THE REPUBLIC OF TURKEY
İSTANBUL KÜLTÜR UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

Risk Management Practice in Construction Projects Using Fuzzy Group TOPSIS Approach – a Case Study

MASTER OF SCIENCE THESIS

By Anass EL HILALI

Department: Industrial Engineering

Program: Engineering Management

Supervisor: Assist. Prof. Zeynep GERGİN

JUNE 2021

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1800000824

Date of submission: **28 May 2021**

Date of defence examination: **17 June 2021**

Supervisor and Chairperson: **Dr. Öğr. Üyesi Zeynep Gergin**

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JUNE 2021

ACKNOWLEDGEMENT

My thanks go first to my thesis supervisor, Assistant Professor Zeynep Gergin for offering me the opportunity to work on this thesis, for the trust she has placed in me, and for time which I have learned a lot of things thanks to her wise advice.

I'm gratefully thanking all the Master students, researchers, teachers and staff that I have had the opportunity to work with during last 2 years in Kultur University.

Finally, all my work goes to my family members and my loved ones, who have never stopped encouraging me at all times.

27/05/2021 ANASS EL HILALI

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LIST OF SYMBOLS

A^+ The positive ideal solution (PIS)

A^- The Negative ideal solution (NIS)

C^+_i Relative closeness to the ideal solution of the i^{th} alternative

D^+_i Separation measure from the positive solution

C^+_- Separation measure from the negative solution

d_j Degree of divergence of the j^{th} attribute

E_j Entropy of the j^{th} attributes

i Number of alternative

j Number of attribute

J Total number of alternatives

n Total number of alternatives

p_{ij} Discrete probability distribution of the i^{th} alternative with respect to the j^{th} attribute

r_{ij} Normalized value of the i^{th} alternative with respect to the j^{th} attribute

v_{ij} Weighted normalized value of the i^{th} alternative with respect to the j^{th} attribute

w_j Weighted value the j^{th} attribute

xij Attributes value of the i^{th} alternative with respect to the ^{jth} attribute

CC^* Closeness coefficient of individual alternative.

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Programı : **Mühendislik Yönetimi**

Tez Danışmanı : **Dr. Öğretim Üyesi Zeynep GERGİN**

Tez Türü ve Tarihi : **Yüksek Lisans – Haziran 2021**

ÖZET

Risk Management Practice in Construction Projects Using Fuzzy Group TOPSIS Approach – a Case Study

ANASS EL HILALI

Günümüzde inşaat projelerinin zamanlama ve kalite hedefleriyle birlikte finansman masraflarını karşılayamayacağı ve risk yönetimi sürecini uygulayamazsak daha kötü senaryolara yol açabileceği açıkça görülmüştür. Bu çalışma, inşaat projeleri için bir risk yönetimi uygulaması sağlamak üzere tasarlanmıştır. Proje yaşam döngüsünü etkileyen birçok risk faktörünü vurgulamak ve etkileyen risk faktörlerini sıralamasını için düzenlenmiştir. İnşaat projelerinde kritik riskleri yönetmek ve önlemek için bir risk yanıt stratejisi oluşturulmas hedeflemektedir. Bu tez, nicel bir risk yaklaşımı ile bir ulaştırma inşaatı projesi için risk yönetimi uygulaması örneği göstermektedir. Uygulanan vaka çalışması, proje yöneticilerinin proje risklerini projeleri olumsuz etkileyen üç kritere bağlamında değerlendirmesi ve en iyi risk yanıt stratejisini akıllıca seçmeleri için yardımcı olmak amacıyla uygulanmıştır.

Bu çalışmada, Grup TOPSIS ve Bulanık TOPSIS metodlarının birleşik bir uygulaması olarak riskleri sıralamak ve önceliklendirmek için Bulanık Grup TOPSIS (FG-TOPSIS) adında hibrit bir metodoloji tasarlanmıştır. Uygulanan metodoloji, belirli risk faktörlerinin proje zaman ve maliyet planları üzerindeki etkilerinin algılanmasını geliştirmekte ve riskler genel proje gecikmeleri açısından ölçülmektedir. Sonuç olarak, proje yöneticileri, en önemli risk eylem planı için uygun bir strateji geliştirmek üzere karar desteğine sahip olacaktır.

Keywords: Fuzzy Group TOPSIS (FG-TOPSIS), risk management, project management, construction projects, multi-attribute group decision making technique (MAGDM).

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Program : **Engineering Management**

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Degree Awarded and Date : **MS – June 2021**

ABSTRACT

Risk Management Practice in Construction Projects Using Fuzzy Group TOPSIS Approach – a Case Study

ANASS EL HILALI

Nowadays, it has been clear that construction projects could fail to meet their financing charges together with scheduling and quality objectives, which may lead to worse scenarios if we could not apply the risk management process. This study is designed to provide a risk management practice for construction projects. It is highlighting many risk factors that are affecting the Project life cycle and ranking them in order to make a risk response strategy to manage and avoid critical risks in construction projects. This thesis suggests a quantitative risk approach and illustrates its tools in terms of risk management for a transportation project. A case study is presented for the application of the used risk management approach for project managers to pick up wisely the best risk response strategy based on three risk evaluation criteria that has adverse effects impact on project.

The study is adopting a hybrid methodology to prioritize and rank risks using Fuzzy Group Technique for Order Preference by Similarity to Ideal Solution (FGTOPSIS) as combined methods of Group TOPSIS and Fuzzy TOPSIS. The applied methodology is enhancing the perception of risk factors' impacts on project schedule plan and cost, and the risks are quantified in terms of overall project delays. As a result, the project managers would have a decision support to develop a proper risk response strategy for the most important risks.

Keywords: Fuzzy Group TOPSIS (FG-TOPSIS), risk management, project management, construction projects, multi-attribute group decision making technique (MAGDM).

1. INTRODUCTION

Any construction project can have a high-risk degree from the beginning until the closure. Risk has many definitions and can occur at any time during the phases of the project and may affect its aims. Especially large investment, long-term construction periods, involving a wide range, complex technology, encounter many risks in the processes of initiating, monitoring (planning and executing), and development.

Risk Management can be defined in many terms as it is a notion used in all manufacturers' companies especially the construction sector has taken approximately the whole of it. It should be conducted on all projects in all phases. Thus the risk management should be studied and analyzed before the first steps of the implementing part of any project. Hence, studies and analysis of risk management must be conducted as the first part of any project and should be made on some criteria to avoid critical cases, especially before the kick-off of the first phases. That would lead to identifying the possible tangible and intangible costs risks and the ways how they can be solved or prevented.

Although many contracting companies have begun to understand what risk management is, they remain trapped by not using models and technologies that lead to effective risk management and control. Despite the awareness existing in the companies about risk effect on the project cycle, some companies still cannot deal with it with serious reactions, and managers still do not realize risk management's importance. The construction projects are constructed in an unstable domain since many conditions can change related to the project's complexity and its challenges. From this standpoint, risk management becomes an important achievement for the fulfillment of project goals.

The aim of this study is to analyze risk practices that are faced in daily operations of construction companies via detailed examination of a specific case, a transportation project in Casablanca / Morocco, and prioritizing the project's risks using Fuzzy Group Technique for Order Preference by Similarity to Ideal Solution (FG-TOPSIS) in order to help the construction company for efficient risk management. The fulfillment of this aim requires achieving research objectives that would be the answers to the following questions:

Q1: What are the risk factors in construction projects?

Q2: What are the most critical risk factors for the case study?

Q3: What can be the best risk response strategy that could be implemented for this case study?

