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Trends on MCDM in Construction Management from 2019 to 2022 Based on a SWOT Analysis

2019'dan 2022'ye İnşaat Yönetiminde Kullanılan ÇKKV Yöntemlerinin SWOT Analizine Dayalı Olarak Değerlendirilmesi

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Abstract

The purpose of this study is to investigate publications utilizing multi-criteria decision-making (MCDM) methods in construction management to identify their strengths, weaknesses, opportunities and threats through a SWOT analysis. A variety of academic search engines was used to systematically search publications between January 2019 and May 2022 for this purpose. An in-depth analysis of 249 articles was conducted; first, they were ranked based on academic databases, indexes, and years, then they were classified according to their major applications in construction management, and finally, a SWOT analysis was carried out. The studies demonstrate that these methods improve the consistency and robustness of decision-making; however, they mainly concentrate on macro-level aspects, which is considered a disadvantage. Even though models heavily rely on participants' knowledge and experience, they can be eliminated by integrating perspectives from a variety of experts and professionals. Using the findings of this study, researchers will be able to plan their future original studies based on opportunities identified, as well as improve possible weaknesses and eliminate threats outlined in previous studies.

Keywords: Construction management, MCDM, SWOT, hybrid methods, optimum solution

Öz

Bu çalışmanın amacı, inşaat yönetiminde çok kriterli karar verme (ÇKKV) yöntemlerini kullanan yayınları inceleyerek güçlü ve zayıf yönlerini, fırsatları ve tehditleri SWOT analizi yoluyla tespit edip ortaya çıkarmaktır. Bu amaçla Ocak 2019 ile Mayıs 2022 tarihleri arasındaki yayınların sistematik olarak taranmasında çeşitli akademik arama motorları kullanıldı. Ulaşılan makalelerden 249'u derinlemesine analiz edildi; öncelikle akademik veritabanlarına, indekslere ve yıllara göre sıralandı, ardından inşaat yönetimindeki başlıca uygulamalarına göre sınıflandırıldı ve son olarak SWOT analizleri yapıldı. Araştırmalar, bu yöntemlerin karar vermenin tutarlılığını ve sağlamlığını artırdığını göstermekle birlikte esas olarak makro düzeydeki yönlere yoğunlaştığını belirtmekte ve bu da dezavantaj olarak değerlendirilmektedir. Modeller ağırlıklı olarak katılımcıların bilgi ve deneyimlerine dayansa da, çeşitli uzman ve profesyonellerin bakış açılarının entegre edilmesiyle bu durumun ortadan kaldırılabileceği kanaatine varılmıştır. Bu çalışma, araştırmacıların bu konularda geçmiş çalışmalarda fırsat olarak tespit edilen özgün çalışmalarını planlamalarının yanı sıra olası zayıf yönlerin iyileştirilmesi ve tehditlerin ortadan kaldırılması açısından da oldukça katkı sağlayacağı düşünülmektedir.

Anahtar Kelimeler: İnşaat yönetimi, ÇKKV, SWOT, hibrit yöntemler, optimum çözüm

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1. Introduction

Many industries rely on decision-making for their success, but the construction industry is especially dependent on information processing (Zhu et al., 2021). The construction sector makes significant and positive contributions to socio-economic development in both developed and developing economies and has been one of the most important sectors for years as it contributes to the meeting of the most fundamental needs, including shelter, transportation, water supply, and energy use (Ajayi & Chinda, 2022). Several complex factors affect construction works, and the right decision may not be obvious at first glance (Oz et al., 2017; Oz et al. 2019). When the optimal solution cannot be easily seen in construction, multi-criteria decision-making (MCDM) methods are used to make decisions that consider multiple factors at the same time (Zhu et al., 2021). Therefore, the most appropriate decision-making method for solving the related problem in the construction industry must be determined by examining previous studies concerning MCDM in detail. For the development of better practices and further research in the future, it is essential to understand their strengths, weaknesses, opportunities, and threats.

As shown in Figure 1, the MCDM process consists of many steps from identifying the problem to choosing the best alternative. MCDM methods have come to the forefront with many different approaches since the 1950s-1960s (Köksalan, 2011).

According to Arslan (2018), MCDM methods can be divided into three groups, namely (1) the basic methods such as the graphical method, the simplex method, linear programming, integer programming, and goal programming, (2) the single analytical methods such as AHP, ANP, MAUT, SMART, TOPSIS, data envelopment analysis, gray relational analysis, and (3) the hybrid methods such as AHP-VIKOR, fuzzy-TOPSIS, and AHP-genetic algorithm (Arslan, 2018).

Several weighting methods can be applied to solve different MCDM techniques, and the weights of the criteria have a significant impact on the decision-making process. According to Odu (2019), the most commonly used weighting methods can be classified into four groups: (1) subjective weighting methods such as point allocation method, direct rating, and ranking method, (2) pairwise comparison methods such as AHP, ratio method, swing method, Delphi method, nominal group technique, and simple multi-attribute ranking technique, (3) objective weighting methods such as entropy method, criteria importance through inter-criteria correlation, mean weight, standard deviation, statistical variance procedure, and ideal point method, (4) integrated weighting methods such as multiplication synthesis, additive synthesis, optimal weighting based on the sum of squares, and optimal weighting based on the relational coefficient of graduation. In terms of computations, subjective weighting methods are easier than objective

