ID 36

Decision Tree Analysis in Project Risk Management: A Systematic Review

Aynur ZAKU[1], Furkan UYSAL[2]

[1] Social Sciences University of Ankara, Ankara, Turkey
[2] Social Sciences University of Ankara, Ankara, Turkey
aynur.zaku@student.asbu.edu.tr

Abstract

The most critical step repeated at each process in risk management is "decision making." Decision trees, part of artificial intelligence, have been used in an integrated manner with different methods in decision-making under uncertainty in recent years. The main reason for this is the need to quantify uncertainty in project risk management and the need for a flexible decision-making process in project management. This article aims to determine which project risk management processes the appropriate methods are used more frequently and determine the literature gap. In this context, literature review and bibliometric analysis methods were used. The results indicate that the integrated use of related risk assessment methods has increased in the last five years. The methods were most frequently used in quantitative risk analysis, qualitative risk analysis, and risk identification processes. It has been determined that the number of studies conducted on risk monitoring and control processes is very few compared to the number of studies on other risk management processes.

Keywords

Project risk management process group, decision tree, event tree analysis (ETA), fault tree analysis (FTA), bow tie analysis

1. Introduction

Risks are associated with uncertainty where either the output of an event or the event itself cannot be forecasted. According to Chapman and Ward (2003), uncertainties in project management come from estimates, the basis of estimates, design and logistics, objectives and priorities, relationships between project parties. Researchers have proposed several project risk management methodologies to manage these sources of uncertainties. ISO 31000, Prince 2, and PMBOK guide are commonly used methods (Řeháček, 2017). Moreover, these different methods were compared and contrasted in various aspects (Karaman and Kurt 2015; Chin *et al*. 2012, Obrová and Smolikova 2013). As a result, several tools are proposed to select the best suitable approach for selecting project risk management methodology in the built environment, such as Forbes *et al*. (2008). Among all proposed methodologies, Project Management Institute's (PMI) Project Management Body of Knowledge (PMBOK) has been widely accepted and used by construction management practitioners. PMBOK defines project risk as "an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives" (PMI, 2017). These uncertainties have to be managed through seven processes. PMI's project risk management processes start with planning a project risk management plan and continue with identifying risks, performing qualitative and quantitative risk analysis, planning risk responses, implementing risk responses, and monitoring risks. As stated by Forbes *et al*. (2008), the whole process depends on the identification of risks, since determining the risky event and associated uncertainty starts with identification. Evaluating the identified risks is another major component of risk management using qualitative and quantitative techniques.

Even though project risk management literature has been widely studied, there are very few numbers of systematic reviews based on PMI's process groups. For example, the chronological development of risk assessment techniques and models in construction risk management has been proposed by Tesfaye *et al.* (2016), and risk modeling techniques with fuzzy logic are given by Rezakhani (2012). Bahamid (2017) compiled studies on risk management in construction projects in developing countries, and Xia *et al.* (2018) examined risk management in construction projects in an integrated framework with stakeholder management. A systematic review on new and emerging tools in project risk management could serve researchers and practitioners to see the gap in the literature.

When the PMI's project risk management processes are considered, the essential step repeated at each process is "decision making." In a project, we move forward by deciding whether to continue the project or not, the project timeline, identifying and prioritizing risks, and the strategy to be executed. However, we also want to know our options and possible consequences before deciding to make the right decision. Decision trees have been developed to schematize choices, branches, and outcomes to facilitate decision-making between different options. However, decision-making has a complex structure as it includes many parameters, and it does not seem possible to answer all problems with a single method.

Since there are scarce resources in terms of systematic reviews on project risk management and decision making is a complex process, decision trees are selected as the primary subject matter of this paper. Therefore, a systematic review is conducted for decision trees in project risk management, and literature gaps are determined based on PMI's seven project risk management processes.

2. Methodology

This paper used literature review and bibliometric analysis as the primary search method. A three-phase search process was followed as a starting point for a comprehensive literature review. The first phase included searching and filtering the keywords determined after expert opinion. The second phase included finding the related literature on the decision trees with the article abstracts' analysis. The final phase included finding the general trends and literature gap in the literature. The general flow of the research is shown in Figure 1.

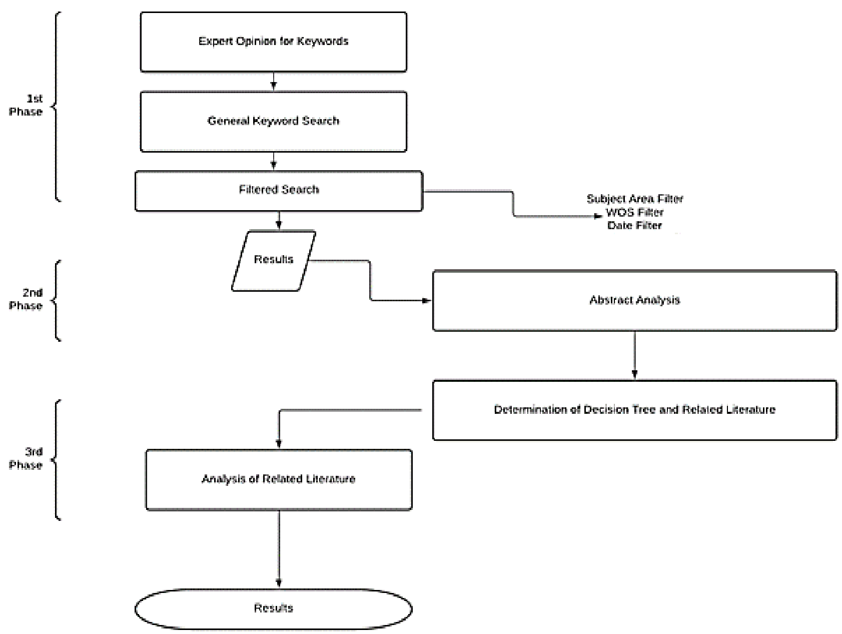

Figure 15. General Flow of Research

This study determined the target information source of scientific articles registered in the Web of Science (WOS) database. ***In the first phase*** of the research, the keywords were determined after expert opinions. Five key experts who have academic publications on project risk management and have experience at least five years in construction were asked to determine the most suitable keywords related to project risk management. Eleven keywords were selected, and a search was conducted with these eleven keywords.

