

A META ANALYSIS OF DECISION MAKING PROBLEMS IN CONSTRUCTION RISK MANAGEMENT

KERIM KOC and ASLI PELIN GURGUN

Dept of Civil Engineering, Yildiz Technical University, Istanbul, Turkey

Various Multiple Criteria Decision Making (MCDM) methods are being commonly used in the area of construction risk management to deal with decisions that are subjected to several factors affecting the selection of the best possible choice in the projects. There are many techniques developed to provide assistance to decision-makers during decision-making process, each having different advantages and disadvantages. This study discusses some of the most frequently applied MCDM methods in construction risk management such as: AHP, ANP, TOPSIS, VIKOR, and DEMATEL, with their own application principles. It aims to introduce a meta-analysis about the use of MCDM methods within the last two decades and provide an extensive literature review study about construction risk management. It is expected to assist practitioners and researchers to suggest effective methods for specific type of risks to be addressed in construction projects. The discussion of pros and cons of each method will also provide some insights to get use of multiple MCDM methods rather than a single means to enhance the analysis outputs.

Keywords: MCDM, AHP, ANP, TOPSIS, VIKOR, DEMATEL.

1 INTRODUCTION

Due to its complex nature, construction industry is especially prone to risks, which have huge impacts on the project performance. There have been numerous attempts to deal with these risks in the literature. Several MCDM tools were used to aid decision-making processes in construction risk management. Some of the most commonly used MCDM tools are: Analytical Hierarchy Process (AHP), Analytical Network Process (ANP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Even though researchers have not paid enough attention to “Vise Kriterijumska Optimizacija I Kompromisno Resenje” (VIKOR) method, it can be regarded as an alternative to TOPSIS method since normalization techniques in these two methods are different (Opricovic and Tzeng 2004). In addition, “The Decision Making Trial and Evaluation Laboratory” (DEMATEL) is also not a commonly used MCDM method, however, since it indicates the causal links (Costa *et al.* 2019), it becomes a necessary instrument in risk management studies.

Meta analysis is a statistical technique integrating previous researches in a systematic manner (Hunter and Schmidt 1990). Literature review is useful to reveal research tendency, productivity and emphasis (Kog and Yaman 2014). However, the main difference of meta analysis from review studies is its quantitative characteristics (Holzmann 2013).

In this study, studies about construction risk management and MCDM tools were reviewed via search engine Scopus in order to point out the intensified and less examined aspects of risk

management literature. Only research articles published between 2000 and 2019 were investigated, and they were classified and analyzed on the basis of meta analysis. It was observed that AHP was the most commonly used MCDM tool. Project/construction risks, in a general term, were the most commonly indicated topic followed by safety risks. There is a huge gap in the literature about the DEMATEL and VIKOR methods. The findings will provide future research directions to the researchers of risk management literature.

2 INVESTIGATED MCDM METHODS

The comparison of investigated MCDM methods is given in Table 1. AHP is one of the most widely used MCDM techniques, and was first developed by Saaty in 1970s. It is composed of three main levels in the hierarchy as: goal, criteria and alternatives. All elements in each node are compared to each other and relative weights of each factor are calculated.

ANP is basically an extension of AHP and based on a network structure considering the interdependencies between factors (Li and Wang 2019). This requires more time for pairwise comparisons compared to AHP. The main steps of ANP are similar to AHP as well as pros and cons. In ANP method, interrelationships among criteria are considered; however, the validity of relationships remains to be addressed. Complex interrelationships among factors can be identified through DEMATEL method. Factors were concluded to be either causes or effects in the decision problem as a result of DEMATEL method.

Table 1. The comparison of investigated MCDM methods.

Attributes	AHP	ANP	TOPSIS	VIKOR	DEMATEL
Development	1970s	1980s	1980s	1990s	1970s
Weight elicitation	Pairwise comparison	Pairwise comparison	Given	Given	Not required
Core process	Pairwise comparison	Pairwise comparison	Closeness to the positive and negative ideal solution	Maximum group utility and minimum individual regret	The effect of each attribute on the others
Number of attributes	<10	<10	Any	Any	Any
Validation	Consistency check	Consistency check	None	Acceptable advantage, acceptable stability	None
Scale	1 to 9	1 to 9	Any	Any	0 to 4
Number of questions in 10 attributes	45	≥45	10	10	90
Interdependency	No	Yes	No	No	Aim

TOPSIS technique was developed in 1980s and 1990s, and has been used commonly in construction management literature. The main aim of TOPSIS method is to prioritize alternatives by considering the shortest distance from the ideal solution and the longest distance from the negative ideal solution, in a geometrical manner (Antuchevičienė *et al.*, 2010). It was developed as an alternative for the ELECTRE (Elimination et Choice Translating Reality) method (Liaudanskienė *et al.* 2015). To apply TOPSIS method, criteria scores should be numeric and increasing or decreasing, as well as having commensurable units (Behzadian *et al.* 2012).