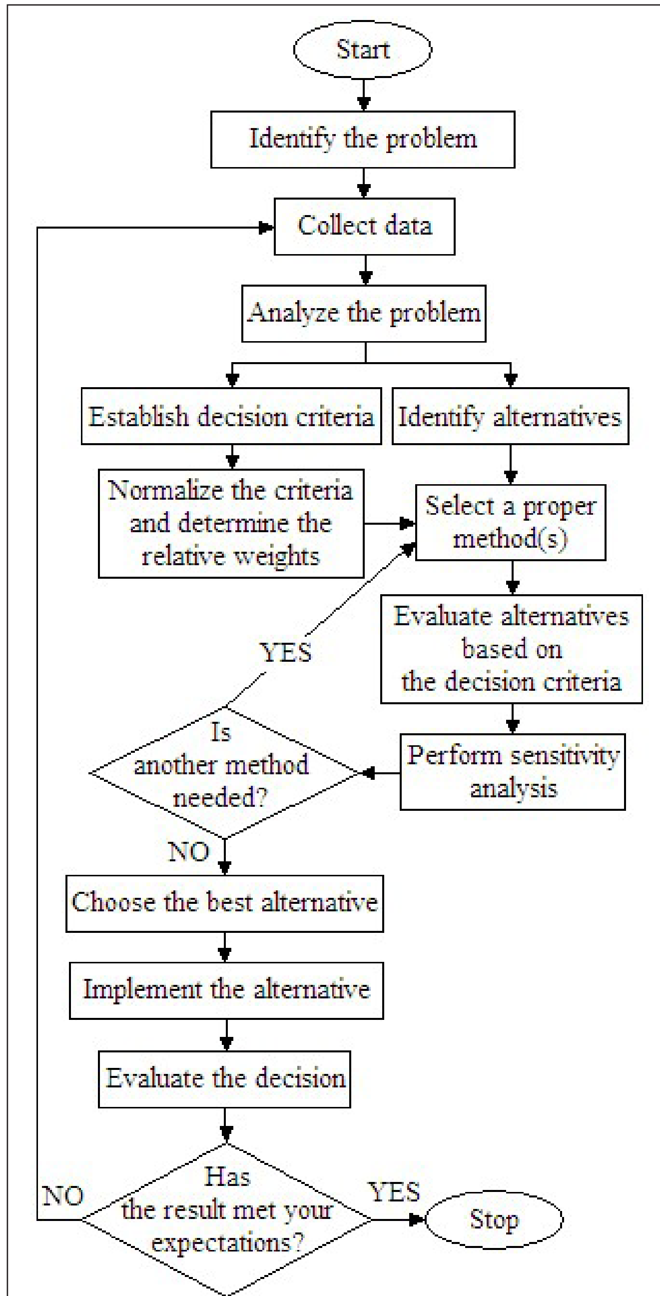

Figure 1. Steps of the decision-making process adapted from dos Santos et al., 2017.

weighting methods, which rely on mathematical functions to determine weights without the decision-maker's involvement (Odu, 2019).

An essential part of a decision-making process is normalizing data, and MCDM methods use those techniques to convert input data into numerical and comparable data by using a common scale. Vafaei et al. (2016) state that some normalization methods are better suited to specific decision methods than others, and each normalization method has two formulas, one for benefit criteria and the other for cost criteria. In a benefit criterion, high values correspond to high normalized values (maximization), and in a cost criterion, high values correspond to low normalized values (minimization). It's possible to normalize data using various methods; the most commonly applied techniques are linear (max), linear (max-min), linear (sum), vector normalization and logarithmic normalization (Vafaei et al., 2016).

MCDM studies in the field of construction management have been searched in the literature and it is evident that there is a substantial body of research; the studies between 2019 and May 2022 were focused on identifying recent trends in this research area to facilitate and simplify data search. After an exhaustive review of related literature and applying filters, 249 studies out of 350 were subjected to deep analysis. Seen that hybrid methods which are composed of the combination of two or more techniques have been mostly used in these studies, evaluation criteria have been determined according to the nature of the problem generally by using a survey or interviewing with experts, and various weighting methods have been used to determine the criteria weights, and finally, a sensitivity analysis has been performed in most studies.

Previous studies have mostly used MCDM methods in a problem and evaluated the output of the problem, and it is generally stated that incorrectly determined evaluation criteria or their importance weights may lead to inappropriate decisions and unsuccessful implications. For example, Zavadskas et al. (2014) indicated that selecting contractors based on the wrong criteria may lead to poor performance. The unique aspect of this study is that it examines the strengths, weaknesses, opportunities and threats based on the statements of previous articles that use MCDM in construction management through a SWOT analysis. This study will help those working in the field of construction management to select the most optimum decision-making methods to use for the problem and do research to know which issues are prominent, on-trend or interesting to the scientific community.

2. Material and Methods

In this study, a SWOT analysis is used to identify strengths, weaknesses, opportunities and threats of publications utilizing multi-criteria decision-making (MCDM) methods in construction management. SWOT analysis is a tool used to identify and analyze environments to support strategic decision-making (Kajanus et al., 2012). According to Zavadskas et al. (2010), the SWOT analysis can also be used to develop management strategies for construction firms. Three main sections were used to categorize the study: (1) An analysis of the statistical distribution of publications related to the topic, (2) a classification of construction management publications based on their application areas, and (3) making suggestions based on a SWOT analysis.

Various search methods can be used to find the information needed, including quick and dirty, snowball, and cited references. The cited reference search finds more recent publications on a topic; each document includes bibliographical details, an abstract, and a list of references used (Erasmus University Rotterdam, 2023). The cited reference search in this study was used to search academic databases and search engines for publications relating to construction management and multi-criteria decision-making, including ISI Web of Science, Google Scholar, Science Direct and PubMed. The methods for multi-criteria decision-making problems were then scanned, filtered, and listed by rapid review. An approach called rapid review is a method of producing information in a short amount of time by simplifying or eliminating the systematic review process (Tricco et al., 2015). This paper uses acronyms and their full forms listed in Table 1.