Table 15. Keywords Determined After Expert Opinions

No	Key Words
1	“risk management” AND “project*” AND “decision tree”
2	“project management” AND “risk*” AND “decision tree”
3	“risk plan*” AND "project*" AND “decision tree”
4	“risk identif*” AND "project*" AND “decision tree”
5	“qualitative risk” AND “project” AND “decision tree”
6	“quantitative risk” AND “project” AND “decision tree”
7	“risk strategy*” AND “project*” AND “decision tree”
8	“risk response*” AND "project*" AND “decision tree”
9	"risk control" AND "project" AND " decision tree"
10	“risk monitor*” AND “project” AND "decision tree"
11	"ETA" OR " FTA" OR " Bowtie" OR " fault tree" OR "event tree" AND "project*"

Article search was carried out in article topic in WoS using the keywords given in Table 2. These searches were filtered with the below methods;

- # of articles without filter: Refers to the number of articles in search results before any filters are applied.
- # of articles: Refers to the number of articles after the article filter is applied.
- # Date filter: Refers to the number of articles after the date filter is applied (The articles published between 2012 and 2021 are included).
- SCI-Expanded and SSCI Index: Refers to the number of articles after the WoS Index filter is applied (The articles indexed in SCI-Expanded and SSCI Index are included).
- WoS Category: Refers to the number of articles after the WoS Category filter is applied. (Engineering Civil and Construction Building Technology categories included).

Table 16. 1st Phase of Keyword Search

# of Articles without Filter	# of Articles	# Date Filter	SCI and SSCI Index	WoS Category
131524	114351	53421	43899	502

In the second phase of the research, all 502 article abstracts, titles, author names, and sources are downloaded for further analysis. The keywords project, decision tree, fault tree, and event tree were searched separately in the abstracts. Since the bow-tie analysis includes both ETA and FTA analysis, no additional searches were done for this keyword. The number of articles obtained is also shown in Table-3.

Table 3. 2nd Phase of Research: Abstract Analysis

# of Articles-1st Phase	“Project” filter	“Decision Tree” filter	“Fault Tree” filter	“Event Tree” filter
502	159	36	121	34

- # of articles-1st phase: Refers to the number of articles obtained from 1st phase of the research
- “Project” filter: Refers to the number of articles after the word “project” filter is applied.
- “Decision Tree” filter: Refers to the number of articles after the words “decision tree” filter is applied.
- “FTA” filter: Refers to the number of articles after the word “FTA” filter is applied.

- "ETA" filter: Refers to the number of articles after the word "ETA" filter is applied.

The abstracts of the articles shown in Table-3 were analyzed and divided into two categories within the scope of project risk management processes (articles not within the scope of project risk management were excluded). In this context, 39 articles for Decision Tree Analysis and 37 articles for ETA and FTA were determined for further analysis.

In the third phase of the research, a total of 75 identified articles were reviewed and classified one by one according to the seven process groups of the PMI's project risk management process. If research can be categorized in more than one process group, each process group is counted separately. Obtained results were analyzed in 3 stages. Decision trees and project risk management processes in the first stage; ETA, FTA, bow tie analysis, and project risk management processes in the second stage; all tree analysis and project risk management processes in the third stage. The number of articles by year is graphed to see the trend of decision trees in Project risk management processes. Finally, to determine and show the gap in the literature, the phases in the project risk management processes in which decision trees are used are quantified and delivered on a radar chart.

3. Results

3. 1 First Stage Results

In the ten years between 2012 and 2021, the number of articles using decision trees in project risk management is 39. The distribution of the articles within the scope of project risk management by years is given in Figure 2.

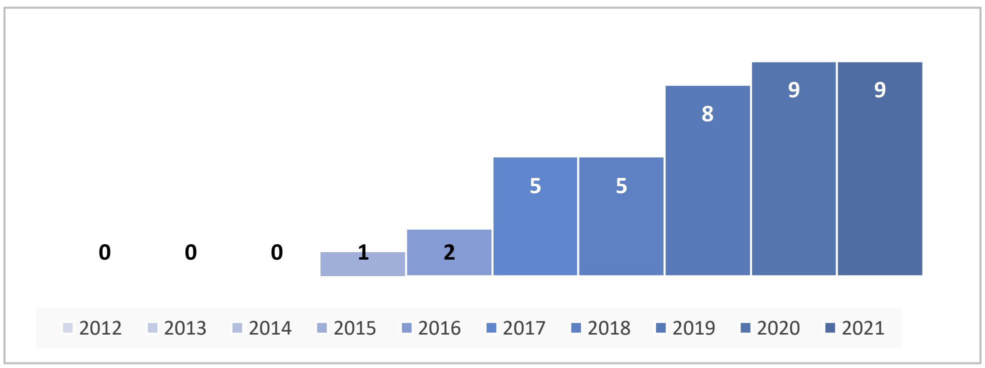

Figure 2. Number of Publications using Decision Tree Analysis in the Project Risk Management Process

