiple objectives: preferences and value trade-offs. Cambridge university press.

Khan Babar, A. H., & Ali, Y. (2022). Framework construction for augmentation of resilience in critical infrastructure: Developing countries a case in point. Technology in Society, 68(October 2021), 101809. https://doi.org/10.1016/j.techsoc.2021.101809

Kim, Y., Eisenberg, D. A., Bondank, E. N., Chester, M. V., Mascaro, G., & Underwood, B. S. (2017). Fail-safe and safe-to-fail adaptation: decision-making for urban flooding under climate change. Climatic Change, 145(3–4), 397–412. https://doi.org/10.1007/s10584-017-2090-1

König, P. D., & Wenzelburger, G. (2021). The legitimacy gap of algorithmic decision-making in the public sector: Why it arises and how to address it. Technology in Society, 67(July). https://doi.org/10.1016/j.techsoc.2021.101688

Koopmans, C., & Mouter, N. (2020). Cost-benefit analysis. In Advances in Transport Policy and Planning (1st ed., Vol. 6, pp. 1–42). Elsevier Inc. https://doi.org/10.1016/bs.atpp.2020.07.005

Leleur, S., Petersen, N., & Barfod, M. (2007). The COSIMA Approach to Transport Decision Making: Combining Cost-benefit and Multi-criteria Analysis for Comprehensive Project Appraisal.

Li, Z., Zhang, X., Ma, Y., Feng, C., & Hajiyev, A. (2019). A multi-criteria decision making method for urban flood resilience evaluation with hybrid uncertainties. International Journal of Disaster Risk Reduction, 36(March), 101140. https://doi.org/10.1016/j.ijdrr.2019.101140

Lindfors, A. (2021). Assessing sustainability with multi-criteria methods: A methodologically focused literature review. Environmental and Sustainability Indicators, 12(July), 100149. https://doi.org/10.1016/j.indic.2021.100149

Lohman, H. A. C., Morgan, V. L., Li, Y., Zhang, X., Rowles, L. S., Cook, S. M., & Guest, J. S. (2023). DMsan: A Multi-Criteria Decision Analysis Framework and Package to Characterize Contextualized Sustainability of Sanitation and Resource Recovery Technologies. ACS Environmental Au, 3(3), 179–192. https://doi.org/10.1021/acsenvironau.2c00067

Lounis, Z., & McAllister, T. P. (2016). Risk-Based Decision Making for Sustainable and Resilient Infrastructure Systems. Journal of Structural Engineering, 142(9), 1–14. https://doi.org/10.1061/(asce)st.1943-541x.0001545

Macharis, C., & Bernardini, A. (2015). Reviewing the use of multi-criteria decision analysis for the evaluation of transport projects: Time for a multi-actor approach. Transport Policy, 37, 177–186. https://doi.org/10.1016/j.tranpol.2014.11.002

Mackie, P., Worsley, T., & Eliasson, J. (2014). Transport appraisal revisited. Research in Transportation Economics, 47(1), 3–18. https://doi.org/10.1016/j.retrec.2014.09.013

Mardani, A., Zavadskas, E. K., Govindan, K., Amat Senin, A., & Jusoh, A. (2016). VIKOR Technique: A Systematic Review of the State of the Art Literature on Methodologies and Applications. Sustainability, 8(1). https://doi.org/10.3390/su8010037

Mardani, A., Zavadskas, E. K., Khalifah, Z., Jusoh, A., & Nor, K. M. D. (2016). Multiple criteria decision-making techniques in transportation systems: a systematic review of the state of the art literature. Transport, 31(3), 359–385. https://doi.org/10.3846/16484142.2015.1121517

Marleau Donais, F., Abi-Zeid, I., Waygood, E., & Lavoie, R. (2019). A review of cost–benefit analysis and multicriteria decision analysis from the perspective of sustainable transport in project evaluation. EURO Journal on Decision Processes, 7. https://doi.org/10.1007/s40070-019-00098-1

Marlow, D. R., Beale, D. J., & Burn, S. (2010). A pathway to a more sustainable water sector: sustainability-based asset management. Water Science and Technology, 61(5), 1245–1255. https://doi.org/10.2166/wst.2010.043