2.1. Distributions of the Selected Publications Based on Statistics

After an exhaustive review of 350 MCDM studies in construction management between January 2019 and May 2022, duplicates and out-of-scope records were refined and 249 studies were selected for analysis. As shown in Figure 2, these publications were sorted by types of index and by years; the 249 selected studies were almost evenly distributed by publication year, 172 of which were published in journals with the Science Citation Index Expanded (SCIE).

Table 1. List of acronyms.

Full name	Acronym	Full name	Acronym
Accident causation theory	ACT	Ideal and anti-ideal virtual units method	IAIVUM
Additive value function	AVF	Improved grey correlation analysis	IGCA
Additive-veto model	AVM	Interpretative/Interpretive structural modeling	ISM
Analytic hierarchy process	AHP	Interval-valued fuzzy numbers/sets	IVFS
Cybernetic Fuzzy AHP	CYBERF-AHP	Interval-valued intuitionistic Fuzzy	IVIF
Interval AHP	INT-AHP	Interval-valued hesitant fuzzy numbers	IVHFN
Sparse AHP	S-AHP	Interrater agreement analysis	IRA
Artificial neural network	ANN	INP method	INPM
Analytic network process	ANP	Degree of project utility and investment value assessments	INVAR
Analysis of variance	ANOVA	Life cycle assessment/Life cycle cost analysis	LCA
Additive ratio assessment	ARAS	Multi-attributive border approximation area comparison	MABAC
ARAS with grey values	ARAS-G	Measuring attractiveness by a categorical based evaluation technique	MACBETH
Alternative queuing method	AQM	Malmquist productivity index	MPI
Bayesian-structural equation modeling	B-SEM	Malmquist-luenberger index	M-LI
Bi-objective mixed linear programming	Bi-OMLP	Measurement of alternatives and ranking according to compromise solution	MARCOS
BCC input-oriented model	BCC-IOM	Multiple attribute decision support system	MADSS
Best worst method	BMW	Mann-Whitney U test	M-WUT
Case analysis	CASEA	Maslow's hierarchy	MASLOWH
Case-based reasoning	CBR	Maximum consistency model	MAXCM
Choosing by advantages	CHOBA	Maximizing deviation principle	MAXDP
Choquet integral	CHOQI	Multi attribute utility theory	MAUT
Closeness coefficient	CCOEF	Meta-Malmquist productivity index	M-MPI
Cloud theory	CLOUDT	Matrix cross-reference multiplication applied to a classification	MICMAC
Cloud and matter-element extension theories	CMEET	Integrated value model for sustainable assessment	MIVES
Combined Compromise Solution	CoCoSo	Mixed center-point triangular whitenization weight function	MCPTWWF
Grey combined compromise solution	CoCoSo-G	Monte carlo simulation	MCS
Combinative distance assessment	CODAS	Mutual information theory	MIT
Constraint programming optimizer	CPOPT	Multi-criteria ranking method	MCRM
Complex Proportional Assessment	COPRAS	Nearest neighbor element analysis method	NNEAM
COPRAS with gray relations	COPRAS-G	Niche field model	NFM
Cooperative game theory	CGAMET	NK model	NKM
Correlation and consensus-driven clustering method	CCDCM	Nuo method	NUOM
Criteria importance through inter-criteria correlation	CRITIC	Order relationship analysis	ORA
Data envelopment analysis	DEA	Pareto optimal solutions	PAREOPTS
Delphi	Delphi	Preference selection index	PSI

Table 1. Cont.

Full name	Acronym	Full name	Acronym
Decision-making trial and evaluation laboratory	DEMATEL	Preference ranking organization method for enrichment evaluation	PROMETHEE
Discrete event simulation	DESIM	Proportional risk assessment technique	PRAT
Distance friction minimization	DFMIN	Principal component analysis	PCA
Dominance-based rough set	DBRS	Quality function deployment	QUALFD
Double normalization-based multi-aggregation	DNBMA	Qualitative flexible multiple criteria	QUALIFLEX
Dynamic analysis	DYMA	Quasi-compensatory rationality	QUASICR
Evaluation based on Distance from Average Solution	EDAS	Rank order centroid method	ROC
Economic feasibility analysis	EVAFA	Quadruple-bottom line approach	QUADBLA
Elman neural network invasive weed optimization model	E-NNIWOM	Quality function deployment based method	QUALFDBM
Environmental impact analysis	EIA	Relative closeness coefficients	RELCC
Exponential chaotic differential evolution	ECDE	Revised Simos' method	REVSIMM
Elimination et choix traduisant la realité	ELECTRE	Robust nonparametric production frontier method	RNPFM
Entropy weight method	EWM	Risk matrix approach	RMA
Epsilon-based measure	EBM	Risk impact-frequency analysis	RIFA
Evidential reasoning	ER	Relative Important Index	RII
Enhanced Russell model	ERM	Relative preference alternative	RPR
Evaluation index system	EIS	Regression analysis techniques	REGAT
Exploratory factor analysis	EXPFA	Rough AHP	R-AHP
Experts grading method	EXPGM	Rough TOPSIS	R-TOPSIS
Factor comparison method	FCOMM	Rough dombi aggregator	RDA
Failure mode and effects analysis	FMEA	Standardized quantitative assessment approach	SQAA
Fine-Kinney method	F-KM	Simple additive weighting/Weighted sum model	SAW/WSM
Frequency-adjusted importance index	FAII	Single-valued neutrosophic set	SVNS
Full consistency method	FUCOM	Shapley value model	SVM
Fuzzy	Fuzzy	Social network analysis	SNA
Fuzzy cluster analysis	F-CA	Social willingness-to-pay	SWTP
Fuzzy cognitive map	F-COGM	Spatial-temporal analysis	SPATTA
Fuzzy comprehensive evaluation method	F-CEM	Spearman's correlation coefficient	SCC
Fuzzy positive ideal solution	F-POSIS	Strategic-aligned projects	SAP
Fuzzy negative ideal solution	F-NEGIS	Super efficiency DEA	SE-DEA
λ -Fuzzy measure	L-FM	Supply chain operations reference model	SCOR
Fuzzy axiomatic design	F-AXD	Surrogate machine learning model	SMLM
Fuzzy-eckenrode method	F-EM	Systems thinking approaches	SYSTA
Fuzzy fault tree analysis	F-FTA	System dynamics modeling	SDM
Functional index evaluations	FUNCIE	Simple multi-attribute rating technique	SMART
Pearson's correlation coefficient	PEARSONCC	Stepwise weight assessment ratio analysis	SWARA
Picture Fuzzy sets	PICFS	Technology acceptance model	TAM