The contribution of this thesis to the literature is in line with some previous works which are used in construction project risk assessment, and it will help the construction managers working in transportation projects to take into consideration the most critical risks, so they can make their decisions on risk response strategy by being able to avoid, mitigate, accept or transfer the risk to another party based on the provided method of analysis. Although fuzzy models and TOPSIS method is widely used in decision making, with this study Fuzzy Group TOPSIS (FG-TOPSIS) method which is a hybrid approach combining Group TOPSIS and Fuzzy TOPSIS methods is used for the first time to prioritize the construction risks.

The rest of the thesis is developed as follows: The second chapter gives brief information about Risk Management Process. The literature review showing the previous studies on risk management for transportation projects is provided under Chapter 3. Chapter 4 explains the questionnaire developed, and FGTOPSIS method that is implemented in the thesis. Chapter 5 gives the collected data together with FGTOPSIS's implementation for Casablanca Tramway Project. The final chapter discusses the general findings and gives recommendations for future studies.

2. PROJECT RISK MANAGEMENT

2.1 Project Life Cycle

It is a scheme considered as a time interval or the duration between the birth of an idea or the expression of a need and the receipt of the work by the client. During this limited period, the efforts vary from one stage to another of the life cycle. The effort begins slowly, gradually reaches a maximum then its level decreases until the time of closing. According to the project life cycle given in Figure 2.1, there are 4 different phases of a project which are the following four major phases; initiation, planning, Execution / implementation, and closure, and risk management should be considered.

Figure 2.1: Project life cycle, (PMI, 20013)

In *initiation* phase the specifications of the project should be defined as well as its objectives, the teams trained and the responsibilities assigned. Then *planning* is implemented and plans must be developed to determine everything that the project involves. Project schedule should be developed; possible risks, resources, budget, and the strategies for the communications with project stakeholders are identified. *Execution / implementation* is the operational phase of the project. Plans are implemented and performance data for controls are collected. The realized durations, costs and specifications are evaluated for controls. A phase of *controlling and monitoring* should follow the previous stages for evaluating the project performance.

It also assists the company to figure out other risks as unknown or non-identified before, as well, as keeping the identified risks under control. The implementation of a project must be the subject of reporting and the dissemination of results to management. We assess and draw lessons from the project in the *control* phase: ‘Has the project lived up to the expectations of all stakeholders? What parts of the project were imperfectly accomplished and what made the project successful?’ are some questions answered.

2.1.Process of Risk Management

Courbage (2013) defined the risk management as an ensemble of financial and operational activities that maximizes the value of a company by reducing the costs related to cash flows. It’s mainly done by diversifying and risk hedging using self-insurance, market insurance and self-protection. The costs to be minimized are both the expected payments and the financing of the investment as well as the impacts on the stakeholders. There are also speculative risks, which consist of undertaking activities that are opportunistic in relation to future risks (Wang and Yuan, 2011).

Its aim is to create a framework for companies to effectively deal with uncertainty for project’s benefit.

Risk management process implements methods to continue the project life in a smooth manner without problems or difficulties. The risk management process includes five successive phases as given in Figure 2.2 and explained in the succeeding sections.

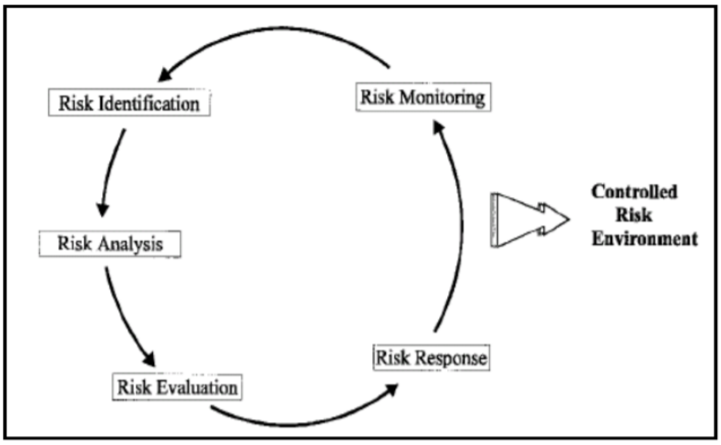

Figure 2.2: Risk management lifecycle (Baker et al., 1999)

2.1.1. Risk Identification

Identification of risks is the primary phase and the base of all subsequent stages. If the risk could not be settled precisely, unknown risks will be present and consequently not be managed (Zou, et al 2006).

Usually, the risk identification process starts with a comprehensive and accurate analysis of the company's operations and the development of possibilities for the various risks. This process should be continuous and include the development of risk identification lists and updating them continuously to ensure the required efficiency of the project (Rezakhani, 2012).

Risk identification is to identify maximum of factors and events which may possibly unbalance the progress of the project or affect its objectives and covers the following steps (Choudhry, 2013):

- Identify the sources of risk,
- identify the impact areas of the identified risks,
- Identify the events with their causes and potential consequences which could affect the project's success in both ways positive and negative,
- Examine the chain reactions of particular consequences,
- Study all sources and / or significant consequences of the risk.

In order to reduce the potential risks, risks should be distinguished (PMI, 2013) carefully. (Smith et al. 2006) lists various methods for this phase illustrated in Table 2.1.

Table 2.1: Techniques of identifying risks (Smith et al. 2006)

Information gathering methods	**Workshops**
	Brainstorming
	Interviews
	Questionnaires
	Benchmarking
	Consulting experts
	Past experience
	Delphi technique
	Risk breakdown structure
	Visit locations
Documentation	**Databases, historical data from similar projects**
	Templates
	Checklists
	Study project documentation (plan, files etc.)
	Study specialist literature
Research	**Stakeholder analysis**
	Research assumptions
	Research interfaces

2.1.2. Risk Analysis

It is a fundamental step on the ground that it comprises a necessary measure for every identified risk. As a matter of fact, every incident would have more or less disastrous impacts (consequences) and a higher or lower possibility of happening.

The impacts can be of several kinds based on the consequence, such as, environmental, human and social, financial, legal, and on the image of the company.

There are two used methods to analyze the identified risks. First is the qualitative method, which is used when risks are measured in a descriptive scale. The other one is the quantitative methods which are based on numeric estimations (Winch, 2002). (Flanagan & Norman, 1993) provide a sequence for these approaches given in Figure 2.3.