Martani, C., Adey, B. T., Robles, I., Gennaro, F. di, Pardi, L., Beltran-Hernando, I., Toribio-Diaz, C., Redondo, N. J., & Díaz, A. A. M. (2021). Estimating the resilience of, and targets for, a transport system using expert opinion. Infrastructure Asset Management, 8(4), 191–208. https://doi.org/10.1680/jinam.20.00029

Masood, T., Israr, A., Zubair, M., & Qazi, U. W. (2023). Assessing challenges to sustainability and resilience of energy supply chain in Pakistan: a developing economy from Triple Bottom Line and UN SDGs' perspective. International Journal of Sustainable Energy, 42(1), 268–288. https://doi.org/10.1080/14786451.2023.2189489

Mechler, R., Czajkowski, J., Kunreuther, H., Michel-Kerjan, E., Botzen, W., Keating, A., McQuistan, C., Cooper, N., & O\textquoterightDonnell, L. (2014). Making communities more flood resilient: The role of cost benefit analysis and other decision-support tools in disaster risk reduction. Zurich Flood Resilience Alliance.

Medjoudj, R., Aissani, D., & Haim, K. D. (2013). Power customer satisfaction and profitability analysis using multi-criteria decision making methods. International Journal of Electrical Power & Energy Systems, 45(1), 331–339. https://doi.org/https://doi.org/10.1016/j.ijepes.2012.08.062

Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. Landscape and Urban Planning, 147, 38–49. https://doi.org/10.1016/j.landurbplan.2015.11.011

Melkonyan, A., Gruchmann, T., Lohmar, F., & Bleischwitz, R. (2022). Decision support for sustainable urban mobility: A case study of the Rhine-Ruhr area. Sustainable Cities and Society, 80(March), 103806. https://doi.org/10.1016/j.scs.2022.103806

Messner, F., Zwirner, O., & Karkuschke, M. (2006). Participation in multi-criteria decision support for the resolution of a water allocation problem in the Spree River basin. Land Use Policy, 23(1), 63–75. https://doi.org/10.1016/j.landusepol.2004.08.008

Mishan, E. J., & Quah, E. (2007). Cost-Benefit Analysis 5th edition by E.J. Mishan and Euston QUah. Routledge. https://www.routledge.com/Cost-Benefit-Analysis/Inman-Quah/p/book/9780415349918

Omer, M., Mostashari, A., Nilchiani, R., & Mansouri, M. (2012). A framework for assessing resiliency of maritime transportation systems. Maritime Policy & Management, 39(7), 685–703. https://doi.org/10.1080/03088839.2012.689878

Opricovic, S. (1998). Multicriteria Optimization of Civil Engineering Systems. Faculty of Civil Engineering, Belgrade.

Oses, U., Rojí, E., Cuadrado, J., & Larrauri, M. (2018). Multiple-Criteria Decision-Making Tool for Local Governments to Evaluate the Global and Local Sustainability of Transportation Systems in Urban Areas: Case Study. Journal of Urban Planning and Development, 144(1), 1–17. https://doi.org/10.1061/(asce)up.1943-5444.0000406

Ouyang, N. L., Lu, S. L., Wu, B. F., Zhu, J. J., & Wang, H. (2011). Wetland Restoration Suitability Evaluation at the Watershed Scale- A Case Study in Upstream of the Yongdinghe River. Procedia Environmental Sciences, 10, 1926–1932. https://doi.org/https://doi.org/10.1016/j.proenv.2011.09.302

Oxford Economics. (2017). Global infrastructure outlook. Global Infrastucture Hub: Sydney, Australia, 64. https://www.oxfordeconomics.com/recent-releases/99f4fa86-a314-4762-97c6-fac8bdcbe40a%0Ahttps://outlook.gihub.org/%0Ahttps://www.oxfordeconomics.com/recent-releases/Global-Infrastructure-Outlook

Paradowski, B., Więckowski, J., & Dobryakova, L. (2020). Why TOPSIS does not always give correct results? Procedia Computer Science, 176, 3591–3600. https://doi.org/https://doi.org/10.1016/j.procs.2020.09.027

Pazzini, M., Corticelli, R., Lantieri, C., & Mazzoli, C. (2023). Multi-Criteria Analysis and Decision-Making Approach for the

Urban Regeneration: The Application to the Rimini Canal Port (Italy). Sustainability (Switzerland), 15(1). https://doi.org/10.3390/su15010772