As shown in Figure 2, while only three articles were published between 2012 and 2016, the number of studies has started to increase since 2017. The main reason for this increase is the increasing prevalence of machine learning methods and integrated studies of decision tree analysis with these new methods. The most frequently used methods integrated with decision tree analysis are as follows: Naive Bayesian (Hassan *et al.*, 2021; Liang *et al.*, 2021; Ahmad *et al.*, 2020; Gondia *et al.*, 2020; Lu *et al.*, 2020; Hu *et al.*, 2019), Bayesian Network (Ahmad *et al.*, 2020; Hu *et al.*, 2019), Analytical Hierarchy Process (AHP); (Maceika *et al.*, 2020; Maceika *et al.*, 2021), which ensures that not only objective factors but also subjective factors are considered in the decision-making process. Gong (2021) and Khazali *et al*. (2019) used a fuzzy logic and decision tree together. Compernolle (2019) and Chen (2017) use Monte Carlo Simulation () in construction projects. Welkenhuysen *et al*. (2017) used Techno-economic simulator PSS (Policy Support System) with Monte Carlo Simulation. Optimization and decision trees are used by Abreu *et al*. (2018) and Niederleithinger *et al*. (2017). Kameshwar (2020) used three separate decision trees for bridge restorations. The integrated use of machine learning with decision trees has increased in project risk management in recent years: The artificial neural network (ANN) (Arbab *et al.*, 2021; Gondia *et al.*, 2020; Shin, 2019; Guerrero *et al.*, 2018), Random Forest (RF), (Arbab *et al.*, 2021; Zhang *et al.*, 2020; Hu *et al.*, 2019; Poh *et al.*, 2018; Liang *et al.*, 2020), Support Vector Regression (SVR), (Arbab *et al.*, 2021), Support Vector Machine (SVM), (Hassan, 2021; Liang *et al.*, 2021; Zheng *et al.*, 2021; Poh *et al.*, 2018), Gradient Boosting Decision Tree (GBDT), (Zheng *et al.*, 2021; Shin, 2019; Liang *et al.*, 2020), K-nearest neighbors (KNN), (Hassan *et al.*, 2021; Zheng *et al.*, 2021; Mahmoodzadeh *et al.*, 2021; Steineder *et al.*, 2019; Poh *et al.*, 2018), J48 Decision Tree (Ahmad *et al.*, 2020; Khazali *et al.*, 2019; Hu *et al.*, 2019). Lin *et al.* (2019) used Classification and regression tree (CART), chi-squared automatic interaction detection

(CHAID), and quick, unbiased efficient statistical tree algorithms (QUEST) methodologies together. Gunduz and Lutfi (2021) used the CHAID and CRT models when deciding whether to bid on the projects or not. Rinaldi *et al.* (2020) used a decision tree-based machine learning algorithm. Howick *et al.* (2016) used the decision tree integratedwith the mixed OR method. Real option (RU), which has more financial use than its application in engineering design analyzed with a binomial decision tree Ajak *et al*. (2015), Tang *et al*. (2017), and Ihm *et al*. (2019) studied with a trinomial decision tree. Other methods in which decision trees are used integrated into project risk management are asfollows: Comparative analysis, gradient decision tree boosting- GDTB (Gong *et al*. 2021), Chi-square automatic interaction detection decision tree analysis (Cottrell *et al.*, 2019), Matrix analysis of HVAC system, Cost estimation methodology (Cho *et al.*, 2018), scenario analysis (Wang *et al.*, 2016) and operation analysis (Otsuki *et al.*, 2017).

Figure 3; 39 reviewed articles are classified according to PMI Risk Management Process Groups.

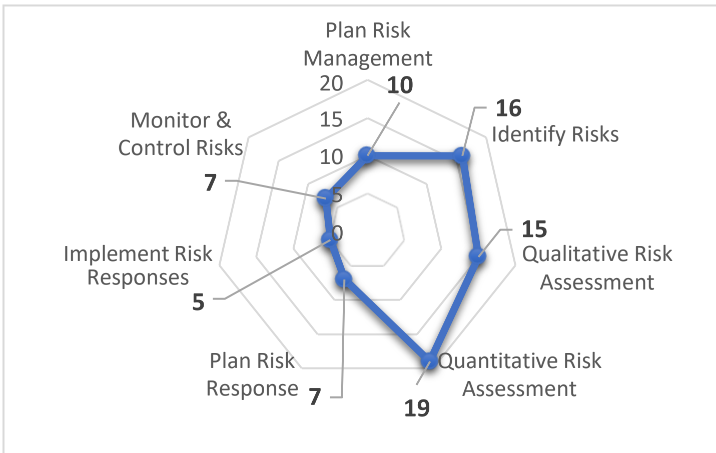

Figure 3. PMI Risk Management Process Groups of the Articles in the First Stage

When integrated methods, including decision tree analysis, are classified according to PMI Risk Management Process Groups, it is seen that studies mainly belong to the risk identification and qualitative and quantitative risk analysis process groups. The number of studies on monitoring and controlling risks is less than other processes. Very few recent studies emerged in plan risk management, plan risk responses, implement risk responses, and monitor and control risk process groups.

3.2 Second Stage Results

Thirty-six articles published on project risk management processes in this analysis stage were analyzed. The distribution of the articles handled within the scope of project risk management by years is given in Figure 4.

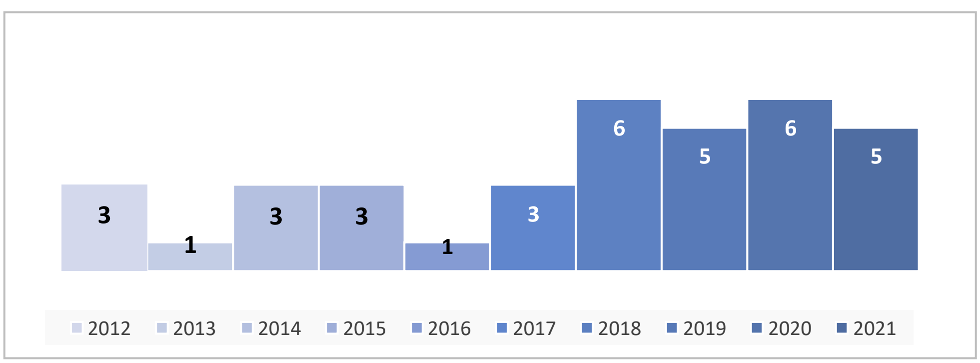

Figure 4: Number of Publications using ETA, FTA, Bow-Tie Analysis in the Project Risk Management Process

Fault tree analysis (FTA) is a risk assessment method used to estimate the probability or frequency of a particular hazard event that may occur. Qualitative or quantitative risk assessment can be made using Boolean algebra's diagram to define the hazard. Event tree analysis (ETA) is a risk assessment method that evaluates the consequences of a hazardous event. A diagram is created over the scenarios of a particular event. The method in which the questions of what can cause a hazardous event and what will happen if a hazardous event occurs together are evaluated together is called the bow-tie analysis. In other words, bow tie analysis combines ETA and FTA. In project risk management, ETA, FTA, and bow tie analysis methods have increased significantly in the last five years.