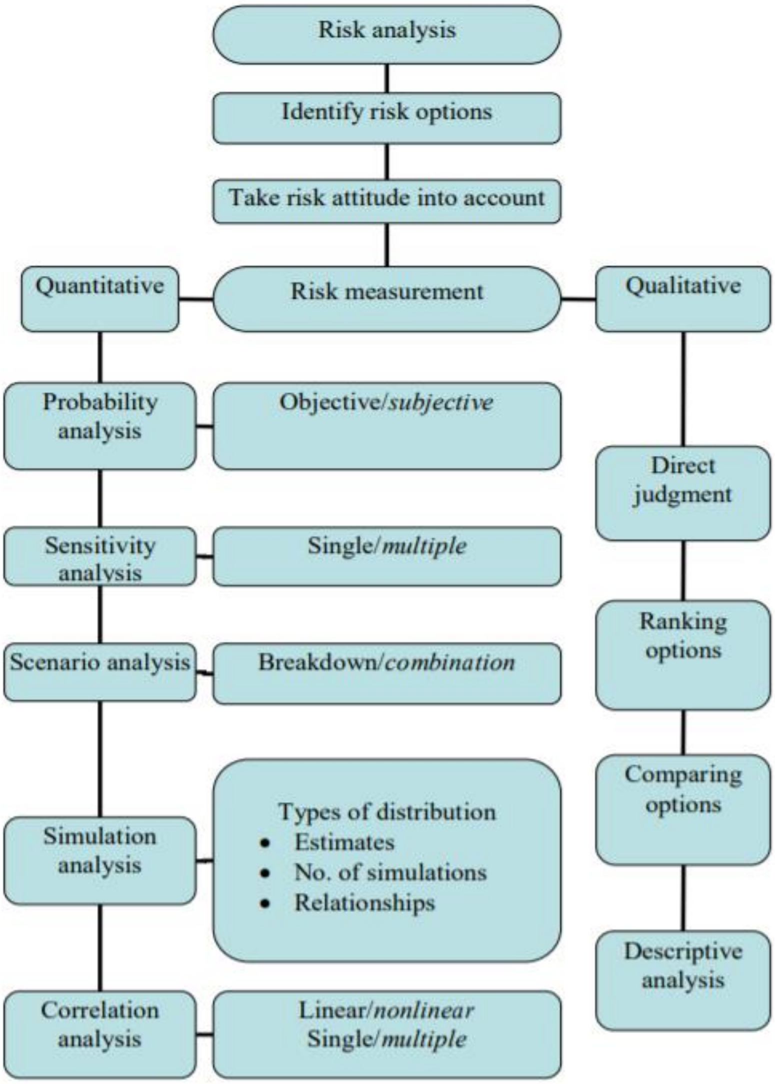

Figure 2.3: Sequence of risk analysis (Flanagan & Norman, 1993)

2.1.2.1.Quantitative risk analysis

It is the numerical procedure that analyzes identified risks' consequences. To carry out the quantitative risk study, the following steps must be applied (HSE Book 2014):

 Associate probability assessments with risks (statistics),

 Associate impact assessments with risks (costs, deadlines, specifications),

 Evaluate the probabilities of costs and maximum deadlines,

 Refine hierarchy of risks for treatment of the most critical,

 Analysis by phases, locations, etc. of critical risk.

Even the usefulness of quantitative methods is indisputable, still presents a certain investment in time, effort and also in resources (software, hardware, financial, etc.). It may turn out that this investment is disproportionate to the usefulness of the expected results (Kelly, 2003). There are various quantitative methods used for risk analysis as given below:

Probability Analysis The theory of probability rigorously studies the evolution of the processes observed as well as investigates the issues that have no single value solution.

Monte Carlo Simulation is portrayed as a major tool as it is the most applied method (Lukas, 2004) used to estimate the whole cost and related realization probability depending on each cost of the activity of the project. (Sato, 2013).

Sensitivity Analysis: Most of the analysts prefer to use this kind of tool since it has a huge extent and scope of analyzing the risks (Merna & Stroch, 2000). It is a method to anticipate the result of a decision with a range of some variables.

Breakeven Analysis: It is used to measure the size of the variables which describe the project as attractive or unattractive. It is also a sensitivity analysis application.

Scenario Analysis This method, which consists of questioning practitioners on concrete professional situations, makes it possible to assess their perception of these situations and thus provides rich information on the problems encountered (Rippel, 2010).

2.1.2.2.Qualitative risk analysis

This method is prioritizing the project risks by analyzing and combining their likelihood of happening and their effect. To carry out the qualitative risk study, the following steps must be applied:

- Develop a classification benchmark for the probability of the risk, for example: Unlikely / likely / very likely,
- Develop a classification benchmark for the impact of the risk, for example: Not very serious / serious / catastrophic,
- Establish the criticality matrix (probability and impact scale),

• Prioritize risks.

There are various qualitative methods used for risk analysis as given below:

Hazard and Operability (HAZOP): It is used to assess the potential dangers resulting from malfunctions of human or material origin and also the effects generated. The methods objectives are to identify the hazards that lead to hazardous events when deviating from the normal operating conditions of a system (Tyler et al., 2015).

Human Reliability Analysis (HRA): It deals with the human factors impact on the operating quality. It can be used to assess the influence of human error on safety (Autrey, 2015).

Event Tree Analysis (EVA): It is a technique for identifying and analyzing the frequency of hazards through inductive reasoning to convert different initiating events into possible consequences relating to the operation or failure of technical / human / organizational safety devices (Hong et al., 2009).

Failure Mode and Effect Analysis (FMEA): It is above all of analyzing systems (systems in the broad sense made up of functional or physical elements, hardware, software, humans, etc.), static, based on inductive reasoning. This analysis aims first to identify the impact of each failure mode of the components of a system on its various functions and then to prioritize these failure modes according to their ease of detection and treatment (Potts et al., 2014).

Fault Tree of Causes Analysis (FTA): Starting from a single event, it is a question of looking for the combinations of events leading to the realization of the latter. The fault tree analysis can also be continued as part of a reconstruction of the causes of an accident (Ruijters et al., 2015)

2.1.3. Risk Response Planning

This is the process for enhancing choices and alternatives represented in front of the project team to raise possibilities for success and diminish the risks facing the project. The risk response should cover all aspects in terms of cost, quality, time, and management strategy. Risk response planning requires the collection and presentation of risk management approaches and techniques that are not only intended to remove risks but to reduce their consequences through prevention, corrective action, and transportation. The project manager ensures that the planned risk responses are appropriate (in terms of time, cost and content) and realistic and that the person in charge of the risk is well designated. It takes responsibility for implementing and monitoring the provisions relating to risks (PMI, 2013).

Risks can have different degrees of familiarity:

• Risks already known: they are identified, analyzed, with responses to the risks are planned in the project (Potts, 2008).

• Risks known to be unknown: they are identified, but cannot be taken into consideration until they actually occur. For these risks no response is planned but a contingency provision is put in place.

• Unknown and unforeseeable risks: these are those which have not been identified and may arise suddenly in the project. For these risks an additional sum must be added to the contingency reserve.

Among several risk response strategies, some are listed briefly below:

2.1.3.1.Avoidance and prevention

All the companies constantly create and set up a protective system to avoid negative actions towards the project or its tasks. The project can be canceled at all if it has a risk that has very high impact with the negative outcome. The response can be a scope modification in order to avoid/prevent the negative effects. (Darnall & Preston, 2010) propose to use well-developed techniques in order to avoid unexpected risks. Some activities are listed below:

- Detailed strategy.
- Approaches and methods of analysis.
- Prevention, safety and security systems
- Reviews and comments about operations.
- Orderly inspections and control
- Giving Training and skills enhancement
- Permissions to do duties

- Procedures to follows and instructions
- Maintenance Up-to-date

2.1.3.2.Mitigation and Reduction

Some companies determine for risk reduction by monitoring and researching the size of danger that may affect the company. This strategy focuses on reducing the possibility of the uncertainty or decreasing the impact of the negative incidence on the project. Some mitigation strategies are presented in the following (Cooper et al., 2005):

- planning for emergency
- Quality assurance to prevent mistakes and defects
- Separation the activities and relocation resources
- Agreement terms / clauses
- Plans for managing crisis and strategies for recovering disasters.

2.1.3.3.Transfer

Many companies prefer to move the management of risks and their assumption to an expert company which has a sufficient ability or capacity to face it (Potts, 2008), through the establishment of insurance contracts to avoid total assumption of the damage. There are some conditions that require risk transfer when risks are outside the control. The risks must be transferred through insurance policies especially those that are outside the control (Darnall, 2010). And by sharing the risks of other parties and stakeholders, sharing enables the use of other resources and expertise of others (Piney, 2002).

