Reviewing Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to support decision support system development in the Construction Industry

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Abstract
Construction is an industry in which making the right decisions can make the difference between success and failure. Decision support systems are often used to assist in bringing together disparate data sources and presenting them in a cohesive way to the decision-makers. TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), is one of the numerous Multi-Criteria Decision-Making (MCDM) methods, which has been successfully applied in a variety of practical and real-world challenges.
This paper reviews 45 published papers that used TOPSIS approaches in building and construction published from 2011 to 2021 to assess the applicability of TOPSIS. The most relevant papers relating to the TOPSIS technique were analysed and classified into application areas. The review indicated that TOPSIS is flexible and can be used to solve construction decision-making problems as a stand-alone tool or in conjunction with other tools. This paper contributes to the discussion on useful approaches to IT-based systems.

Keywords: Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Construction, Multi-Criteria Decision-Making (MCDM)

1 Introduction

Construction decisions are generally complex and variable in nature because they necessitate management of large amounts of information and knowledge(Ozorhon 2013). Most construction procedures are a collection of various processes, tasks, and requirements, that included a wide range of factors and considerations (Jato-Espino et al 2014). In this manner, Multicriteria Decision Making-Making (MCDM) is one of the major decision theory branches and it is used to facilitate long-term planning and priority setting. It also facilitates identifying the best solution from all available options (Ammar et al 2013; Huang et al 2015). This can help practitioners grasp the scope of the decision problem and make more informed decisions based on the decision knowledge.
Hwang & Yoon (1981) developed a Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), which is one of the most popular MCDM methods. The principal objective of TOPSIS is that the chosen substitute should be the shortest distance from the ideal solution and the farthermost distance from the negative ideal solution (Jahanshahloo et al 2006). The TOPSIS technique is used to integrate all of the system's measured performance values into a single value that can subsequently be utilised as a single performance metric in multi-variable optimisation issues (Darko et al 2019). TOPSIS is a widely adopted decision-making model due to its simplicity,

computational efficiency, and comprehensive mathematical foundations (Şimşek et al 2013). Jato-Espino et al (2014) reviewed the application of multi-criteria decisions in construction throughout the last two decades. Other review papers were conducted by Mardani et al (2015b) and Mardani et al (2015a) to classify applications and methodologies of MCDM and Fuzzy MCDM techniques into different fields. Palczewski & Sałabun (2019) also analysed and compared the implementation of fuzzy TOPSIS methods into limited application areas. Among the several MCDM techniques developed to tackle real-world decision issues, TOPSIS continues to perform effectively in a variety of application areas and has garnered considerable interest from researchers and practitioners (Hosseini et al 2018). Despite the fact that many studies in MCDM methods have been refined to specific application areas, there has been no review specifically focused on TOPSIS applications in construction, which is the intension of this paper. Additionally, the wide range of practical applications of the TOPSIS method imposed a strong motive for classifying applications across various construction areas and sub-areas.

This paper aims to examine the TOPSIS application in construction in order to gain a better understanding of the decision areas and decision problems that TOPSIS can effectively solve. Our contributions in this paper are to first summarise the existing literature on TOPSIS applications in construction during the last decade, and to identify popular TOPSIS application areas and issues for future investigation.

2 The TOPSIS approach

The TOPSIS approach can be defined using 5 steps (Ramík 2020):

1. Create an evaluation matrix containing the m alternatives and n criteria, giving an $m\ x\ n$ matrix. Normalise this matrix (all values between 0 and 1) by dividing each entry by the square root of the sum of the squares of the original entries;
2. Create the weighted normalised decision matrix;
3. Determine the best and the worst alternative that you could achieve across the criteria;
4. Calculate the L^2-distance between each alternative and the best and worst alternatives;
5. Rank the alternatives based on the distance from the best alternative divided by the sum of the two distances.

The simple analytical basis of the TOPSIS approach is worth exploring because it can be used to (i) explore the range of alternatives and criteria while developing a decision support system and (ii) provide understandable results with rankings to support interpretation once the system is complete. Exploring the range of alternatives and criteria are important during the develop phase of a decision support system as this improves the understanding of the decision space through testing the effect of criteria on the results and analyses. This can then be used to add or remove criteria as the behaviour is studied, and can assist in assigning the weights in the decision matrix through the use of existing solutions against proposed weightings to ensure that the results are appropriate.