Table 1. Cont.

Full name	Acronym	Full name	Acronym
Proximity information	PROXINF	2-dimension uncertain linguistic variables	2DULVs
Probability theory	PROBT	2-dimension uncertain linguistic power generalized weighted aggregation	2DULPGWA
Geomean	GEOM	Tomada de decisao interativa multicriterio	TODIM
Geographic information systems	GEOPIS	Tobit regression model approach	TRMA
Geospatial analysis	GEOSA	Technology organization environment	TOE
Generalized comparative linguistic expressions	GCLEs	Technique for Order Preference by Similarity to Ideal Solution	TOPSIS
Goal programming method	GOALPM	Interval-valued fuzzy TOPSIS	IVF-TOPSIS
Grey relational analysis	GRA	TOPSIS-G Method in Minkowski Space	TOPSIS-GM
Grey clustering model	GCM	Unascertained measurement theory	UMT
Grey system theory	GSM	Više Kriterijumska optimizacija i Kompromisno Rešenje	VIKOR
Graph theory	GRAPHT	Visual tracking method	VTM
Grounded theory	GROUNT	Weighted Aggregated Sum Product Assessment	WASPAS
Group AHP	GR-AHP	Weighted linear combination	WLC
Hesitant Fuzzy technique	HESFT	Weighting, rating and calculating	WRAC
Hierarchical Fuzzy expert	HFEXP	Z-order-m method	ZOM
Integrated determination of objective criteria weights	IDOCRIW		

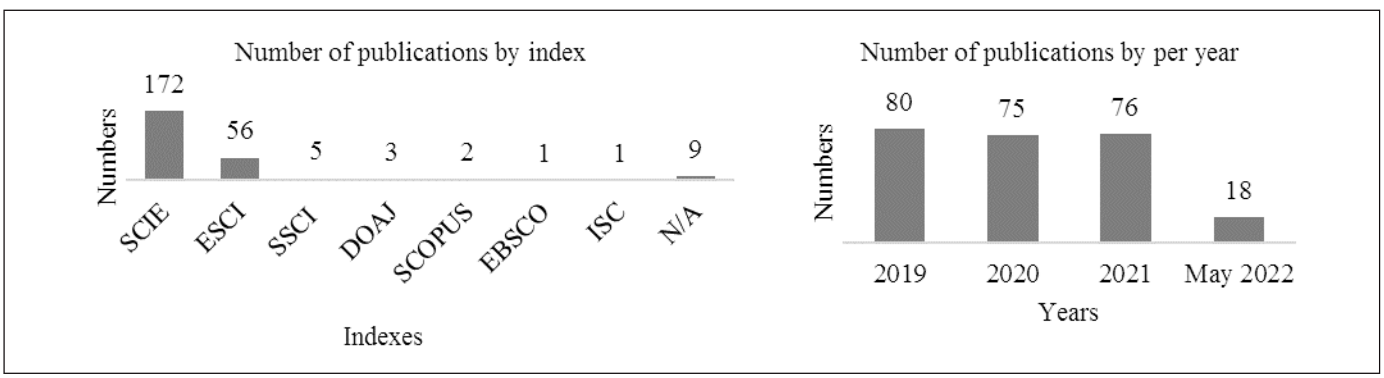

Figure 2: Publication statistical distributions.

3. Results

The publications were categorized into fourteen major application areas of construction management, as shown in Table 2. The two most popular subjects in these studies were "risk issues and assessments" and "party selection", while "maintenance/repair strategies" were among the least popular.

Table 3 shows the MCDM techniques used in the fourteen major application areas. Single analytical and basic methods were used in 53 studies, while hybrid methods were used in 196 studies. Various normalization techniques were used in these studies, and sensitivity analyses were performed in most. The 196 related studies mostly used 2 method hybrid techniques, while 4 method hybrid techniques were rarely used. AHP has been the most commonly used method in related studies, followed by DEA and TOPSIS. Additionally, Zavadskas et al. (2016) stated that AHP is the most common method for determining alternative weights. It is evident from Table 3 that the 2 methods were used in 90 studies; Fuzzy-TOPSIS in 6, AHP-Fuzzy in 5, AHP-TOPSIS in 4, and the other 2 combination methods in less than 4 studies. The 3 methods were used in 69 studies; ANP-DEMATEL-Fuzzy in 4, AHP-Fuzzy-TOPSIS in 3 and the other 3 combination methods in less than 3. The 4 methods were used in 26 studies, the 5 methods in 9, and the 6 methods and 8 methods in one study.