2.1.3.4.Retention / Acceptation

It is the strategy of the internal management's control risks (Zhi, 1995); managing risks through the organization that undertakes the project where risk reduction is unlikely, the future financial loss is low, the chance of incidence is marginal and the transition is uneconomic (Akintoyne & MacLeod, 1997).Some companies adopt the acceptance of risk as a position because the nature of their work is dangerous in order to ensure the company's operations while accepting and taking responsibility for facing the consequences of risks resulting from the business environment.

2.1.4. Risk Monitoring and Controlling

This step for risk management starts from the identification of emerging risks, planning as well as analyzing them. The identified risks are then monitored, and the existing ones are re-analyzed. After that, it is the keeping track of conditions as well as residual risks, and finally the inspection of risk responses' effectiveness (PMI 2013).

In summary, risk monitoring and control is a steady process throughout project's life. It starts from monitoring the identified risks, figuring out if the predicted risk has changed and if up-to-minute ones came up. Fixing up the risk management plan in the case of validation of the projects' assumptions.

Some tools as well as support are indispensable for this process considering the collected experiences and information, in addition to the major practices which support learning along with capitalization of what the project management team seized.

In the list below there are some techniques and manners for risk monitoring and controlling (PMI, 2013):

- Risk reassessing and identifying the new potential ones. It is an operation that lasts and repeated in the lifecycle.
- Monitoring project’s status– is there any circumstance that can impact and remain with new probable risks?
- Status meetings – discussions and meeting with the owner, of the risk and share the experience and assisting to manage it.
- Risk register updates.

2.2.Risk Management in Construction Projects

Construction filed is facing various risks which may occur in any part in the project. There are many types of construction projects as grouped in Figure 2.4, and similar or custom risks are involved in each of them.

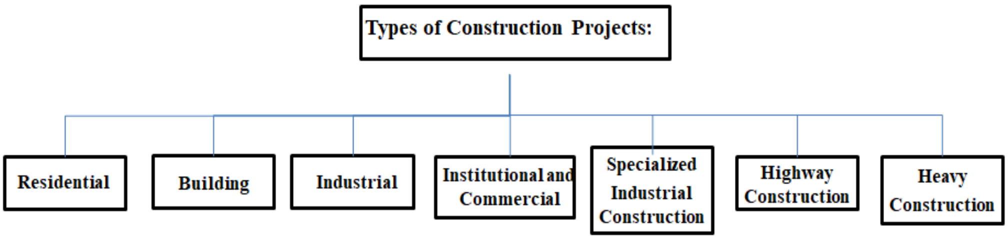

Figure 2.4: Type of construction projects (Rayment, 2017)

The risks faced in construction projects vary and are grouped by different researchers. Some risks can be identified as follows:

• **Natural risks:** Natural disasters constitute these risk types, such as tsunami, flood, etc.

• **Industrial / Human activities risks:** Fires, detonations or releasing of poison gas are example of Industrial risks .They may cause illness / death. (Goh et al., 2013).

• **Financial risks:** These are related to financial problems that may affect the value of the company's shares because of a crisis or due to poor of estimate of initial (Xanbo et al, 2012).

• **Political risks:** The change of the political regime in the instructions and regulations may affect the project cycle.

• **Social risks:** It is related to the conception of the society to the project itself and its stakeholders (Xanbo et al, 2012).

• **Legal risks:** Bankruptcy of a supplier.

• **Risks on deadlines:** The mistakes made in estimating the schedule of the project and its phases.

• **Intrinsic risks:** They are related to the administrative and the managerial decisions and responsibilities, like assigning roles to the same personals while there is no follow up (Aven, 2011).

Construction project risks have been grouped by (Enshassi et al., 2001) as given in Figure 2.5.

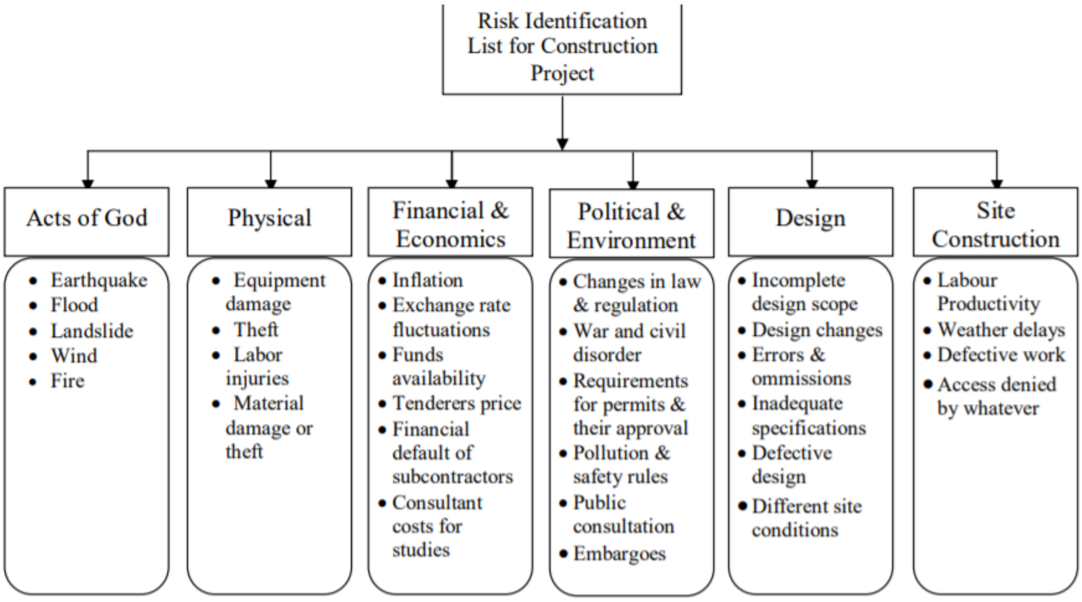

Figure 2.5: Risk categorization for construction projects (Enshassi et al., 2001)

Most of the types of construction have mutual risk factors, and they are grouped as categories of risks. A comprehensive table developed for this thesis, mainly based on the study of Gupta (2018) and Enshassi (2001) risk factors, is listed in Table 2.2.

Table 2.2 shows the risk factors and grouped in terms of categories, they may impact the project during its phases, and they will be used in our methodology as the alternatives of the method.

Table 2.2: Key risk factors in construction project (Gupta, 2018; Enshassi, 2001)

Risk category	Risk Factors	References
Construction/sub-contractor risks	Low productivity of man or machine	Shen, 1997
	Defective construction	Frimpong et al, 2003
	Unavailability of man, machine or material	Sambasivan, 2007
	Poor coordination among subcontractor	Shen, 1997
	Conflict with subcontractors	Wang et al, 2000
Financial /political/economic risk	Bureaucracy and sluggish governmental process	Zou et al, 2006
	Financial instability of sub-contractor	Frimpong et al, 2003
	Inadequate cost estimations	Frimpong et al, 2003
	Inflation of construction material/labor cost	Frimpong et al, 2003
	Prosecution by third party	Zou et al, 2006
Design related risks	Design change request by client	Ling et al, 2006
	Defective design by designer	Zou et al, 2006
	Inadequate site information	Zou et al, 2006
	Poor communication of design	Zou et al, 2006
	Poor understanding of instructions	Ling et al, 2006
Management risks	Late delivery of machine/material at construction site	Frimpong et al, 2003
	Unsuitable weather conditions	Sambasivan, 2007
	Labor disputes and strikes	Wang et al, 2000
	Accidents at site	Ling et al, 2006
Acts of God	Earthquake	Enshassi, 2001
	Landslide	Enshassi, 2001
	Wind	Enshassi, 2001
	Flood	Enshassi, 2001

3. LITERATURE REVIEW

Project risk management literature of last ten years is reviewed to analyze the methods used in the previous studies. A comprehensive analysis is also performed for methods used specifically for construction project risk management and given with Table 3.1.