The most frequently used methods integrated with decision tree analysis are as follows: Fuzzy logic in integration with FTA and ETA (Abad *et al.*, 2020; Alipour-Bashary *et al.*, 2021a; Krechowicz, 2020; Nasirzadeh *et al.*, 2019; Shoar and Banaitis, 2019; Alipour-Bashary *et al.*, 2021b; Hsu *et al.*, 2020; Chen *et al.*, 2018; Ardeshir *et al.*, 2014; Gierczak, 2014; Abdelgawad *et al.*, 2012; Abad *et al.*, 2019; Marzouk and Mohamed, 2018; Marhavilas *et al.*, 2020; Shahhosseini *et al.*, 2018; Shoar *et al.*, 2019). The second most common method used in integration with FTA and ETA is the Bayesian network (Zhou *et al.*, 2018; Chen *et al.*, 2015; Leu *et al.*, 2015), but Guan *et al.* (2020), Zhang *et al.* (2014 and 2019) used fuzzy logic and Bayesian methods together with ETA and FTA. Ardeshir *et al.* (2014) and Marhavilas *et al.* (2020) preferred AHP with fuzzy logic. Another method integrated with ETA and FTA is Monte Carlo simulation (Vileiniskis *et al.*, 2017; Shoar *et al.*, 2019; Gernay *et al.*, 2016; Abdelgawad *et al.*, 2012). Zhang *et al.* (2019) used fuzzy fault tree analysis, fuzzy weighted index, and a risk response matrix in the designed model. On the other hand, Krechowicz (2020) used a Fuzzy set, fault tree analysis (FTA), artificial neural network (ANN), rough set (RS), cloud model (CM), and Bayesian network (BN) together for all phases. Marzouk *et al.* (2018) propose a framework with a new integrated system comprising fault trees, artificial neural networks, and analytical network processes.

Heravi et al. (2015) used ETA for conflict management for changes in construction projects project participants Liu *et al.* (2015) used fault tree analysis to evaluate project skill risks of project teams. Song *et al.* (2012) used ETA with alternative dispute resolution (ADR) techniques. Tsai *et al.* (2018) proposed the decision-making support system of risk management from risk efficiency with FTA. Aljassmi (2013) used a fault tree with defect management, and Zhang (2021) used it with optimization. Figure 5 is obtained when the 36 reviewed articles are classified according to PMI Risk Management Process Groups.

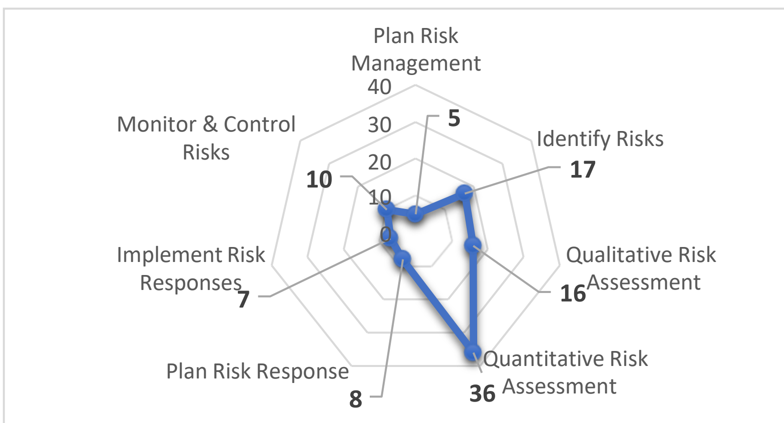

Figure 5: PMI Risk Management Process Groups of the Articles in the Second Stage

As shown in Figure 5, ETA, FTA, and Bowtie Analysis were mainly used to quantify risks in PMI project risk management processes. Unlike decision tree analysis, integrated models using these methods and including all stages have also been proposed. ETA, FTA, and bow tie analyses are often used to identify risks and the qualitative analysis of risks, with the quantitative analysis of risks.

3.3 Third Stage Results

In the third stage, 39 articles, including decision tree analysis and 36 articles including ETA, FTA, and Bowtie analysis (75 articles in total), were grouped according to project risk management processes. Project risk management processes in various fields such as tunnels (Liang *et al.*, 2021; Leng *et al.*, 2020; Sharafat *et al.*, 2021; Zhang *et al.*, 2019; Ardeshir *et al.*, 2014; Zhang *et al.*, 2014; Gierczak, 2014), Public-Private Partnership (PPPs), (Zheng *et al.*, 2021; Marzouk *et al.*, 2018), contracts (Gunduz and Al-Ajji, 2021; Hassan *et al.*, 2021; Zheng *et al.*, 2021; Poh *et al.*, 2018; Siu *et al.*, 2018; Turner *et al.*, 2017; Marzouk *et al.*, 2018) in construction technologies and civil engineering projects were evaluated. The distribution of the articles handled within the scope of project risk management by years is given in Figure 6.

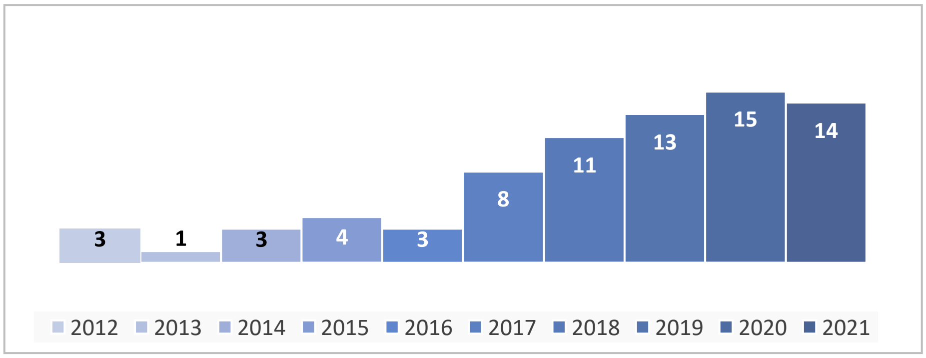

Figure 6: Number of Publications using DT, ETA, FTA, Bow-Tie Analysis in the Project Risk Management Process

When the distribution of 75 articles by year is examined, it is seen that 81% of them were published in the last five years. This ratio indicates an increasing interest in using decision trees with hybrid methods in project risk management. Figure 7 is obtained when the 75 reviewed articles are classified according to PMI Risk Management Process Groups.