3.1. The SWOT Analysis

Finally, a SWOT analysis was made to identify the strengths, weaknesses, opportunities, and threats of the MCDM studies by searching some keywords indicated below. For this purpose, answers to the following questions were sought in the studies, and then a succinct SWOT analysis was developed.

Table 2. Major application areas studied in construction management.

Classification	References selected at random from 249 studies	Study numbers
Risk issues and assessments	(Erol et al., 2022; Gunduz & Almuajebh, 2020; Roghabadi & Moselhi, 2020)	40
Party selection (contractor, subcontractor, supplier, partner, etc.)	(Abdullah & Alshibani, 2022; Bonyani & Alimohammadlou, 2020; Liang & Chong, 2019)	34
Performance assessments (construction, management, organizational, labor, financial, projects, etc.)	(Banihashemi & Khalilzadeh, 2022; Li et al., 2021; Yuan et al., 2020)	27
Construction assessments or selection (technology, method, system, cost, etc.)	(Sing et al., 2021; Tamošaitiene et al., 2021; Xiahou et al., 2022)	25
Occupational risks and issues (health/safety)	(Gunduz & Khader, 2020; Prasad, 2019; Qi et al., 2022)	23
Resources assessments/selection (finance, equipment and machinery, materials, labor, technical and office staffing, etc.)	(Dehooei & Dehshiri, 2019; Gharouni Jafari, 2021; Kar & Jha, 2022)	23
Project planning/assessments/selection	(Kalan & Ozbek, 2020; Kiani et al., 2022; Kim et al., 2021)	22
Construction contract issues/selection	(Shalaby & Hassanein, 2019; Su et al., 2020; Wu & Xu, 2021)	16
Managerial issues	(Haruna et al., 2021; Iqbal et al., 2021; Ma et al., 2022)	11
Green construction assessments (material, benefits, costs, risks, technology, etc.)	(Mojumder & Singh, 2021; Sun et al., 2022; Tabatabaee et al., 2019)	8
Location/facility/site selection	(Biluca et al., 2020; Bozanic et al., 2019; Garg & Sharma, 2020)	7
Construction and demolition waste issues	(Khoshand et al., 2020; Liu et al., 2020; Negash et al., 2021)	5
Lean construction assessments	(Bayhan et al., 2022; Dehdasht at al., 2020; Demirkesen & Bayhan, 2020)	5
Maintenance/Repair strategies	(Abdelkader et al., 2022; Das & Nakano, 2021; Ighravwea & Sunday, 2019)	3

Table 3. Major application areas studied in construction management and used methods.

Risk issues and assessments	ANP, Fuzzy	ANP, DEMATEL, FMEA, Fuzzy	S-AHP	COPRAS-G, DEMATEL, EWM, Fuzzy	MCS, RMA, TOPSIS	AHP	ANP, Delphi	WASPAS	ANP, DEMATEL	DEA, Fuzzy, F-COGM, ISM
	AHP, DEMATEL, TOPSIS	DEMATEL, FCOMM, Fuzzy	AHP, Fuzzy, MCS	Delphi, DEMATEL	ANP, TOPSIS	CODAS, SWARA	DYMA, GCM, VTM	ANN, SE-DEA	EWM, Fuzzy, TOPSIS	EWM, F-COGM, GRA
	SMART	Fuzzy, TOPSIS	AHP, BMW, Fuzzy, GEOPIS	AHP, Delphi, Fuzzy, LCA	ANP, DEMATEL, Fuzzy	TOPSIS	CASEA, DEMATEL, ORA, SYSTA	ANP, FMEA, Fuzzy	DEMATEL	ANP, Delphi
	CoCoSo, Fuzzy, SAW/WSM	DEMATEL	ANP, DEMATEL	AHP, Delphi, Fuzzy	CPOPT, TOPSIS	AHP, Fuzzy, PRAT	GR-AHP, PCA	DBRS, MCRM	AHP, CGAMET, F-CEM, SVM	DEA, MPI
Party selection (contractor, subcontractor, supplier, partner, etc.)	AHP, IGCA, QUALFD	BMW, CoCoSo-G, DEMATEL	HESFT, QUALIFLEX	AHP, PROMETHEE	AHP	BMW	ARAS, COPRAS, FUCOM, MABAC, RDA, SAW/WSM, SCC, WASPAS	CHOBA	AHP, EWM, TOPSIS	AHP
	ELECTRE, EWM, Fuzzy, NFM, VIKOR	AHP, TOPSIS	AHP	BMW, Fuzzy, VIKOR	CLOUDT, Fuzzy, PROBT	AHP, FUNCIE, LCA, SQAA	AHP, SVNS, SWARA, WASPAS	DEA	AHP, CHOQI	AHP, F-CEM, UMT
	AHP, GEOM	BMW, Fuzzy, WASPAS	EVAFA, GOALPM	ANP, Fuzzy, MABAC	AHP, PEARSONCC, SCC	AHP	DEA, DFMIN	COPRAS, INVAR	AHP, FUCOM, MARCOS, PAREOPTS, TOPSIS	SWARA, WASPAS
	Fuzzy, SWARA, VIKOR	DEA	Fuzzy, TOPSIS	AHP, LCA, SWTP						
Performance assessments (construction, management, organizational, labor, financial, projects, etc.)	DEA, EIA, ERM, LCA	CCOEF, Fuzzy, F-POSIS, F-NEGIS, TOPSIS	AHP, F-CEM	AHP, COPRAS, LCA	DEA, TRMA	Fuzzy, IRA, M-WUT, VIKOR	AHP	F-COGM, GRA, GROUNT	DEA	EXPFA, MACBETH
	DEA, INPM, NUOM, TOPSIS	AHP, Fuzzy	AHP	FMEA, Fuzzy, SWARA, WASPAS	DEMATEL, ISM, MICMAC	AHP, TOPSIS	DEMATEL, Fuzzy, SDM	TOPSIS	DEMATEL, GSM, NKM	DEA, SPATTA
	MIVES	Delphi, DEMATEL, Fuzzy	GOALPM	DEA, IAIVUM	AHP, Fuzzy, TOPSIS	DEA, MPI	DEA, MPI			

Table 3. Cont.