Pribadin and Pangeran (2006) studied multiple types of risks in a water supply project. The objective is to identify and prioritize the most significant risk in water supply projects using quantitative and qualitative risks assessment methods such as Monte Carlo simulation.

Mojtahedi, Mousavi and Makui (2010) studied ‘Management, Construction, Engineering, Procurement, Engineering Commissioning’ risks in a gas refinery plant construction. They developed a procedure for classifying potential risks using multi-attribute group decision making technique (MAGDM).

Zhang, Cai, and Mu (2011) created an Analytic Hierarchy Process (AHP) procedure to rank and prioritize the risk factors in highway tunnels which is related to transportation projects.

Dey (2011), suggested a hybrid system of project risk management using combined Multi Criteria Decision Making (MCDM) techniques and decision tree analysis (DTA) to present the elements affecting the decision tree.

Hatefi and Seyedhoseini, (2012) Provided a methodology that correlates risks from Work Breakdown Structure (WBS) by using SCERT approach that contribute in each activity and tend to Identify risks that are related to that activity as Management risks.

Fang, Marle, and Zio (2013), suggested a structure of analysis to support DM in project risk response planning process to lead to risk response planning process, and to indicate and execute preventive and corrective actions as a risk response strategy.

Karimi et al. (2013), proposed a MCDM method. They suggested FTOPSIS, to provide a process for coming up with best model, multi risk factors has been presented in this study.

Saiful Islam (2013) used relative significance out came via a questionnaire of experts, to prove that the improper planning and budgeting is the most critical risk factors.

Nguyen et al. (2013) suggested a new resolution approach decision-making technique to help managers pick the best strategic risk response and to indicate the consequences of expected risks.

Suchith Reddy (2015), suggested a case study to identify, characterize, and evaluate risks involved in the project by the stakeholders, to evaluate the vulnerability of critical risks, and to determine the risk in order to reduce its effects.

Pfeifer, Barker, Marquez, and Morshedlou (2015) suggested a genetic algorithm for an identification of many activities which are mostly responsible for project risk which leads to postponements in the project's achievement.

Sabaghi, Mascle, and Baptiste (2015) proposed 2 methods which are TOPSIS and DOE Methods to select the best alternative taking into account the criteria of the project.

Dziadosz, and Rejment (2015) presented 3 different methods used for the risk assessment by implementing synchronous signaling of characteristics' features and particularizing of the usefulness degree.

Gładysz et al. (2015) proposed a computational approach which supports project risk management, using PERT method, helps to determine which risks should be eliminated in order to satisfy the schedule and the cost of the project according to the customer requirements.

Pangsri (2015) combined 3 methods in his study to support decision makers who are facing numerous and conflicting assessments. Factors were presented as machine and equipment, experience of worker, responsibility, capital, and man power to select the best choice.

Zhang (2016) offers a method for measuring risk interdependence; depending on risk interdependence analysis, and made a model to select the best risk response strategies according to the estimated risk loss & risk interdependence to investigate risk interdependence effects.

Zhao, Hwang and Gao (2016) suggested a method based on a fuzzy environment that calculates the probability of occurrence, size of impact, the criticality of some risk factors, to indicate the most critical factors in a project.

Basahel and Taylan (2016) studied different type of risk categories such as, management commitment, safety rules and procedures, safety policies, safety training, and safe behavior a method to identify and evaluate the factors that affect workplace safety conditions at construction sites as a fuzzy environment.

Wanjari and Dobariya (2016) evaluated many risk factors and they used them in the study to lead to significant cost overruns and to classify factors into three parts of the overall questionnaire.

Muriana and Vizzini (2017) proposed a method of risk prevention in risk assessment. The proposed technique indicates the risk impacts using a set of input factors. Weighted Sum Method (WSM) applications were for the quantification of the risk degree.

Abd El Khalek et al. (2017) identified risk factors that are affecting the infrastructure cross-country pipelines projects to evaluate risk factors weights and their impact

Gitinavard et al. (2017) discuss how much the application of safety management has increased in construction projects in a fuzzy environment, while decision makers has to come with the right decision based on method proposed by the authors.

Islam et al. (2017) implemented fuzzy, combined, and hybrid methods in construction risk management. The authors concluded that these methods are limited by their lengthy calculations.

Xianghui and Wang (2018) presented a Fuzzy Analytic Hierarchy Process (FAHP) risk method which evaluates risks of tunnel portals. Risk factors used in this article are related to tunnel construction project as they were: Design changes and cross section sizes.

Gupta et al. (2018) used both kind of risk methods, qualitative and quantitative as they presented many type of risk categories and risk factors. The objective of this study is to identify and prioritize the most significant risk in construction projects.

Shoar (2018) presented a model combining 2 methods as a hybrid framework: Ant Colony Optimization (ACO) and FTOPSIS) for solving risk response action selection problem by considering: (1) the impact of risk events on the project objectives, (2) the interactions between risk events, and (3) management criteria and preferences.

Koulinas (2019) assess safety risks and tried to make the best decisions that a constraint cost would be spent to maximize health and safety in workplace. Based on many risk factors related to construction projects, the results were compared with real and non-real fatal accident.

Barghi (2020) used 2 methods of risk assessment Authors were able to rank the risk factors and come out with a result from fuzzy decision-making trial and evaluation laboratory (DEMATEL) and Fuzzy analytical network process (FANP) techniques. Many risk factors has been considered to come out with the objective which is to decrease the severity of risks such as time and cost, human resource, quality, contract, area, and communication.

Table 3.1 below shows the detailed information on the type of construction, the methods applied for risk management implementation as well as the considered risk factors of the reviewed literature:

Table 3.1: A review of previous risk assessment literature

Study	Category or Risk Factors Used	Type of Construction Project	Method Applied
Pribadin & Pangeran, 2006	cost, construction schedule, initial and future tolls, traffic volume, macro-economic conditions	Specialized industrial projects	Monte Carlo simulation
Mojtahedi, Mousavi & Makui, 2010	management, engineering, procurement, construction, commissioning	Specialized industrial projects	Multi-attribute group decision making
Zhang, Cai, Li, and Mu, 2011	Topography, structural design, geology, unfavorable condition, special stratigraphy, tunnel section and depth of embedment, shafts and pilot tunnels	Highway construction	Analytic hierarchy process (AHP)
Hatefi & Seyedhoseini, 2012	Management risks	Industrial projects	Synergistic Contingency Evaluation and Review Technique(SCERT approach)
Dey, 2011	Technical, financial, political and economic, organizational, natural hazards, statutory construction clearance	Building projects	AHP and decision tree analysis (DTA)