The foundation of VIKOR was advocated by Opricovic and Tzeng (2004) in the twentieth century. It provides a maximum group utility of the ‘majority’, and a minimum of individual regret of the ‘opponent’. Unlike TOPSIS method, linear normalization is used in VIKOR method. After determination of rankings of the criteria or alternatives, two conditions are checked in VIKOR method: acceptable advantage and acceptable stability. If both of the conditions are satisfied, then the proposed rankings are accepted (Opricovic and Tzeng 2004).

3 METHODOLOGY

Search engine Scopus was used with the following keywords: (AHP OR ANP OR TOPSIS OR VIKOR OR DEMATEL) AND (Construction) AND (Risk) AND (Management), by limiting the results between 2000 and 2019 (up to July). Then, research articles were filtered, resulting in 158 scientific papers. Each paper was investigated on the abstract level and 28 of them were excluded from this study due to scope divergence. At the end, 130 research papers were found suitable to this research. The methodology adopted in this study is illustrated in Figure 1.

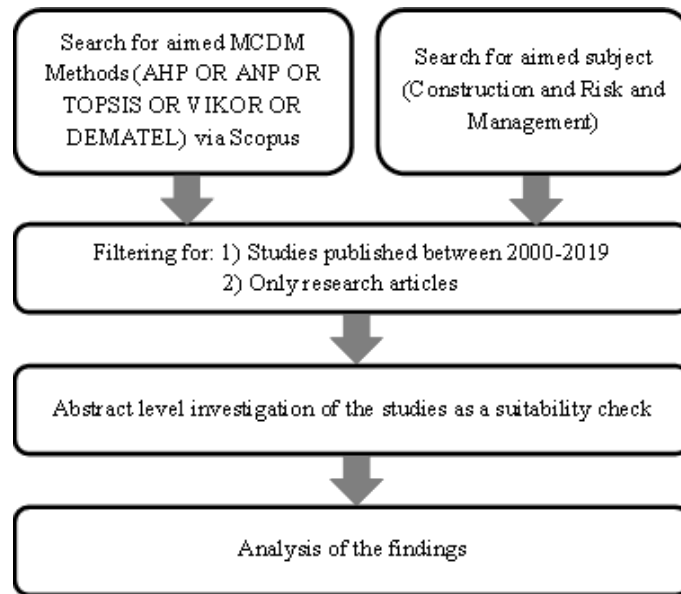


Figure 1. Research flowchart.

4 RESULTS AND DISCUSSION

In this research, 130 peer-reviewed research papers published between 2000 and 2019 were analyzed (Figure 2). The trend line in the figure shows that publications have been increasing over the last two decades. Table 2 shows the distribution of publications according to the country of corresponding authors' institution. Results indicate that 28% of them were conducted in China, followed by Iran and Canada by 11 and 7% respectively. This indicates that the number of studies conducted in China only is higher than other countries in the world, apart from the following 10 countries. Majority of the studies were performed in Asia by 63% followed by Europe by 17% (Table 3). Top five journals that published aforementioned studies are also given in Table 4.

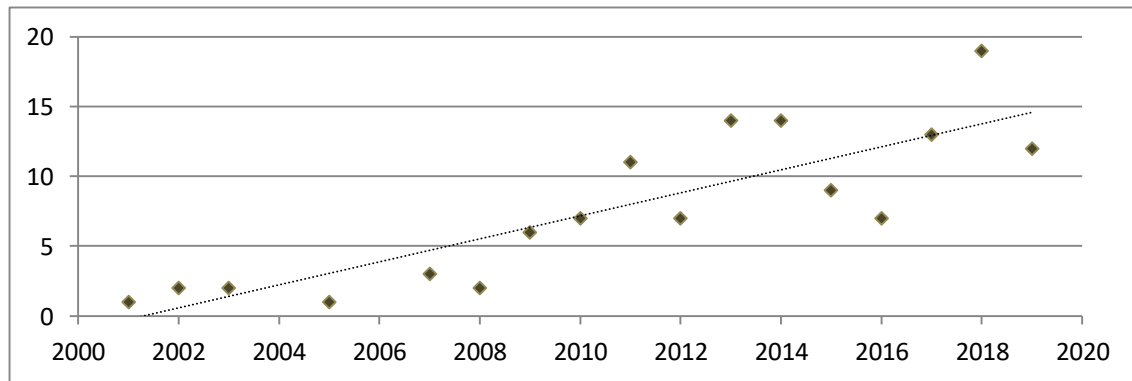


Figure 2. Yearly distribution of the studies.