Construction assessments or selection (technology, method, system, cost, etc.)	AHP	AHP	ANP, DEMATEL, Fuzzy, LCA, TOPSIS	Fuzzy, MAUT	AHP, SYSTA	AHP, Fuzzy, GEOM	AHP	BMW, Fuzzy, IVFS, IVF-TOPSIS	AHP, RII	AHP, Fuzzy
	MAUT	AHP	EWM, SAW/WSM	EBM, M-LI	AHP, DEA, F-CEM	ANP, Fuzzy, F-CEM	Fuzzy, TOPSIS	AHP, TOPSIS	AHP	SAW/WSM
	ANP, DEMATEL, Fuzzy	CCDCM, QUALFDBM, TOPSIS	ANP, LCA	Fuzzy, TOPSIS	ANOVA, DEA					
Occupational risks and issues (health/safety)	Fuzzy, UMT	Delphi, F-EM	Delphi, F-KM, Fuzzy, F-FTA, TOPSIS	DEA	AQM, BMW, PICFS	ANP, DEMATEL, Fuzzy	ANP, TOPSIS	BCC-IOM, DEA	AHP, PROMETHEE	AHP
	IVIF, MABAC, RPR, WASPAS	ACT, GRA, SYSTA	DEMATEL, GSM	Delphi, DEMATEL	AHP, Delphi	AHP	R-AHP, R-TOPSIS	AHP, PAREOPTS	EDAS, Fuzzy	CoCoSo, CRITIC, PSI
	Fuzzy, SWARA, TOPSIS	DEMATEL	DEMATEL, TAM, TOE							
Resources assessments/selection (finance, equipment and machinery, materials, labor, technical and office staffing, etc.)	COPRAS, SAW/WSM, TOPSIS	BMW, Fuzzy, TOPSIS	CHOQI, L-FM, TODIM	CODAS, IVIF	ANP, Delphi, DEMATEL, TOPSIS	ANP, FAII	AHP	AHP, RII	DEA	MAUT
	COPRAS, ROC	DESIM, E-NNIWOM, SMLM	ANP, ISM	AHP, Fuzzy	ANP, CMEET	SAW/WSM, TOPSIS, VIKOR	AHP, MASLOWH	AHP, Delphi, PROMETHEE	AHP, EDAS, EWM, SNA, 2DULVs, 2DULPGWA	AVM, QUASICR, TOPSIS
	DEA, TRMA	DEA	DEA, M-MPI							
Project planning/assessments/selection	AHP, Fuzzy, TOPSIS	AHP, Fuzzy	AHP, Fuzzy, SAW/WSM, TOPSIS, VIKOR	ARAS-G, GEOM, SWARA, TOPSIS-GM	ANP, DEMATEL, Fuzzy	TOPSIS	Fuzzy, LCA, MADSS, TOPSIS	AHP, Fuzzy	MCS, TOPSIS	HESFT, MAXCM, TOPSIS
	TOPSIS	AHP, HFEXP	Fuzzy, F-POSIS, MAXDP, RELCC, TOPSIS	FUCOM, Fuzzy, MABAC	EWM, ER, PAREOPTS	AHP	AHP, GEOPIS, SAP, TOPSIS	INT-AHP, TOPSIS	DEA	AHP, Fuzzy, TOPSIS
	ANP, Fuzzy, ISM	DEA, MPI								

Table 3. Cont.

Construction contract issues/ selection	SAW/WSM	AHP, GOALPM, MAUT, REVSIMM, TOPSIS	B-SEM, CBR, RNPFM, ZOM	BMW, GRA	Fuzzy, TOPSIS	AHP, REGAT	DEMATEL, Fuzzy, ISM	ANP	Bi-OMLP, DEA, Fuzzy	AHP
	ELECTRE, GCLEs, HESFT	EWM, VIKOR	AHP, MAUT	AHP, ELECTRE	AHP, QUADBLA, RII	AHP				
Managerial issues	DEMATEL, ISM	AHP, F-CA, NNEAM	AVF	GEOPIS, GEOSA	DEMATEL, SDM	AHP, TOPSIS	ANP, DEMATEL, SCOR, TOPSIS	TOPSIS	AHP, FMEA	AHP, WRAC
	CYBERF-AHP, Delphi, Fuzzy, IVIF									
Green construction assessments (material, benefits, costs, risks, technology, etc.)	DEA	Delphi, DEMATEL, Fuzzy	AHP, ANOVA, SCC	ER	DEA	AHP, MCPTWWF	CBR, GRA	DEA, MPI		
Location/facility/ site selection	BMW, GRA, VIKOR	AHP, F-CEM	AHP	BMW, IVFS, MARCOS	EWM, ER, PAREOPTS	DNBMA, HESFT, SWARA	ANP, ISM			
Construction and demolition waste issues	CHOQI, ELECTRE, EIS, IVHFN	DEA, Fuzzy	Fuzzy, TOPSIS	AHP, ELECTRE, GEOPIS, WLC	ANP, EIS, F-CEM					
Lean construction assessments	EWM, TOPSIS	ANP	ANP, Delphi	AHP, RIFA	TOPSIS					
Maintenance/ Repair strategies	ARAS, F-AXD, SWARA, WASPAS	TOPSIS	COPRAS, CRITIC, ECDE, GRA							

(a) Strengths: What is the originality, value, purpose, aim, contribution or unique knowledge of the study?