3 Methodology

The current study took a comprehensive approach to review the state-of-the-art research on TOPSIS application in construction over the last decade.

Scopus was used to conduct the primary search for TOPSIS literature which compared to other databases, has been described as a search engine that covers more journals and more recent publications (Chadegani et al 2013). Other studies in the construction fields also recommended Scopus (Hosseini et al 2018; Oraee et al 2017). Moreover, because the goal of this study was to investigate the most recent topics and trends within TOPSIS, only literature published in the last decade was included. A ten-year period is typically used to select more recent articles for review, according to multiple scholars (Jin et al 2018). The research was carried out in the advanced search section of the chosen search engine for the keyword 'TOPSIS AND CONSTRUCTION'. After conducting a preliminary search, 105 research papers were discovered. The contents of each paper were then reviewed to filter out unrelated papers that did not have a construction focus. 45 papers were eventually deemed valid for further analysis.

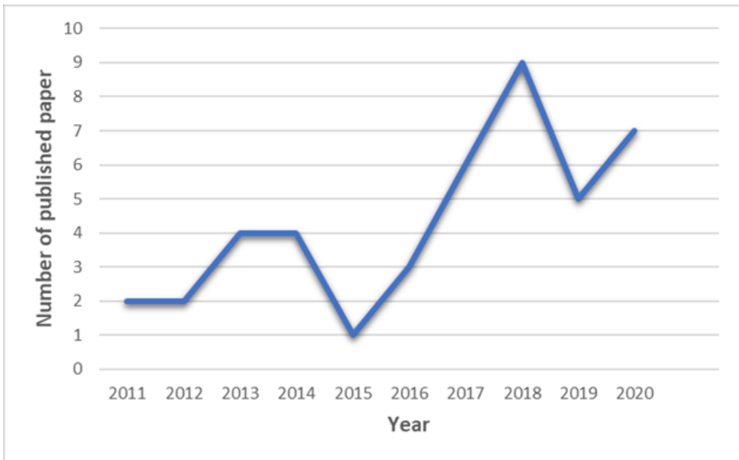

Figure 1. Distribution of publications per year across the period studied

Figure 1 depicts the distribution of journal articles published from 2011 to 2021, highlighting the general upward trend in publications over this period. In Table 1, a summary of the given application areas is presented in a descending order, with the numbers and percentages of implementations per category. The top six application areas were revealed to be sustainable management, supplier prequalification and selection, safety management, material selection, building design, and scheduling and planning.

Table 2 depicts an overview of all 45 papers identified, as well as a quick reference guide and useful information about TOPSIS applications in construction. It is presented to illustrate TOPSIS's versatility and value in a variety of construction scenarios. Furthermore, other techniques that have been used in conjunction with the TOPSIS technique are mentioned. The table was divided into decision areas based on the decision problems. To begin, the research interests of the papers aided in the identification of the decision areas. Second, the research objectives of the papers outlined the decision problems that TOPSIS was designed to solve.

Table 1. Number of implementations in the given categories

Application Areas	Number of Implementations	Percentage
Sustainable Management	8	18
Contractor/ Supplier Prequalification and Selection	7	15
Safety Management	5	11
Building Design	4	9
Material Selection	4	9
Scheduling and Planning	4	9
Risk Management	3	7
Project Success	3	7
Construction Technology	3	7
Bidding	2	4
Procurement	1	2
Project Delivery System	1	2
TOTAL	**45**	**100**