Rahat, R., Pradhananga, P., Calle Muller, C., & ElZomor, M. (2023). Multi-criteria evaluation of Safe-to-Fail flood solution alternatives for developing resilient coastal cities. Sustainable and Resilient Infrastructure, 00(00), 1–16. https://doi.org/10.1080/23789689.2023.2257503

Reed, D. A., Kapur, K. C., & Christie, R. D. (2009). Methodology for Assessing the Resilience of Networked Infrastructure. {IEEE} Systems Journal, 3(2), 174–180. https://doi.org/10.1109/jsyst.2009.2017396

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

Rezvani, S. M., de Almeida, N. M., Falcão, M. J., & Duarte, M. (2022). Enhancing urban resilience evaluation systems through automated rational and consistent decision-making simulations. Sustainable Cities and Society, 78(June 2021). https://doi.org/10.1016/j.scs.2021.103612

Rezvani, S. M. H. S., de Almeida, N. M., & Falcão, M. J. (2023). Climate Adaptation Measures for Enhancing Urban Resilience. Buildings, 13(9), 2163. https://doi.org/10.3390/buildings13092163

Riabacke, M., Danielson, M., & Ekenberg, L. (2012). State-of-the-Art Prescriptive Criteria Weight Elicitation. Advances in Decision Sciences, 2012, 276584. https://doi.org/10.1155/2012/276584

Roy, B. (1996). Multicriteria Methodology for Decision Aiding. In Nonconvex Optimization and Its Applications. Springer US. https://doi.org/10.1007/978-1-4757-2500-1

Saarikoski, H., Mustajoki, J., Barton, D. N., Geneletti, D., Langemeyer, J., Gomez-Baggethun, E., Marttunen, M., Antunes, P., Keune, H., & Santos, R. (2016). Multi-Criteria Decision Analysis and Cost-Benefit Analysis: Comparing alternative frameworks for integrated valuation of ecosystem services. Ecosystem Services, 22, 238–249. https://doi.org/10.1016/j.ecoser.2016.10.014

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

Saaty, T. L. (2003). Decision-making with the AHP: Why is the principal eigenvector necessary. European Journal of Operational Research, 145(1), 85–91. https://doi.org/10.1016/S0377-2217(02)00227-8

Saaty, T. L. (2006). The Analytic Network Process BT - Decision Making with the Analytic Network Process: Economic, Political, Social and Technological Applications with Benefits, Opportunities, Costs and Risks (T. L. Saaty & L. G. Vargas (eds.); pp. 1–26). Springer US. https://doi.org/10.1007/0-387-33987-6_1

Sailing, K. B., & Landex, A. (2006). Computer based ex-ante evaluation of the planned railway line between Copenhagen and Ringsted by use of a Decision Support System named COSIMA-DSS. WIT Transactions on the Built Environment, 88, 65–74. https://doi.org/10.2495/CR060071

Salling, Kim B, Jensen, A. V, & Leleur, S. (2005). COSIMA-DSS Evaluation system: A new decision support system for large-scale transport infrastructure projects.

Salling, Kim Bang, & Pryn, M. R. (2015). Sustainable transport project evaluation and decision support: Indicators and planning criteria for sustainable development. International Journal of Sustainable Development and World Ecology, 22(4), 346–357. https://doi.org/10.1080/13504509.2015.1051497

San-José Lombera, J.-T., & Garrucho Aprea, I. (2010). A system approach to the environmental analysis of industrial buildings. Building and Environment, 45(3), 673–683. https://doi.org/https://doi.org/10.1016/j.buildenv.2009.08.012

Shahtaheri, Y., Flint, M. M., & de la Garza, J. M. (2018). Sustainable Infrastructure Multi-Criteria Preference Assessment of Alternatives for Early Design. Automation in Construction, 96(August), 16–28. https://doi.org/10.1016/j.autcon.2018.08.022

Sheng, Z. (2017). Mega Infrastructure Construction Management Theories: Overview. In Fundamental Theories of Mega Infrastructure Construction Management (pp. 49–75). Springer International Publishing. https://doi.org/10.1007/978-3-319-61974-3_3

Shishegaran, A., Shishegaran, A., Mazzulla, G., & Forciniti, C. (2020). A novel approach for a sustainability evaluation of developing system interchange: The case study of the sheikhfazolah-yadegar interchange, Tehran, Iran. International Journal of Environmental Research and Public Health, 17(2), 1–25. https://doi.org/10.3390/ijerph17020435

Sijtsma, F. J. (2006). Project evaluation, sustainability and accountability : combining cost-benefit analysis (CBA) and multi-criteria analysis (MCA). In Stichting Ruimtelijke Economie Groningen, Rijksuniversiteit Groningen.