(b) Weaknesses: What are the deficiencies, inadequacies, shortcomings, or imperfections of the study to be improved?

(c) Opportunities: What are the opportunities, occasions, and suggestions for future or further studies?

(d) Threats: What are the threats, threatenings, obstacles, barriers, or constraints of the study?

3.2. Strengths

- Uses linguistic expressions of experts under hesitancy behaviors in the complex decision-making environment.
- Deals with the uncertainty arising from experts' limited awareness.
- Presents a systematic and scientific approach instead of the decision maker's knowledge, experience and intuition.
- Improves accuracy and reliability by including uncertainty and complexity.
- Uses various single or hybrid techniques for similar problems to select the most suitable method(s) by comparing the results.
- Increases the legitimacy of the final decision by including the demands of various stakeholders.
- Increases the consistency and robustness of the decision-making process.
- Makes the results of the decision more reasonable and objective.
- Helps construction managers make fast and desirable decisions.
- Easily applicable to real cases, especially in various regions.
- Provides a guideline for construction management by identifying the main barriers such as technical, economic, social, regulatory and environmental.
- Identifies critical barriers to implementing digitalization in the construction industry.
- Evaluates key performance indicators for measuring the management performance of construction firms.
- Easily integrated into building information modeling (BIM), the Internet of Things (IoT) and artificial intelligence systems (AIS).
- Helps to prioritize various drivers, enablers and barriers of construction management practices.
- Helps to select and rank the most influential persons in the sustainable prevention of accidents at work.
- Evaluates the most important levels of safety risks or construction laborers' safety levels in construction projects.
- Helps to classify security risks resulting in accidents and fatalities due to intense labor and machine environment interactions.
- Evaluates construction safety performance or construction laborers' safety levels.
- Significantly reduces conflicts and encourages agreement by ensuring transparency and mutual trust between the parties.

3.3. Weaknesses

- Unavailability or reluctance of experts for involvement.
- Experts with insufficient experience or knowledge in the field of study.
- A small sample size of respondents, experts or decision-makers in a study.
- Distraction of participants during interviews, which may affect the reliability of answers.
- Identification of dependencies between some of the ambiguity factors and possible measures.
- Considering interrelationships among criteria and attributes of enablers and barriers.
- Only one case is being considered to validate the applicability of the proposed method.
- Testing for large-size construction companies only.
- Analyzing the work only from a macro perspective.
- Considering only a theoretical evaluation or only a single country's context.
- Connection between the study results and the effectiveness of reality.
- Subjects being studied are still at the infancy stage or still vague for all stakeholders.

3.4. Opportunities

- Sufficient number of experts in the surveys should be included to make the results more accurate.

- Different perspectives of experts or professionals familiar with the field of study should be included in models to evaluate criteria more widely.
- The performance of the model should be tested with additional experts and on different projects.
- Perspectives of various experts from academia that have different points of view should be included in studies to improve the results.
- Perspectives of various stakeholders like clients, suppliers, employees, designers, government and agencies should be included in studies to improve the results.
- Various categories of respondents from multiple nations should be included to obtain more interesting results.
- Sufficient number of questionnaire responses from different types of projects should be added to improve the cases.
- A method to determine the weights of factors based on experts' consensus degrees should be developed.
- Results of the models should be analyzed with different weights of different individuals.
- Relationship between the factors should be evaluated not only qualitatively but also quantitatively.
- Sufficient number of factors should be included in the problem to enhance the efficiency estimation.
- Inner-dependencies of factors should be reconsidered for different locations.
- A list of criteria for specific problems should be provided to help the decision-makers speed up the process of defining criteria and focus on the criteria weighting.
- Different techniques should be applied to compare their results and enhance the accuracy of the assessment.
- Proposed models can be investigated in different types of problems by changing the factors, weights and alternatives.
- Proposed models should be applied to different locations to allow greater generalizability of the results beyond the current scope
- Proposed models should be validated in different contexts such as different countries or different construction sectors or projects.
- Performance of the models can be tested with a sufficient number of projects from the construction industry and multiple cases around the world to give more confidence in the results and standardize the proposed method.
- A combination of various decision-making techniques and artificial intelligence technologies may be applied more to decision-making problems.

3.5. Threats

- Small number of experts' opinions due to time limitations.
- Uncertainty and vagueness of the expert's judgments.
- Limited number of experts or experts only from the same country.
- High dependency greatly on participants' knowledge and experience.
- Factors of different practices and regulations in each country.
- Taking much time to provide a comprehensive list of criteria.
- Difficulties in data collection because of the limited number of qualified professionals.
- Constraints of data accessibility.
- Surveys obtained from respondents from a specific region that is not being generalized to other regions.
- Unknown or uncertain attributes of alternatives.
- Generating different results in case of a change in the sample groups or activities.
- The scope of the research is limited only to the stakeholders in the construction industry of a particular country.
- Using only optimal cases by removing non-optimal cases.
- Generating different results based on the context of a specific issue, different business contexts, working environments, and cultural backgrounds.
- Limitations of the methods being used to evaluate the internal influencing mechanism of factors.