Table 2. Summary of applications of TOPSIS in construction

Decision Areas	Decision Problems	Other Method	Ref.
Sustainable Management	Concrete mixture design process for high-quality sustainable concrete production	Fuzzy sets theory	(Mohd et al 2020)
	Sustainable construction alternatives minimising environmental emissions	-	(Marzouk & Abdelakder 2019)
	Life cycle sustainability for modular buildings	AHP; ELECTRE	(Kamali et al 2018)
	Supply chain efficiency improving sustainable performance in prefabricated construction	Fuzzy sets theory; AHP	(Liu & Zhang 2018)
	TBL sustainable construction materials supply processes	BIM	(Alireza et al 2017)
	Incorporating the economic and IT index in green construction	Entropy method; AHP	(Li & Liang 2016)
	Evaluation and ranking structural materials over their total life against sustainability criteria	Entropy method; AHP	(Bakhoum & Brown 2013)
	Green construction model of steel building systems for residential projects	-	(Chen et al 2011)
Contractor/ Supplier Prequalificatio n and Selection	Supplier selection in establishing a supply chain	Fuzzy sets theory; ELECTRE	(Pinar & Boran 2020)
	Contractor eligibility and ranking in terms of prior strength and efficiency	Fuzzy sets theory; AHP	(Taylan et al 2018)
	Evaluating and ranking the contractor objectives	TFN	(Bintoro et al 2017)
	Ranking contractor selection criteria besides lowest bid for public construction projects	Entropy method	(Alptekin & Alptekin 2017)
	Integrated construction materials management supporting supplier	-	(Safa et al 2014)
	Establishing criteria in contractor for contractor prequalification	Fuzzy sets theory	(Nieto-Morote & Ruz-Vila 2012)
	Multi-criteria assessment of contractors in the bidding process	Fuzzy sets theory	(Wei et al 2011)
Safety Management	Risk assessment of workers safety	Fuzzy sets theory; FBWM	(Mohandes et al 2020)
	Risk assessment for health, safety, and worker well-being	-	(Koulinas et al 2019)
	Planning labour evacuation for construction sites	BIM	(Marzouk & Daour 2018)
	Assessing safety for high-rise construction projects	Fuzzy sets theory; AHP; DEMATEL	(Ardeshir & Mohajeri 2018)
	Impact factors on workplace safety conditions on construction sites	Fuzzy sets theory; AHP	(Basahel & Taylan 2016)
Building Design	Seismic design for concrete framed buildings	ACO; AHP; PROMOTHEE	(Lanseur et al 2021)
	Seismic upgrading of RC schools	-	(Formisano et al 2017)
	Seismic retrofit of existing RC structures and super-elevation of existing masonry constructions	ELECTRE; VIKOR	(Formisano & Mazzolani 2015)
	High strength self-compacting concrete mix design	-	(Şimşek et al 2013)
Material Selection	Design of Trombe wall systems	Entropy method	(Oluah et al 2020)

	Designing composite beams in steel-framed multi-storey buildings	-	(Tomas et al 2020)
	Sustainable materials selection	Fuzzy sets theory; BIM	(Fazeli et al 2019)
	Optimal roofing material selections	-	(Rahman et al 2012)
Scheduling and Planning	Schedule delay risk assessments	FCE	(Gebrehiwet & Luo 2018)
	Risk assessment to improve the planning of construction projects	-	(Heravi & Gerami Seresht 2018)
	Prioritising activities in resource leveling	AHP; PROMETHEE; OWA; HWA	(Markou et al 2017)
	Temporary facilities layout planning	Fuzzy sets theory; GA	(Song et al 2017)
Risk Management	Comparing risk mitigation schemes to control the construction risks to an acceptable level and determining the optimal schemes	SPA	(Zhang et al 2020)
	Construction projects risk assessment	Fuzzy sets theory; AHP	(Taylan et al 2014)
	Risk assessment of construction objects in connection with the construction of a commercial center	Fuzzy sets theory	(Tamošaitienė et al 2013)
Project Success	Identifying, evaluating, and ranking critical success factors in construction projects	Fuzzy sets theory	(Maghsoodi & Khalilzadeh 2018)
	Analysing and ranking EPC critical activities for large-scale residential construction projects	-	(Kabirifar & Mojtahedi 2019)
	Success criteria for completed construction projects	-	(Pinter & Pšunder 2013)
Construction Technology	Facilitating selection of new technologies	DSS	(Gicala et al 2019)
	Comparing construction approaches under sustainable development	WSM	(Gicala & Sobotka 2018)
	Evaluating 4D CAD comparing model construction using 2D and 4D models	SAW; CORPAS	(Reizgevicius et al 2014)
Bidding	A computer model to assist in the project bid or no bid decision	Fuzzy sets theory	(Al-Humaidi 2016)
	Risk assessment model for an optimal bidding	Fuzzy sets theory; AHP	(Nazam et al 2014)
Procurement	construction materials procurement	ANP	(Kar & Jha 2020)
Project Delivery System	Selecting the most suitable construction project delivery approach	AHP	(Mahmoud et al 2020)