Fang, Marle, & Zio, 2013	Technical, contractual, financial, management	Transportation construction	Design Structure Matrix (DCM)
Karimi et al. 2013	economic and political, management, resources, weather, project's member	Commercial projects	Multi-criteria decision making (TOPSIS-F)
Nguyen et al., 2013	Time and cost	Building projects	ProRisk a decision-making technique
Saiful Islam, 2013	Financial, management, technical, environmental	Building projects	Relative significance technique (RST)
Suchith Reddy, 2015	Risks in worksite, managerial, Design and Construction	Building projects	Brainstorming technique
Pfeifer, Barker, Marquez & Morshedlou, 2015	Time, Cost, and Operational Performance	Building projects	Genetic algorithm
Sabaghi, Mascle & Baptiste, 2015	Design, cost, capacity, volume	Building projects	TOPSIS and Design of experiments (DOE)
Gładysz, 2015	Technological changes, equipment failures, delays in deliveries of equipment,	Building projects	Program Evaluation and Review

	construction accident, poor quality of works performed, poor quality of materials, adverse weather conditions		Technique (PERT)
Pangsri, 2015	Machine and equipment, experience of worker, responsibility, capital, and man power	Building projects	TOPSIS, Delphi and AHP
Zhang, 2016	Non-qualified installation or construction craft, goods and materials' inferior quality, potential risk on traffic safety	Building projects	Sensitivity analysis
Zhao, Hwang & Gao, 2016	Macro-economic risks, contractual problems, safety, procedure complexity, design or technical issues, human resources, equipment and materials, cost overrun	Building projects	Fuzzy synthetic evaluation approach (FSE)
Basahel & Taylan, 2016	Managerial risks, safe behaviors	Building projects	Fuzzy AHP, Fuzzy TOPSIS
Wanjari & Dobariya, 2016	Increasing of costs, delay schedule, and lack of co-ordination	Building projects	Analysis of variance (ANOVA)
Muriana & Vizzini 2017	Design, cost , capacity, volume, progress, duration	Industrial projects	Weighted Sum Method (WSM)
Abd El Khalek et al, 2017	Financial, political and economic, cultural, market and geographical distance, previous	Specialized Industrial Project	Fuzzy AHP

	experience, design, legal issues, resources procurement, quality, construction, team work, force major, technology, environmental		
Gitinavard et al., 2017	Construction personnel, technical performance measure, risk monitoring, and safety construction investment	Building projects	TOPSIS and AHP
Islam et al., 2017	Cost, Schedule and Management	Specialized industrial projects	Fuzzy analytical network process (FANP)
Gupta et al., 2018	Construction/ subcontractor, financial / political/ economic, design related, management	Institution and commercial projects	GTOPSIS and Judgmental risk analysis process (JRAP)
Xianghui & Wang, 2018	Design changes and cross section sizes	Heavy construction projects	Fuzzy AHP
Shoar, 2018	Estimation of duration, opponents problems, delaying in utility services, design changes, technical complexity, problem in supplying equipment from aboard and shortage of material	Commercial, building projects	Hybrid ACO and FTOPSIS
Koulinas, 2019	Safety risk factors	Specialized industrial projects	Fuzzy TOPSIS and Plysteer

			Residual Aligning Torque (PRAT)
Barghi, 2020	Time and cost, Management, quality.	Building projects	Fuzzy DEMATEL and fuzzy ANP

The contribution of this thesis to the literature is in line with some previous works which are used in construction project risk assessment, and it will help the construction managers working in transportation projects to take into consideration the most critical risks, so they can make their decisions on risk response strategy by being able to avoid, mitigate, accept or transfer the risk to another party based on the provided method of analysis. Although fuzzy models and TOPSIS method is widely used in decision making, with this study Fuzzy Group TOPSIS (FG-TOPSIS) method which is a hybrid approach combining Group TOPSIS and Fuzzy TOPSIS methods is used for the first time to prioritize the construction risks. It could help to make a risk response strategy among many risk factors that affect the project based on experts who work in the same projects in different phases with different years of experience background.

4. METHODOLOGY

The methodology starts with the identifying key risk factors through a detailed literature review. Selected risk factors are weighted and evaluated by the experts via a custom-developed questionnaire. The data collected with the questionnaire is input to the Fuzzy Group Technique for Order Preference by Similarity to Ideal Solution (FGTOPSIS) to rank the risk factors. The results are compiled and proposed to the managers as a source for identifying the suitable risk response strategy. These steps of the methodology are;

Step 1. Survey design

- Identification of key risks for the survey
- Designing the questions

Step 2. Risk prioritization with FG-TOPSIS

4.1. Survey Design

4.1.1. Identifying Key Risk Factors

The 23 risk factors given in the previous sections with Table 2.2 are identified via a thorough literature review and used for this thesis study are as follows:

1. Low productivity of man or machine,
2. Defective construction,
3. Unavailability of man, machine, or material,
4. Poor coordination among subcontractor,
5. Conflict with subcontractors,
6. Bureaucracy and sluggish governmental process,
7. The financial instability of sub-contractor,
8. Inadequate cost estimations,
9. Inflation of construction material/labor cost,
10. Prosecution by the third party,
11. Design change request by client,
12. Defective design by designer,
13. Inadequate site information,
14. Poor communication of design,

15. Poor understanding of instructions,
16. Late delivery of machine/material at a construction site,
17. Unsuitable weather conditions,
18. Labor disputes and strikes,
19. Accidents at the site,
20. Earthquake,
21. Landslide,
22. Wind,
23. Flood.

To come out with results for the proposed method and to quarry out qualitative risk analysis, 3 criteria are assigned. These are: "Probability of occurrence", "Impact on Cost", and "Impact on Time". Their weights will be the average taken from the experts as they see the impact of each criterion on the project.

4.1.2. Questions of the Survey

A survey composed of 8 questions is developed in this thesis. The survey is composed of 3 sections.

The first section is to collect a general data about the roles of the responders and their phases where they are contributing in the project, as well as the years of experience and the familiarity with the concept of RMP. The questions are as follows:

Name:

Surname:

Which role do you have in the project (Project Manager / Engineer)?

Which phase of the project do you take part in (Initiation, Planning, Execution / Implementation, or Closure please specify if there are many parts)?

How many years of experience do you have in transportation projects? (Please specify in years by number)

The responders which are the decision makers are grouped based on their years of experience, and their experience converted to a fuzzy numbers from a decimal number to match the weights scale of the alternatives fuzzy numbers as given in Table 4.1 below:

Table 4.1: Fuzzy ratings for different group's weight.

Responder Experience	**Given Weights**
Less than 3 Years	(0.1,0.3,0.5)
3-6 Years	(0.3,0.5,0.7)
More than 6 Years	(0.5,0.7,0.9)

The Second section is for collecting data which is used in the FG-TOPSIS Method. The responders will be choosing between a seven scale linguistic variable to define the impact criterion's weight and the score given for each risk factor. The criteria used to measure the risks factors are "Probability of occurrence", "Impact on Cost", and "Impact on Time". In this step, 3 scores are given by the respondents for each of the 23 risk factors listed under section 4.1.1. Below are the questions of this section:

1. *Regarding the role, you have in the project, please define please define the weight of each criterion affecting the project in the table below. The answer should be answering how much the criterion is affecting the project and it should be in a scale in the range of (Very low, Low, Medium low, Medium, Medium high, High, Very high) respectively from the less to the most important one.*

Probability of Occurrence	**Impact on Cost**	**Impact on Time**
VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH

2. *How much each risk factor affecting the project based on the probability of occurrence, Impact on time, and Impact on Cost? The scale of each risk factor should be in the range of (Very low, Low, Medium low, Medium, Medium high, High, Very high) respectively from the less occurring risk to the most one.*

Risk Factors	Probability of occurrence	Impact on Cost	Impact Time
Low productivity of man/machine	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Defective construction	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Unavailability of man/machine/ material	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Poor coordination among subcontractor	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Conflict with subcontractor	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Bureaucracy and sluggish governmental process	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Financial instability of sub-contractor	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Inadequate cost estimations	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Inflation of construction material/labor cost	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Prosecution by third party	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Design change request by client	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Defective design by designer	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Inadequate site information	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Poor communication of design	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Poor understanding of rules and regulations	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Late delivery of machine/material at construction site	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Unsuitable weather conditions	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Labor disputes and strikes	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Accidents at site	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Earthquake	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Landslide	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Wind	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH
Flood	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH	VL/L/ML/M/ MH/H/VH

All data will be converted to Triangle Fuzzy Numbers (TFNs). Table 4.2. shows the fuzzy conversion scale.