Silva, R. R. da, Santos, G. D., & Setti, D. (2022). A multi-criteria approach for urban mobility project selection in medium-sized cities. Sustainable Cities and Society, 86(July), 104096. https://doi.org/10.1016/j.scs.2022.104096

Singh, P., Amekudzi-Kennedy, A., Ashuri, B., Chester, M., Labi, S., & Wall, T. A. (2023). Developing adaptive resilience in infrastructure systems: an approach to quantify long-term benefits. Sustainable and Resilient Infrastructure, 8(sup1), 26–47. https://doi.org/10.1080/23789689.2022.2126631

Sjöstrand, K., Lindhe, A., Söderqvist, T., & Rosén, L. (2018). Sustainability assessments of regional water supply interventions – Combining cost-benefit and multi-criteria decision analyses. Journal of Environmental Management, 225(July), 313–324. https://doi.org/10.1016/j.jenvman.2018.07.077

Sparrevik, M., Barton, D. N., Bates, M. E., & Linkov, I. (2012). Use of stochastic multi-criteria decision analysis to support sustainable management of contaminated sediments. Environmental Science and Technology, 46(3), 1326–1334. https://doi.org/10.1021/es202225x

Sudha Rani, N. N. V, Satyanarayana, A. N. V, & Bhaskaran, P. K. (2015). Coastal vulnerability assessment studies over India: a review. Natural Hazards, 77(1), 405–428. https://doi.org/10.1007/s11069-015-1597-x

Teotónio, I., Cabral, M., Cruz, C. O., & Silva, C. M. (2020). Decision support system for green roofs investments in residential buildings. Journal of Cleaner Production, 249. https://doi.org/10.1016/j.jclepro.2019.119365

Teotónio, I., Oliveira Cruz, C., Matos Silva, C., & Lopes, R. F. R. (2023). Bridging CBA and MCA for evaluating green infrastructure: Proposal of a new evaluation model (MAGICA). Socio-Economic Planning Sciences, 85(April 2020). https://doi.org/10.1016/j.seps.2022.101446

Thacker, S., Adshead, D., Fay, M., Hallegatte, S., Harvey, M., Meller, H., O'Regan, N., Rozenberg, J., Watkins, G., & Hall, J. W. (2019). Infrastructure for sustainable development. Nature Sustainability, 2(4), 324–331. https://doi.org/10.1038/s41893-019-0256-8

Tischler, S. (2017). Finding the right way - A new approach for route selection procedures? Transportation Research Procedia, 25, 2809–2823. https://doi.org/10.1016/j.trpro.2017.05.247

Tiwari, D. N., Loof, R., & Paudyal, G. N. (1999). Environmental-economic decision-making in lowland irrigated agriculture using multi-criteria analysis techniques. Agricultural Systems, 60(2), 99–112. https://doi.org/10.1016/S0308-521X(99)00021-9

Tripathy, P., Khambete, A. K., & Chauhan, K. A. (2019). An Innovative Approach to Assess Sustainability of Urban Mobility—Using Fuzzy MCDM Method. In Innovative Research in Transportation Infrastructure (pp. 55–63). Springer Singapore. https://doi.org/10.1007/978-981-13-2032-3_6

Tsamboulas, D., & Mikroudis, G. (2000). EFECT - evaluation framework of environmental impacts and costs of transport initiatives. Transportation Research Part D: Transport and Environment, 5(4), 283–303. https://doi.org/10.1016/S1361-9209(99)00038-3

Tscheikner-Gratl, F., Egger, P., Rauch, W., & Kleidorfer, M. (2017). Comparison of Multi-Criteria Decision Support Methods for Integrated Rehabilitation Prioritization. Water, 9(2). https://doi.org/10.3390/w9020068