4 Review of TOPSIS applications in construction areas

4.1 Sustainable management

Rapid growth in urbanisation followed by the building sector is believed to be one of the most resource-intensive industries and a prominent cause of overall environmental pollution in the modern world (Alireza et al 2017; Marzouk & Abdelakder 2019). Sustainability is aimed at balancing natural resources and human society's environmental, social and economic needs. Sustainable buildings attract the attention of both researchers and practitioners because of the benefits they provide, such as increased productivity, reduced waste, and pollution, lower energy consumption, increased quality, shortened construction time, and simplified renovation process (Chen et al 2011; Kamali et al 2018; Li & Liang 2016). To address the above objectives, MCDM enables the consideration of different aspects of sustainability in order to rank project alternatives and aggregate factors to provide the best overall sustainable solution (Bakhoum & Brown 2013; Liu & Zhang 2018).

4.2 Contractor/ Supplier prequalification and selection

The construction sector is expanding, and due to successfully complete these projects' requirements, an experienced management team of contractors and on-time delivery is required (Taylan et al 2018). The contractor/supplier selection process takes into account a number of project-specific factors, including their financial standing, technical capability, experience, and credibility (Safa et al 2014). Prequalification and selection of contractor/supplier are key decision-making issues, as all these criteria have both quantitative and qualitative considerations. Also, the task to establish a common scale for assessing all criteria is difficult (Alptekin & Alptekin 2017). Decision-making methods have developed into effective tools for assisting decision-makers in effectively resolving these problems by more accurately reflecting uncertainty in calculations than crisp sets do (Pinar & Boran 2020). TOPSIS approach or group decision-making methods are used to model this uncertainty in order to select and evaluate the best contractor (Bintoro et al 2017; Nieto-Morote & Ruz-Vila 2012).

4.3 Safety management

Construction sites are high-risk environments with a large number of workers performing a variety of tasks (Ardeshir & Mohajeri 2018). One of the primary goals of a safety management system in a successful construction site is to ensure a safe working environment (Basahel & Taylan 2016). Different factors, such as management commitment, effective resource utilisation, safety rules, and safe behavior, all play a role in ensuring safe workplace conditions. Consequently, using multidimensional systematic techniques to measure these factors would be more reasonable and reliable, because a variety of quantitative and qualitative attributes must be considered and the decision criteria are non-linear (Mohandes et al 2020). To address this issue, the TOPSIS method, which is part of an integrated multi-criteria approach, can be used to assess different factors and make informed decisions in order to transfer systematic knowledge between engineers, managers, and practitioners (Marzouk & Abubakr 2016).

4.4 Building design

The building design is a dynamic and multi-criteria task that is critical to structural efficiency and building costs for projects undertaken at the initial stage of construction (Kaveh & Mahdavi 2019; Şimşek et al 2013). TOPSIS technique in conjunction with other MCDM methods has been used to assist designers to make optimal decisions. For instance, it was applied by Lanseur et al (2021) to develop the seismic design of concrete buildings and by Formisano et al (2017) to offer the optimum solution for seismic retrofitting of reinforced concrete structures.

4.5 Material selection

Material selection is a critical approach affecting the overall performance of any system. A wide range of criteria and factors must be taken into consideration by stakeholders in order to select optimal design and customer requirements (Tomas et al 2020). The choice of appropriate materials can also reduce energy consumption and building maintenance costs (Fazeli et al 2019). TOPSIS method has been adopted to develop a system for supporting knowledge decisions in the field of material selection (Oluah et al 2020; Rahman et al 2012). This method has the advantage of being efficient and simple to use, as well as being able to rank materials based on predefined preferences (Shanian & Savadogo 2006).

4.6 Scheduling and planning

Construction projects are prone to fail if an efficient strategic plan and schedule are not in place from the start. The term "construction planning" refers to the process of selecting appropriate policies, processes, and procedures to accomplish the project's objectives (Song et al 2017). Alternatively, project scheduling is one of the most important processes in project management because it determines how much manpower, machines, materials, and equipment will be used to complete project activities (Song et al 2017). The implementation of multi-criteria decision models has been reviewed by researchers to tackle the issue in the scheduling and planning process of construction projects due to their complex nature (Heravi & Gerami Seresht 2018; Markou et al 2017).