Table 4.2: Fuzzy ratings for different alternative's weight

Linguistic Variables	TFNs
Very low(VL)	(0.1,0.1,0.1)
Low(L)	(0,1,0.1,0.3)
Medium low(ML)	(0.1,0.3,0.5)
Medium(M)	(0.3,0.5,0.7)
Medium high(MH)	(0.5,0.7,0.9)
High(H)	(0.7,0.9,1)
Very high(VH)	(0.9,1,1)

3. *Is there any other risk factor that you see is important that should be taken into consideration and is not mentioned above? (YES / NO) if yes, please specify*

The last section is to see if the survey covered all the identified risk factors in transportation projects or other risk factors could be identified by the experts that should be taken into consideration and analyzed with the risk factors of the literature.

4.2. FGTOPSIS Method

The method used for risk prioritization is Fuzzy Group Technique for Order Preference by Similarity to Ideal Solution (FGTOPSIS). FGTOPSIS method is a hybrid method that incorporates Group TOPSIS and Fuzzy TOPSIS methods.

Fuzzy TOPSIS is a method where the aim is to rank many multi-attributes in fuzzy environment according to their weightage combined with many criteria in order to prioritize the most impacted risk factors. The objective of method is to pick the best alternative, among various alternatives, which has on the one hand, the shortest distance to the ideal alternative (the best alternative on all the criteria), and, on the other hand part, which has the greatest distance to the ideal negative alternative (the one which degrades all the criteria) based on a group of decision makers. To resolve the problem, the basic concepts of fuzzy set theory need to be known. It was presented by Zadeh (2015) to hold real-life problems' uncertainties. In the Fuzzy Group TOPSIS approach, fuzzy importance weights of criteria ($\tilde{w}_j$; j =

1,2,...number of criteria (n)) and fuzzy rating of alternatives ($x^{\sim}_{ij}$; i = 1,2,...$numberofalternative(m)$, j = 1,2,...$numberofcriteria(n)$) are the inputs of the method and placed into a matrix. These weights are defined by decision makers grouped under different categories based on a defined criteria, ie. experience. Below are the implementation steps of the methodology (FG-TOPSIS). The FTOPSIS part of the formula is adopted from (Sarkis, 2020);

Step 1: Decision makers assign linguistic evaluations to the criteria.

Step 2: Linguistic variables are converted to fuzzy numbers to compute criteria weights.

Step 3: Group weights of the decision makers are identified (according to their experience).

Step 4: Aggregated fuzzy group weights are calculated for criteria;

$$w_j^k = (w_{j1}^k, w_{j2}^k, w_{j3}^k);$$

$$w_{j1} = \min_k\{w_{j1}^k\};\ w_{j2} = \frac{1}{k\sum_{k=1}^{k} w_{j2}^k};$$

$$w_{j3} = \max_k\{w_{j3}^k\};$$

$$\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$$

$$\tilde{W} = \begin{pmatrix} y_{11} & \cdots & y_{1n} \\ \vdots & \ddots & \vdots \\ y_{m1} & \cdots & y_{mn} \end{pmatrix}$$

Step 5: Decision makers rate the alternative risk factors with linguistic variables.

Step 6: Linguistic variables are converted to fuzzy numbers to compute criteria weights.

Step 7: Constructing the decision matrix.

$$\tilde{x}_{ij}^k = (a_{ij}^k, b_{ij2}^k, c_{ij}^k);$$

$$a_{ij} = \min_k\{a_{ij}^k\};\ b_{ij} = 1/k\sum_{k=1} b_{ij}^k;\ c_{ij} = \max_k\{c_{ij}^k\};$$

$$\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$$

$$\tilde{D} = \begin{pmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \cdots & \tilde{x}_{mn} \end{pmatrix}$$

Step 8: Assessment of the normalized fuzzy decision matrix.

$$\tilde{R} = [\tilde{r}_{ij}]_{m \times n} ; i = 1,2, \ldots, m; j = 1,2, \ldots, n;$$
$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right);$$
$$where\ c_j^* = \max_i\{c_{ij}\}\ for\ benefit\ criteria$$
$$\tilde{r}_{ij} = \left(\frac{\tilde{a}_j}{c_{ij}}, \frac{\tilde{a}_j}{b_{ij}}, \frac{\tilde{a}_j}{a_{ij}}\right);$$
$$where\ \tilde{a}_j = \min_i\{a_{ij}\}\ for\ non\text{-}benefit\ criteria$$

Step 9: Calculation of the weighted fuzzy normalized matrix: Sub-factors fuzzy weights * the normalized fuzzy value.

$$\tilde{V} = [\tilde{v}_{ij}]_{m \times n} ; i = 1,2, \ldots, m; j = 1,2, \ldots, n;$$
$$where\ \tilde{v}_{ij} = \tilde{r}_{ij} \otimes \tilde{w}_j ; i = 1,2, \ldots, m; j = 1,2, \ldots, n;$$

Step 10: Calculating of FPIS and FNIS.

$$A^+ = \{\tilde{v}_1^+, \tilde{v}_2^+, \ldots, \tilde{v}_n^+\};$$
$$where\ \tilde{v}_j^+ = \max_i\{\tilde{v}_{ij}\};\ i = 1,2, \ldots, m; j = 1,2, \ldots, n;$$
$$A^- = \{\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-\};$$
$$where\ \tilde{v}_j^- = \min_i\{\tilde{v}_{ij}\}; i = 1,2, \ldots, m; j = 1,2, \ldots, n;$$

Step 11: Determining the distance measure of all alternatives from the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS).

$$d_i^+ = \sum_{j=1}^{n} d(\tilde{v}_{ij} - \tilde{v}_j^+);\ i = 1,2, \ldots, m; j = 1,2, \ldots, n;$$
$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij} - \tilde{v}_j^-);\ i = 1,2, \ldots, m; j = 1,2, \ldots, n;$$

Step 12: Computing the Closeness coefficient of individual alternative

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-}; i = 1,2, \ldots, m$$

Step 13: Alternatives ' ranking regarding the closeness index.

5. IMPLEMENTATION AND RESULTS

The implementation of the study is done with a company in Casablanca, Morocco (Yapi Merkezi A.S). The company is constructing and designing the Tramway's project in Casablanca. The total duration of the project is 2 years and 5 months for realizing of the following main work items in the scope:

- Platform length: 14.633 meters
- Number of Stations: 20 stations
- Intersections: 25 intersections
- Storage and Maintenance Workshops: 1Storage and 1 Maintenance Workshop
- Engineering Structures: Intersection with the First Tramline, 1 bridge, slab on pile.

5.1.Data Collection (Questionnaire Outputs)

Six responsible from the company were the responders of the survey given to the company, 3 of them were 'Managers' and 3 of them were 'Site engineers'. The risk factors which are the Sub-attributes and risk categories which are the Attributes used as the alternatives of the method to determine the most critical risks in the project.

Data is collected in a week, by sending the questionnaire via e-mails. The responses are aggregated and processed with the designed Excel spreadsheet, and explained in the following sections. Table 5.1 shows the responders.