Figure 7. PMI Risk Management Process Groups of the Articles (Two Stages together)

Considering the PMI's process groups, the vast majority of the papers are published in the context of the quantitative risk analysis process group.

4. Discussion

The "decision-making" step is critical in each project risk management process. Decision trees, used as decision-making tools, provide ease of use as they schematize options about choices and possible outcomes. However, traditional decision trees deal with discrete values, are insufficient for uncertain situations, and can analyze a limited number of features with good performance. Most risk factors associated with a project are not independent and have causal relationships. There is an increasing interest in risk assessment methods that focus on this relationship between risks to increase the effectiveness of risk management (Guan *et al.*, 2020). Easy integration of decision, event, and fault tree analyses with other methods lead to an effective project risk management methodology.

92% of the research with decision trees in project risk management has been done in the previous five years. In recent years, this ratio shows the increasing interest in using both decision trees and fault/event trees in project risk management processes. When the 39 articles on decision trees were analyzed, it is seen that the most research was on the quantitative risk analysis (n=19) process. However, the number of processes for identifying risks (n=16) and qualitative risk analysis (n=15) is close to the number of quantitative risk analysis processes. The most important reason for this is that the stages of identifying, evaluating, and prioritizing risks are generally handled and used together. However, after the risks are evaluated, the number of studies carried out during the planning risk strategies (n=7) and executing risk strategies (n=5), as well as the control and monitoring of risks processes (n=7), is considerably less than the number of other processes. This shows that planning, executing and control and monitoringof risks have high research potentiaş. In the 39 reviewed articles, including decision tree analysis, the number of processes for planning risk management and identifying and assessing risks constitute 75% of the total project risk management processes. The number of processes for planning responses to risks, implementing risk strategies, controlling and monitoring risks constitute 25% of the project risk management processes.

When project risk management processes analyzed the 36 reviewed articles on ETA and FTA, the most research was on the quantitative risk analysis process (n=36), more than the sum of risk identification (n=17) and qualitative risk analysis (n=16) processes. The number of processes for controlling and monitoring risks is higher than decision trees. The most important reason for this is event tree analysis. Because ETA evaluates controls against the risks that may occur if an event occurs. The least researched process in the articles on ETA and FTA is the process where the project risk management is planned (n=5). In 2 articles, integrated models, including all project risk management processes, were preferred (Zhang *et al.*, 2019; Krechowicz, 2020). In the 36 articles reviewed, the number of processes for planning risk management and identifying and evaluating risks, similar to decision trees, constitutes 75% of the total number of project risk management processes. The number of processes for planning responses to risks, implementing risk strategies, controlling and monitoring risks constitute 25% of the project risk management processes. However, the number of quantitative risk analysis processes alone corresponds to 36% of the total number of processes. This ratio shows that FTA is preferred most frequently in quantitative risk analysis. The majority of the findings indicate that project risk management researches are oriented to quantitative and qualitative risk analysis steps. There are less number of researches in project risk planning, executing and control and monitoring steps.

Limitations of the study is twofolds. First,this study aimed to find research potential based on previous literature researches that can help new researchers in project rist management and only WoS database is used for analysis. Second, the full research articles are filtered from search results. Conference preceeding could be added to the research results. A more comprehensive study could be done with more keywords and more databases.

5. Conclusions

Flexibility and high costs increase the importance of project risk management in the built environment. The use of decision trees, a tool for decision-making under uncertainty, has risen in recent years. According to the results of the bibliometric analysis, it has been determined that the integration of decision trees with methods such as machine learning and fuzzy logic has increased the use of decision trees significantly in the last five years. When the PMI's seven processes related to project risk management are analyzed, the decision tree is mainly used to identify risks and the qualitative and quantitative risk analysis processes. The least amount of study processes are where risk strategies are implemented and risk management is planned. Articles on project risk management generally concentrate on the risk identification and risk assessment phases. Since project risk management is a cyclical process, the planning and implementation of risk strategies and less handling of monitoring and control processes appear as the weakest link in project risk management

For further research, bibliometric analyzes on project risk management in sectors other than construction will reveal the application differences between industries, and good practice examples can be integrated. According to the analysis it is seen that there is a gap in the literature, especially in implementing risk responses, plan risk management, plan risk responses phases. This analysis with decision trees can be repeated with several quantitative risk management methods such as AHP, machine learning, or fuzzy logic.

References

Abad, F., Eshtehardian, E., Taghizade, K (2019), Framework for Proactive Change Management: Assessing the Risk of Change in Construction Projects Using Fuzzy Fault Tree Analysis, *Journal of Architectural Engineering*, 25-2, DOI10.1061/(ASCE)AE.1943-5568.0000358

Abad, F; Naeni, LM (2020), A hybrid framework to assess the risk of change in construction projects using fuzzy fault tree and fuzzy event tree analysis, *International Journal of Construction Management*, DOI: 10.1080/15623599.2020.1790474

Abdelgawad, M., Fayek, A. (2012). Comprehensive Hybrid Framework for Risk Analysis in the Construction Industry Using Combined Failure Mode and Effect Analysis, Fault Trees, Event Trees, and Fuzzy Logic, *Journal of Construction Engineering and Management*. 138. 642-651.