4.7 Risk management

A construction project is regarded as risky due to the number of third parties involved, as well as the complicated conditions surrounding the execution, which include economic, political, social, and cultural factors. Risks are defined as an unforeseen event or condition that results in increased costs and schedule delays throughout the life of a project. Risk management decisions as multi-criteria issues are the outcome of operations that involve considering risk assessment, risk analysis, development of response strategies to mitigate expected outcomes (Tamošaitienė et al 2013; Taylan et al 2014; Zhang et al 2020).

4.8 Project success

Project success is the cornerstone of overall management and long-term project planning. The identification, evaluation, and management of factors play a key role in a project's success or failure, which directly affects the project's goals such as time, cost, and safety and quality (Kabirifar & Mojtahedi 2019). According to Pinter & Pšunder (2013), there are no precise mathematical and quantitative measurement models for project success. Hence, it is necessary to consider the overall success of a construction project as a multi-criteria problem that can be solved using MCDM methods such as TOPSIS (Maghsoodi & Khalilzadeh 2018).

4.9 Construction technology

Gicala et al (2019) and Gicala & Sobotka (2018) demonstrated the efficiency of multi-criteria analysis in a technology selection process based on the principles of sustainable development. By comparing three construction technologies, this analysis simplifies the process of integrated design and evaluation of innovative technologies needed to meet the building's sustainability requirements. Additionally, Reizgevicius et al (2014) used multi-criteria analysis to compare the effectiveness and justification of 4D CAD and 2D CAD in the construction process. During the investigation, it was discovered that the 4D model allows for the management of requirements and the efficient use of resources throughout construction.

4.10 Bidding

With the advancement of economic globalisation, proper project selection has become increasingly important, as inappropriate project selection can have a detrimental effect on a construction system's overall performance and productivity. Therefore, to assist decision-makers in ranking projects based on various attributes, some researchers considered using a group-based TOPSIS approach. In this case, proposed computer models could be used to aid in the decision to bid or not bid on a construction project, as well as risk assessment for project bidding selection (Al-Humaidi 2016; Nazam et al 2014).

4.11 Procurement

Every company that wants to meet its objectives must effectively manage the procurement process. TOPSIS methodology was used by Kar & Jha (2020) to calculate the values of the material criticality (the criticality of materials concerning the activity) that led to prioritise construction materials for procurement based on their features, the supply environment, and the characteristics of the project network. Thus, construction teams were supported in material management by making it available on time and more cost-effective by integrating it with project scheduling.

4.12 Building Project Delivery System

Mahmoud et al (2020) Mahmoud et al. (2020) compared three main types of project delivery with two MCDM methods for investigating the variations in decision-making results for achieving the most appropriate project delivery approach. Finally, it was demonstrated that TOPSIS method makes decisions easier for management and non-technical users in the project delivery system.

5 Conclusion

This paper examines the application of TOPSIS in the construction industry in order to gain a better understanding of the problem areas that TOPSIS can address. This review-based research into the application of TOPSIS used a holistic approach to achieve the following three primary objectives: 1) summarise TOPSIS application literature in construction published over the past decade, 2) classify areas and problems of TOPSIS applications, and 3) provide guidance for the potential use of TOPSIS. To achieve this, 45 related TOPSIS publications have been listed and examined by demonstrating their particular cases in 12 different fields of construction. The finding demonstrated that the most common TOPSIS applications in construction include sustainable management and contractor selection. Furthermore, group decision-making was included in more than half of the articles studied that demonstrates applying the combined TOPSIS rather than the stand-alone TOPSIS method.

When applied to both practical and theoretical concerns, the classical TOPSIS method has benefited from extensions that have made it more representational and applicable. The fuzzy set approach, group decision-making, entropy technique, AHP, genetic algorithms, and mathematical programming are all frequently used tools for extending the TOPSIS method. The fuzzy set technique appears to be the most commonly used in TOPSIS. Numerous authors have also recommended that the AHP technique be used in conjunction with TOPSIS to analyse the structure of complex decision-making issues and to estimate the weights of the criteria. Despite the integration of several techniques with the classical TOPSIS method, there are still many additional techniques that have not been applied. These techniques enable the classical TOPSIS to address additional practical and theoretical issues with more representation and applicability. There are also potential research directions that might be considered, such as investigations into the similarities and differences between TOPSIS and other MCDM techniques. This review will assist researchers' and practitioners' attempts to identify TOPSIS publishing resources, as well as those interested in using and evaluating the effectiveness of TOPSIS in addressing specific decision-making problems in construction.

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