Table 2. Distribution of the studies according to countries.

Country	N	%
China	37	28%
Iran	14	11%
Canada	9	7%
India	7	5%
United States	7	5%
Turkey	6	5%
Lithuania	5	4%
Taiwan	5	4%
Malaysia	4	3%
Spain	4	3%
UK	4	3%
Others	28	22%

Table 3. Distribution of the studies according to continents.

Country Group	N	%
Asia	82	63%
Europe	22	17%
Others	26	20%

Table 4. Top five journals about the subject.

Journals	N
Journal of Construction Engineering and Management	7
Journal of Civil Engineering and Management	6
Automation in Construction	4
Canadian Journal of Civil Engineering	4
International Journal of Project Management	3

The sub-topics of the studies are given in Table 5. The findings indicate that project or construction risks were investigated at most, by 20% disregarding a specific type of risk. In particular, safety was found to be the most commonly examined risk group, which was studied 23

times by researchers. “Others” in the table include risks about PPP projects, project delivery system based risks, risks about delay or duration, risks in supply chain, stakeholder associated risks, and external risks, which can be regarded as possible research directions for researchers interested in construction risk management. It is noteworthy that financial, delay and quality risks were analyzed by just a few authors, yet they are regarded as the main performance indicators of projects and often referred to as the iron triangle (Atkinson 1999).

Table 5. Distribution of the studies according to sub-topics.

Subject	N	%
Project / Construction risks	26	20%
Safety risks	23	18%
Risks of infrastructure projects	12	9%
Geotechnical/Environmental risks	11	8%
Risks of sustainable construction projects	10	8%
Risks of transportation projects	9	7%
Risks of large projects	7	5%
Risks in contractor selection and prequalification	6	5%
Financial risks	6	5%
Others	20	15%

The distribution of the investigated MCDM methods is provided in Table 6. Table shows that nearly 96% of the studies adopted at least one of the methods as AHP, ANP or TOPSIS. VIKOR method was not combined with any other methods, while DEMATEL was combined frequently with others MCDM techniques. Even though the reason behind the combination of MCDM methods is to compound the strongest features of different tools (Darko *et al.* 2018), there were just a few studies that combined different MCDM methods, of which were related to safety and project risks. However, fuzzy logic was adapted in 51 studies due to the fuzziness in construction risks and subjective judgments of MCDM methods. Among them, 34 studies used fuzzy AHP method. Findings addressed in this study are similar to the findings of Darko *et al.* (2018). They conducted a literature survey in 8 selected peer-reviewed journals and found that there were 77 AHP-based papers published between 2004 and 2014 and the most popular topic was risk management. The main reasons for researchers to choose AHP method are: small sample size (Darko *et al.* 2018), consistency check (Abudayyeh *et al.* 2007) and simplicity.

Table 6. Distribution of the studies according to MCDM methods.

Methods	N	%
AHP	83	64%
ANP	17	13%
TOPSIS	16	12%
VIKOR	4	3%
DEMATEL	1	1%
AHP and TOPSIS	4	3%
ANP and DEMATEL	4	3%
AHP and DEMATEL	1	1%

5 CONCLUSIONS AND RECOMMENDATIONS

Risks in construction industry have a direct impact on project performance. This study is an attempt to figure out the scientific tendency of construction risk management studies by considering five MCDM methods. AHP was found to be the most frequently used MCDM method in this context. Most of the authors focused on risk as a full metric and conducted their researches in Asia. For future studies, time, cost and quality related risks can be analyzed by researchers, since risk of a construction project is mostly regarded with this iron triangle. DEMATEL method can be an efficient tool to identify the relationships between risks in projects. MCDM methods excluded in this research can be used depending on the nature of the searched problem. It was found that there is a gap in the literature in comparative analysis of different MCDM methods. The findings may assist researchers and practitioners who aim to focus on less investigated and most commonly researched perspectives of construction risk management.

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