Uddin, M. S., & Warnitchai, P. (2020). Decision support for infrastructure planning: a comprehensive location–allocation model for fire station in complex urban system. Natural Hazards, 102(3), 1475–1496. https://doi.org/10.1007/s11069-020-03981-2

Vaidya, O., & Kumar Sushil. (2006). Analytic Hierarchy Process: An Overview of Applications. European Journal of Operational Research, 169, 1–29. https://doi.org/10.1016/j.ejor.2004.04.028

Véron-Okamoto, A., & Sakamoto, K. (2014). Toward a Sustainability Appraisal Framework for Transport (SDWP 31). ADB Sustainable Development Working Paper Series, 31, 24. https://www.adb.org/sites/default/files/publication/31198/sdwp-031.pdf

Voogd, H. (1983). Multicriteria Evaluation for Urban and Regional Planning. Pion Ltd.

Wan, C., Yang, Z., Zhang, D., Yan, X., & Fan, S. (2018). Resilience in transportation systems: a systematic review and future directions. Transport Reviews, 38(4), 479–498. https://doi.org/10.1080/01441647.2017.1383532

Wang, S., Gu, X., Luan, S., & Zhao, M. (2021). Resilience analysis of interdependent critical infrastructure systems considering deep learning and network theory. International Journal of Critical Infrastructure Protection, 35, 100459. https://doi.org/10.1016/j.ijcip.2021.100459

Ward, E. J., Dimitriou, H. T., & Dean, M. (2016). Theory and background of multi-criteria analysis: Toward a policy-led approach to mega transport infrastructure project appraisal. Research in Transportation Economics, 58, 21–45. https://doi.org/10.1016/j.retrec.2016.08.003

Xu, L., Marinova, D., & Guo, X. (2015). Resilience thinking: a renewed system approach for sustainability science. Sustainability Science, 10(1), 123–138. https://doi.org/10.1007/s11625-014-0274-4

Yang, W., & Zhang, J. (2021). Assessing the performance of gray and green strategies for sustainable urban drainage system development: A multi-criteria decision-making analysis. Journal of Cleaner Production, 293, 126191. https://doi.org/10.1016/j.jclepro.2021.126191

Yang, Z., Barroca, B., Laffréchine, K., Weppe, A., Bony-Dandrieux, A., & Daclin, N. (2023). A multi-criteria framework for critical infrastructure systems resilience. International Journal of Critical Infrastructure Protection, 42(October 2022). https://doi.org/10.1016/j.ijcip.2023.100616

Yannis, G., Kopsacheili, A., Dragomanovits, A., & Petraki, V. (2020). State-of-the-art review on multi-criteria decision-making in the transport sector. Journal of Traffic and Transportation Engineering (English Edition), 7(4), 413–431. https://doi.org/10.1016/j.jtte.2020.05.005

Yazdani, M., & Graeml, F. (2014). VIKOR and its Applications: A State-of-the-Art Survey. International Journal of Strategic Decision Sciences, 5, 56–83. https://doi.org/10.4018/ijsds.2014040105

Yuan, Z., Wen, B., He, C., Zhou, J., Zhou, Z., & Xu, F. (2022). Application of Multi-Criteria Decision-Making Analysis to Rural Spatial Sustainability Evaluation: A Systematic Review. International Journal of Environmental Research and Public Health, 19(11). https://doi.org/10.3390/ijerph19116572

Zabihi, H., Alizadeh, M., Wolf, I. D., Karami, M., Ahmad, A., & Salamian, H. (2020). A GIS-based fuzzy-analytic hierarchy process (F-AHP) for ecotourism suitability decision making: A case study of Babol in Iran. Tourism Management Perspectives, 36, 100726. https://doi.org/https://doi.org/10.1016/j.tmp.2020.100726

Zhang, W., Wang, N., & Nicholson, C. (2017). Resilience-based post-disaster recovery strategies for road-bridge networks. Structure and Infrastructure Engineering, 13(11), 1404–1413. https://doi.org/10.1080/15732479.2016.1271813

Zhu, Q., & Leibowicz. (2022). A Markov Decision Process Approach for Cost-Benefit Analysis of Infrastructure Resilience upgrades (p. Risk Analysis, 42(7), 1585–1602.). https://doi.org/10.1111/risa.13838