Abreu, A., Booth, R., Prange, M., Bailey, W.J., Bertolini, A., Teixeira, G., Romeu, R., Emerick, A., Pacheco, A., Wilkinson, D. (2018), A decision support approach to value flexibility considering uncertainty and future information, *Journal of Petroleum Science and Engineering*, Volume 167, Pages 88-99

Ahmad, M; Tang, XW; Qiu, JN; Ahmad, F; Gu, WJ (2020), A step forward towards a comprehensive framework for assessing liquefaction land damage vulnerability: Exploration from historical data, *Frontiers of Structural and Civil Engineering*, 14-6, 1476-1491

Ajak, D., Topal, E. (2015) Real option in action: An example of flexible decision making at a mine operational level, *Resources Policy*, 45,109-120

Alipour-Bashary, M., Ravanshadnia, M., Abbasianjahromi, H. *et al*. (2021a), A Hybrid Fuzzy Risk Assessment Framework for Determining Building Demolition Safety Index, *KSCE Journal of Civil Engineering*, 25, 1144–1162

Alipour-Bashary, M., Ravanshadnia, M., Abbasianjahromi, H. and Asnaashari, E. (2021b), Building demolition risk assessment by applying a hybrid fuzzy FTA and fuzzy CRITIC-TOPSIS framework, *International Journal of Building Pathology and Adaptation*, Vol. ahead-of-print No. ahead-of-print.

Aljassmi, H. (2013), Analysis of Causes of Construction Defects Using Fault Trees and Risk Importance Measures. *Journal of Construction Engineering and Management*, 139. 870-880.

Arbab, M., Rahbar, M., Arbab, M. (2021), A Comparative Study of Artificial Intelligence Models for Predicting Interior Illuminance, *Applied Artificial Intelligence*, 35:5, 373-392.

Ardeshir, A., Amiri, M., Ghasemi, Y., Errington, M. (2014). Risk Assessment of Construction Projects for Water Conveyance Tunnels Using Fuzzy Fault Tree Analysis, *International Journal of Civil Engineering*, 12. 396-412.

Bahamid, R.A, Doh, S.I. (2017), IOP Conf. Series: Materials Science and Engineering, 271 012042.

Chapman, C., & Ward, S. (2003), *Project risk management processes, techniques, and insights*, John Wiley & Sons

Chen, BL; He, JC; Wen, XH; Chen, W; Reynolds, AC (2017), Uncertainty quantification and value of information assessment using proxies and Markov chain Monte Carlo method for a pilot project, *Journal of Petroleum Science and Engineering*, 157, 328-339.

Chen, T.T., Wang, C.H. (2015), Fall risk assessment of bridge construction using Bayesian network transferring from fault tree analysis, *Journal of Civil Engineering and Management*, 23. 1-10. 10.3846/13923730.2015.1068841.

Chen, W., Wang, X., Liu, M., Zhu, Y., Deng, S. (2018). Probabilistic Risk Assessment of RCC Dam Considering Grey-Stochastic-Fuzzy Uncertainty, *KSCE Journal of Civil Engineering*, 22(11), 4399–4413. doi:10.1007/s12205-018-0765-4

Chin, C., Spowage, A., & Yap, E. (2012). Project management methodologies: a comparative analysis, *Journal for The Advancement of Performance Information and Value*, 4(1), 106-106.

Cho, J., Kim, Y., Junemo K., Woopyeng P.(2018), Energy-cost analysis of HVAC system for office buildings: Development of a multiple prediction methodology for HVAC system cost estimation, *Energy & Buildings*, Volume 173, 562-576

Compernolle, T., Welkenhuysen, K, Petitclerc, E, Maes, D., Piessens, K. (2019), The impact of policy measures on profitability and risk in geothermal energy investments, *Energy Economics*, 84, 104524, 1-17

Cottrell, B., Lim, I. (2019), Developing a Process for Deploying Systemic Countermeasures at Unsignalized Intersections: Case Study of Virginia, Transportation Research Record: *Journal of the Transportation Research Board*, 2673 (9), 538-54.

Forbes, D., Smith, S. & Horner, M. (2008). Tools for selecting appropriate risk management techniques in the built environment, *Construction Management and Economics*, 26, 1241-1250