4. Discussion

There is no doubt that the construction sector is an important industry that has a long-term impact on the economy, environment, and society and requires high levels of investment, and construction management and technology are two factors that greatly affect the industry. The process of managing a construction project entails setting objectives, identifying user requirements, determining constraints, and determining the resources required. MCDM is an essential tool for solving the basic problems of construction management, and the process has several criteria with different qualitative qualities, measures, and weights. Criteria may be defined subjectively or numerically, depending on the situation (Stojić et al. 2018). Construction management, health, technology, defense, textiles, the food industry, and many other fields have used MCDM methods. Although a variety of existing single or hybrid methods have been extensively used in construction management, new methods are still being developed and applied to a variety of construction management problems to determine the most suitable solution to the problem (Qi et al., 2018; Kazimieras Zavadskas et al., 2019; Erdogan et al., 2019). The development of MCDM methods grew rapidly in the 1980s and 1990s; An overview of MCDM methods was given by Koksalan et al. (2011), Erdogan et al. (2019) analyzed MCDM for sustainability in construction management, Erol et al. (2022), Günduz et al. (2020) and Raghabani et al. (2020) presented detailed studies about the application of MCDM methods to risk issues and assessments, Jato-Espino et al. (2020) examined the applications of MCDM methods in construction, Khoshand et al. (2020) examined the assessment model of benefits, opportunities, costs, and risks related to green roof installation, and so forth.

The study shows that 69% of the publications are indexed in SCIE. Risk assessment and party selection are the two most popular subjects, while maintenance strategies are the least popular. In the related studies, hybrid methods have been used more frequently than single methods; 79% used hybrid methods, while 21% used single methods. In related MCDM studies, the originality lies in the use of expert linguistic expressions during hesitancy behaviors, it uses a systematic and scientific approach rather than decision makers' knowledge, experience and intuition, it takes into account the uncertainty that arises from experts' limited knowledge, by including the demands of various stakeholders, the final decision becomes more legitimate, its results are more objective and reasonable, and by ensuring transparency and mutual trust between the parties, it reduces conflicts and encourages agreement. Studies that needed to be improved were categorized into three groups: experts and participants, evaluation factors and weights, and techniques and models. Among the highlights to be improved are; the inability or reluctance of experts, the lack of experience or knowledge of experts, the small sample size, the distraction of participants during interviews, testing/validation of the applicability of the proposed methods/models, and studies whose topics are too vague or in the early stages for all stakeholders. Further studies should include a sufficient number of experts, different perspectives of experts and professions, perspectives from various academics, perspectives from various stakeholders, as well as different respondents from multiple nations to improve results and improve the accuracy of the evaluation. The cases should be improved by adding sufficient questionnaire responses from a variety of project types. By determining the weights of factors based on experts' consensus degrees, the process can be sped up and the efficiency estimation improved. Not only should the relationship between the factors be evaluated qualitatively, but also quantitatively. Models should include a sufficient number of factors, and inner-dependencies should be reconsidered for different regions. Specific criteria for specific problems should be provided. Different weights should be applied to the models to analyze the results. There were several barriers, obstacles, or constraints mentioned in the relevant studies, including uncertainty and vagueness of expert judgments, high reliance on participants' knowledge and experience, difficulty in collecting data, and unknown or uncertain alternative attributes. Taking advantage of the significant role the construction sector plays in economic development will not only benefit the business, but also the country as a whole, since reaching an effective, appropriate or optimum solution quickly with the appropriate MCDM method will make a significant impact. Academics, researchers and professionals in the construction industry can use this study as a guide for their future studies.

5. Conclusions

The selection of the most suitable MCDM techniques for the problem will provide important contributions not only to the business but also to the country's economy by finding an effective and optimum solution quickly. It is necessary to examine previous studies regarding MCDM in detail to determine which decision-making method is most appropriate for the related problem in the construction industry, as well as to understand the strengths, weaknesses, opportunities and threats associated with them to develop better practices and conduct further research in the future. SWOT and MCDM methodologies based on previous relevant studies summarized in this study can quickly lead to an effective, appropriate or optimum solution to a construction problem, which will significantly improve construction management.

For this purpose, the studies between January 2019 and May 2022 were searched using academic search engines, ranked according to academic databases, indexes, and years, and then classified. MCDM studies have been successfully applied in fourteen major areas of construction management and 69% of related publications were indexed in SCIE, while studies on “risk issues and assessments”, and “party selection” have been the most popular subjects, while “maintenance/repair strategies” have been the least popular. It is on trend to use hybrid methods instead of single methods in the related studies. It has been noted in previous publications that the studies have more strengths than weaknesses, even though there are some limitations or obstacles. However, it has been observed that construction management has many fields to explore in the future.

As a result of this study, researchers will be able to determine which MCDM method is used in which field of construction management, as well as gain an idea of future studies in this area. For example, methods that have never been studied before on a similar subject may contribute more to literature and the field than others. The study’s methodological approach is very important in identifying the methods that are missing in the literature to guide new projects and studies that will fill these gaps. Researchers will also be able to plan studies on issues that have been identified as opportunities in previous studies, as well as to improve potential weaknesses and eliminate threats during the planning process. The literature may be further enriched in terms of both research articles and reviews if deficiencies can be eliminated and further studies with higher original value can be planned.

This study has some limitations. In total, only 227 out of 249 publications were available for full-text access, so a SWOT analysis could not be conducted on the remaining 22 studies. The SWOT analysis has been abridged due to a large amount of information and similar data that has been gathered from the studies. It’s possible that some information was overlooked owing to the skimming and scanning techniques used to gather relevant information from the studies. A similar analysis could be conducted using text mining techniques or other information retrieval methods in the future. Finally, this study could only cite a few randomly chosen references because of page and word limits.

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