Gernay, T., Khorasani, N.E., Garlock, M. (2016), Fire fragility curves for steel buildings in a community context: A methodology, *Engineering Structures*, 113, 259-276.
Gierczak, M. (2014). The quantitative risk assessment of MINI, MIDI, and MAXI Horizontal Directional Drilling Projects applying Fuzzy Fault Tree Analysis, *Tunnelling, and Underground Space Technology*, 43, 67–77.
Gondia, A., Siam, A., El-Dakhakhni, W., Nassar, A. (2020), Machine Learning Algorithms for Construction Projects Delay Risk Prediction, *Journal of Construction Engineering and Management*, 146(1), 04019085
Gong, H., Sun, Y., Dong, Y., Hu, W., Han, B., Polaczyk, P., Huang, B. (2021) An efficient and robust method for predicting asphalt concrete dynamic modulus, *International Journal of Pavement Engineering*.
Guan, L., Liu, Q., Abbasi, A., Ryan, M. (2020), Developing A Comprehensive Risk Assessment Model Based on Fuzzy Bayesian Belief Network (FBBN), *Journal of Civil Engineering And Management*, 26. 614-634. 10.3846/jcem.2020.12322.
Guerrero, I, Monedero, I., Biscarri, F., Biscarri, J., Millán, R., León, C (2018), Non-Technical Losses Reduction by Improving the Inspections Accuracy in a Power Utility, *IEEE Transactions on Power Systems*, vol. 33, no. 2, 1209-1218
Gunduz, M., Lutfi, H. (2021). Go/No-Go Decision Model for Owners Using Exhaustive CHAID and QUEST Decision Tree Algorithms, *Sustainability*, 13, 10.3390/su13020815
Gunduz, M; Al-Ajji, (2021), Employment of CHAID and CRT decision tree algorithms to develop bid/no-bid decision-making models for contractors, *Engineering Construction And Architectural Management*, 10.1108/ECAM-01-2021-0042.
Hassan, F., Le, T. (2021), Computer-assisted separation of design-build contract requirements to support subcontract drafting, *Automation in Construction*, Volume 122
Heravi, G., & Charkhakan, M.H. (2015). Predicting Change by Evaluating the Change Implementation Process in Construction Projects Using Event Tree Analysis, *Journal of Management in Engineering*, 31, 04014081.
Howick, S., Ackermann, F. Walls, L., Quigley, J., Houghton, T. (2017), Learning from mixed OR method practice: the NINES case study, *Omega*, 69, 70-81
Hsu, PY; Aurisicchio, M; Angeloudis, P; Whyte, J (2020), Understanding and visualizing schedule deviations in construction projects using fault tree analysis, *Engineering Construction And Architectural Management*, 27-9, 2501-2522.
Hu, Y., Castro-Lacouture, D. (2019). Clash Relevance Prediction Based on Machine Learning, *Journal of Computing in Civil Engineering*, 33, 10.
Ihm, S.H., Seo, S. B., Kim, Y. (2019), Valuation of Water Resources Infrastructure Planning from Climate Change Adaptation Perspective using Real Option Analysis, *KSCE Journal of Civil Engineering*, 23. 10.1007/s12205-019-1722-6.
ISO, ISO 31000:2009 (2009), *Risk management – Principles and Guidelines*, Geneva, Switzerland: International Organization for Standardization
Kameshwar, S; Misra, S; Padgett, J (2020), Decision tree-based bridge restoration models for extreme event performance assessment of regional road networks, *Structure And Infrastructure Engineering*, 16-3, 431-451
Karaman, E., & Kurt, M. (2015). Comparison of project management methodologies: prince 2 versus PMBOK for it projects, *International Journal of Applied Sciences and Engineering Research*, 4(4), 572-579.
Khazali, N., Sharifi, M., Ahmadi, M. (2019), Application of fuzzy decision tree in EOR screening assessment, Journal of Petroleum Science and Engineering, 177, 167-180
Krechowicz, M. (2020). Comprehensive Risk Management in Horizontal Directional Drilling Projects, *Journal of Construction Engineering and Management,* 146. 04020034. 10.1061/(ASCE)CO.1943-7862.0001809.
Leng, S., Lin, J., Hu, Z., Shen, X. (2020), A Hybrid Data Mining Method for Tunnel Engineering Based on Real-Time Monitoring Data From Tunnel Boring Machines, *IEEE Access*, vol. 8, 90430-90449
Leu, S., Chang, M. (2015). Bayesian-network-based fall risk evaluation of steel construction projects by fault tree transformation, *Journal of Civil Engineering and Management*, 21(3): 334–342
Liang, W., Sari, Y.A., Zhao, G. *et al.* (2021), Probability Estimates of Short-Term Rockburst Risk with Ensemble Classifiers, *Rock Mechanics Rock Engineering*, 54, 1799–1814.
Liang, W., Sari, A; Zhao, GY; McKinnon, SD; Wu, H (2020), Short-term rockburst risk prediction using ensemble learning methods, *Natural Hazards*, 104-2, 1923-1946.
Lin, C., Fan, C. (2019), Evaluation of CART, CHAID, and QUEST algorithms: a case study of construction defects in Taiwan, *Journal of Asian Architecture and Building Engineering*, 18:6, 539-553
Liu, G. and Yokoyama, S. (2015), Proposal for a Quantitative Skill Risk Evaluation Method Using Fault Tree Analysis, *IEEE Transactions on Engineering Management*, vol. 62, no. 2, pp. 266-279

Lu, Y; Bai, LY; Chen, JT; Tong, WX; Jiang, Z (2020), Development and application of a floor failure depth prediction system based on the WEKA platform, *Geomechanics and Engineering*, 23-1, 51-59

Maceika, A, Bugajev, A., Šostak, O.R. (2020), The Modelling of Roof Installation Projects Using Decision Trees and the AHP Method, *Sustainability*, 12, 1: 59.

Maceika, A; Bugajev, A; Šostak, O.R, Vilutiene, T (2021), Decision Tree and AHP Methods Application for Projects Assessment: A Case Study, *Sustainability*, 13-10

Mahmoodzadeh, A., Mohammadi, M., Ibrahim, H.H., Gharrib KM., Sazan, N., Abdulhamid, N., Ali, HFH. (2021) Forecasting sidewall displacement of underground caverns using machine learning techniques, *Automation in Construction*, 123, 103530.

Marhavilas, PK; Tegas, MG; Koulinas, GK; Koulouriotis, DE (2020), A Joint Stochastic/Deterministic Process with Multi-Objective Decision Making Risk-Assessment Framework for Sustainable Constructions Engineering Projects—A Case Study, *Sustainability*, 12-10

Marzouk, M., & El-Hesnawi, M. (2018). Framework for assessing serviceability and socio-economic risk associated with PPPs projects in Libya, *Journal of Civil Engineering and Management*, 24(7), 556-567.

Marzouk, M; Mohamed, E (2018), Modeling bid/no bid decisions using fuzzy fault tree, *Construction Innovation-England*, 18-1, 90-108

Nasirzadeh, F., Ghasem Kashi, M., Khanzadi, M., Carmichael, D., Akbarnezhad, A. (2019) A hybrid approach for quantitative assessment of construction projects risks: The case study of poor quality concrete, *Computers & Industrial Engineering*, 131, 306-319

Niederleithinger, E; Katzenbach, R; Klingmuller, O; Hillmann, S; Willmes, M. (2017), REFUND: Investigation of existing foundations and decision making before re-use, *Bautechnik*, 94 (10), 676- 681

Obrová V., Smolíková L. (2013) The Comparison of Selected Risk Management Methods for Project Management. In: Hřebíček J., Schimak G., Kubásek M., Rizzoli A.E. (eds) Environmental Software Systems. Fostering Information Sharing, *IFIP Advances in Information and Communication Technology*, vol 413. Springer, Berlin.

Otsuki, M; Akiyoshi, M; Samejima, M. (2017), Identification Method of Improvements in User Operations on Project Manager Skill-Up Simulator, *IEEE Access*, 5, 5811-5818.

Poh, C., Udhyami, C., Ubeynarayana, Goh, Y.M. (2018), Safety leading indicators for construction sites: A machine learning approach, *Automation in Construction*, 93, 375-386.

Project Management Institute, (2017), *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*, Pennsylvania.

Řeháček, P. (2017). Risk management standards for project management, *International Journal of Advanced and Applied Sciences*, 4(6) 2017, Pages: 1-13

Rezakhani, P. (2012). Current state of existing project risk modeling and analysis methods with focus on fuzzy risk assessment–Literature Review. *Frattura ed Integrità Strutturale*, 6(20), 17-21.

Rinaldi, S., Bellagente, P., Ciribini, A., Tagliabue, L., Tiziana, Mainini, A., Speroni, A. B., Cadena, J., Spagnolo, S. (2020). A Cognitive-Driven Building Renovation for Improving Energy Efficiency: The Experience of the ELISIR Project, *Electronics*, 9 (666) 10.3390/electronics9040666.

Shahhosseini, V., Afshar, MR., Amiri, O.(2018), The root of construction project failure, *Scientia Iranica*, 25-1, 93-108.

Sharafat, A., Latif, K., Seo, J.(2021), Risk analysis of TBM tunneling projects based on generic bow-tie risk analysis approach in difficult ground conditions, *Tunnelling, and Underground Space Technology*, 111, 103860

Shin, Y. (2019), Application of Stochastic Gradient Boosting Approach to Early Prediction of Safety Accidents at Construction Site, *Advances in Civil Engineering*, 2019, 1-9.

Shoar, S., Banaitis, A. (2019). Application of fuzzy fault tree analysis to identify factors influencing construction labor productivity: A high-rise building case study, *Journal of Civil Engineering and Management.* 25. 41-52. 10.3846/jcem.2019.7785.

Shoar, S; Nasirzadeh, F; Zarandi, HR (2019), Quantitative assessment of risks on construction projects using fault tree analysis with hybrid uncertainties, *Construction Innovation*, 19-1, 48-70

Siu, M.-F. F., Leung, W.-Y. J., Chan, W.-M. D. (2018). A data-driven approach to identify-quantify-analyse construction risk for Hong Kong NEC projects, *Journal of Civil Engineering and Management*, 24(8), 592-606

Song, X., Peña-Mora, F., Menassa, C., & Arboleda, C. (2012). Insurance as a Risk Management Tool for ADR Implementation in Construction Disputes, *Journal of Construction Engineering and Management*, 138, 14-21.

Steineder, D., Clemens, T., Osivandi, K., Marco. Thiele (2019), Maximizing the Value of Information of a Horizontal Polymer Pilot Under Uncertainty Incorporating the Risk Attitude of the Decision Maker, *SPE Reservoir Evaluation & Engineering*, 22 (2019): 756–774

Tang, BJ; Zhou, HL; Chen, H; Wang, K; Cao, H. (2017). Investment opportunity in China's overseas oil project: An empirical analysis based on real option approach, *Energy Policy*, 105, 17-26.

Tesfaye, E., Berhan, E., & Kitaw, D. (2016). A Comprehensive Literature Review on Construction Project Risk Analysis, *International Journal of Risk and Contingency Management*, 5(4), 1-15.

Tsai, T.C., Li, H.W. (2018), A decision support system (DSS) for construction risk efficiency in Taiwan, *Smart Structures and Systems*, 21. 249-255. 10.12989/sss.2018.21.2.249.

Turner C, Hamilton WI, Ramsden M. (2017), Bowtie diagrams: A user-friendly risk communication tool, Proceedings of the Institution of Mechanical Engineers, Part F: *Journal of Rail and Rapid Transit*. 231(10):1088-1097.

Vileiniskis, M., Remenyte-Prescott, R. (2017), Quantitative risk prognostics framework based on Petri Net and Bow-Tie models, *Reliability Engineering & System Safety*, 165, 62-73

Wang, Z., Fimbres Weihs, G.A. Neal, P.R., Wiley, D.E.(2016), Effects of pipeline distance, injectivity and capacity on CO2 pipeline and storage site selection, *International Journal of Greenhouse Gas Control*, 51, 95-105.

Welkenhuysen, K., Rupert, J., Compernolle, T., Ramirez, A., Swennen, R., Piessens, K. (2017), Considering economic and geological uncertainty in the simulation of realistic investment decisions for CO2-EOR projects in the North Sea, *Applied Energy*, 185, Part 1, 745-761.

Xia, Z., Zou, P. X.W., Griffin, M. A., Wang, X., Zhong, R (2018), Towards integrating construction risk management and stakeholder management: A systematic literature review and future research agendas, *International Journal of Project Management*, Volume 36, Issue 5, Pages 701-715

Zhang, L., Wu, X., Skibniewski, M. J., Zhong, J., Lu, Y. (2014), Bayesian-network-based safety risk analysis in construction projects, *Reliability Engineering & System Safety*, 131, 29-39

Zhang, Y., Zhang, L., Wu, X. (2019), Hybrid BN Approach to Analyzing Risk in Tunnel-Induced Bridge Damage, *Journal of Performance of Constructed Facilities*, 33, 5.

Zhang, Y; Guan, X (2021), Budget allocation decisions for project risk response, *Kybernetes*, DOI10.1108/K-03-2020-0188

Zhang, YX, Javanmardi, A., Liu, YC., Yang, SJ., Yu, XX., Hsiang, S., Jiang, ZH., Liu, M. (2020). How Does Experience with Delay Shape Managers' Making-Do Decision: Random Forest Approach, *Journal of Management in Engineering*, 36(4): 04020030

Zheng, X., Liu, Y., Jun, J., Linda, T., Su, N. (2021). Predicting the litigation outcome of PPP project disputes between public authority and private partner using an ensemble model, *Journal of Business Economics and Management*, 22. 320-345.

Zhou, Y., Li, C., Zhou, C., Luo, H. (2018), Using Bayesian network for safety risk analysis of diaphragm wall deflection based on field data, *Reliability Engineering & System Safety*, 180, 152-167.