Table 5.1: Responders' information

Decision maker	Responder Experience	Role in the project	Contributed in
EXPERT1	3-6 Years	Manager	Planning, Executing, Monitoring and Control, Closure
EXPERT2	3-6 Years	Manager	Planning, Executing, Monitoring and Control, Closure
EXPERT3	3-6 Years	Engineer	Executing, Monitoring and Control
EXPERT4	More than 6 years	Manager	Planning, Executing, Monitoring and Control, Closure
EXPERT5	3-6 Years	Engineer	Executing, Monitoring and Control
EXPERT6	Less than 3 Years	Engineer	Executing

Table 5.2: Linguistic weights given by experts on each criterion

Decision maker	Probability of occurrence	Impact on Cost	Impact on Time
EXPERT1	Medium low(ML)	Medium high(MH)	Medium high(MH)
EXPERT2	Medium high(MH)	High(H)	Medium low(ML)
EXPERT3	Medium low(ML)	High(H)	High(H)
EXPERT4	Medium low(ML)	Medium high(MH)	High(H)
EXPERT5	Medium high(MH)	High(H)	Medium high(MH)
EXPERT6	Medium(M)	Medium high(MH)	Medium(M)

Tables 5.3 to 5.8 are the decision makers' views on the alternatives based on the criteria as linguistic variables.

Table 5.3: Responses of Expert 1

Expert-1 Alternatives	Probability of Occurrence	Impact on Cost	Impact on Time
Low productivity of man/machine	High(H)	Very high(VH)	Very high(VH)
Defective construction	High(H)	High(H)	High(H)
Unavailability of man/machine/ material	High(H)	High(H)	Medium high(MH)
Poor coordination among subcontractor	Medium high(MH)	Medium high(MH)	High(H)
Conflict with subcontractor	Medium high(MH)	High(H)	Medium high
Bureaucracy and sluggish governmental	High(H)	High(H)	High(H)
Financial instability of sub-contractor	Very high(VH)	High(H)	High(H)
Inadequate cost estimations	High(H)	High(H)	Very high(VH)
Inflation of construction material/labor cost	Very high(VH)	Medium high(MH)	High(H)
Prosecution by third party	Medium high(MH)	Very high(VH)	High(H)
Design change request by client	High(H)	Very low(VL)	Very high(VH)
Defective design by designer	High(H)	High(H)	Very low(VL)
Inadequate site information	High(H)	High(H)	High(H)
Poor communication of design	Medium high	High(H)	High(H)
Poor understanding of instructions	Medium high(MH)	Medium high(MH)	High(H)
Late delivery of machine/material at construction site	High(H)	Very low(VL)	High(H)
Unsuitable weather conditions	High(H)	Very low(VL)	High(H)
Labor disputes and strikes	Very low(VL)	Very low(VL)	Very high(VH)
Accidents at site	Very low(VL)	Very low(VL)	Very low(VL)
Earthquake	Very low(VL)	Very low(VL)	Very low(VL)
Landslide	Very low(VL)	Very low(VL)	Very low(VL)
Wind	Very low(VL)	Very low(VL)	Very low(VL)
Flood	Very low(VL)	Very low(VL)	Very low(VL)

Table 5.4: Responses of Expert 2

Expert-2 Alternatives	Probability of Occurrence	Impact on Cost	Impact on Time
Low productivity of man/machine	High(H)	Very high(VH)	Very high(VH)
Defective construction	Medium low(ML)	Very high(VH)	High(H)
Unavailability of man/machine/ material	Medium low(ML)	Low(L)	Medium high(MH)
Poor coordination among subcontractor	Low(L)	Very low(VL)	Low(L)
Conflict with subcontractor	High(H)	Very low(VL)	High(H)
Bureaucracy and sluggish governmental process	High(H)	Medium high	High(H)
Financial instability of sub-contractor	Medium(M)	Medium low(ML)	Medium(M)
Inadequate cost estimations	Medium(M)	Very high(VH)	Low(L)
Inflation of construction material/labor cost	Medium high(MH)	Medium high(MH)	Low(L)
Prosecution by third party	Medium low(ML)	Medium(M)	Low(L)
Design change request by client	Very high(VH)	Medium low(ML)	Medium high(MH)
Defective design by designer	High(H)	Medium low(ML)	Medium high(MH)
Inadequate site information	Medium(M)	High(H)	High(H)
Poor communication of design	Medium low(ML)	Medium(M)	Medium low(ML)
Poor understanding of instructions	Low(L)	Medium high(MH)	High(H)
Late delivery of machine/material at construction site	High(H)	High(H)	High(H)
Unsuitable weather conditions	High(H)	Medium high(MH)	Medium high(MH)
Labor disputes and strikes	Medium(M)	Medium low(ML)	Low(L)
Accidents at site	Medium high(MH)	High(H)	Medium(M)
Earthquake	Very low(VL)	Very low(VL)	Very high(VH)
Landslide	Very low(VL)	Very low(VL)	Medium high
Wind	Very low(VL)	Very low(VL)	Medium low(ML)
Flood	Very low(VL)	Very low(VL)	Medium low(ML)

Table 5.5: Responses of Expert 3

Expert-3 Alternatives	Probability of Occurrence	Impact on Cost	Impact on Time
Low productivity of man/machine	Very high(VH)	Very high(VH)	High(H)
Defective construction	Medium high(MH)	Very high(VH)	High(H)
Unavailability of man/machine/ material	High(H)	Low(L)	Medium(M)
Poor coordination among subcontractor	Medium high(MH)	Low(L)	Low(L)
Conflict with subcontractor	Medium high(MH)	Very low(VL)	Medium(M)
Bureaucracy and sluggish governmental process	Medium(M)	Low(L)	High(H)
Financial instability of sub-contractor	Medium(M)	Medium low(ML)	Medium(M)
Inadequate cost estimations	Medium(M)	Very high(VH)	Very low(VL)
Inflation of construction material/labor cost	Very high(VH)	Very high(VH)	Low(L)
Prosecution by third party	Medium(M)	Medium low(ML)	High(H)
Design change request by client	Very high(VH)	Very high(VH)	High(H)
Defective design by designer	Medium high(MH)	High(H)	Medium
Inadequate site information	High(H)	High(H)	High(H)
Poor communication of design	Medium(M)	Medium(M)	Medium low(ML)
Poor understanding of instructions	Low(L)	Medium low(ML)	Medium low(ML)
Late delivery of machine/material at construction site	Medium low(ML)	Low(L)	Medium(M)
Unsuitable weather conditions	High(H)	Medium	Medium
Labor disputes and strikes	Medium high(MH)	Medium low(ML)	Medium
Accidents at site	High(H)	High(H)	Medium
Earthquake	Low(L)	Very high(VH)	Very high(VH)
Landslide	Very low(VL)	Very high(VH)	Medium
Wind	Very low(VL)	Medium	Medium(M)
Flood	Very low(VL)	Medium(M)	Medium(M)

Table 5.6: Responses of Expert 4

Expert-4 Alternatives	Probability of Occurrence	Impact on Cost	Impact on Time
Low productivity of man/machine	High (H)	High (H)	Medium
Defective construction	High (H)	High (H)	High (H)
Unavailability of man/machine/ material	Very high(VH)	Medium	Medium
Poor coordination among subcontractor	Medium high(MH)	Medium	Medium
Conflict with subcontractor	Very high(VH)	High (H)	High (H)
Bureaucracy and sluggish governmental process	Medium high(MH)	High (H)	Medium
Financial instability of sub-contractor	Very high(VH)	High (H)	High (H)
Inadequate cost estimations	Medium high(MH)	Very high(VH)	Medium
Inflation of construction material/labor cost	Medium(M)	Medium(M)	Medium(M)
Prosecution by third party	Medium low(ML)	Medium(M)	Medium(M)
Design change request by client	Medium high(MH)	Medium	Medium
Defective design by designer	High (H)	High (H)	Medium
Inadequate site information	High (H)	High (H)	Medium
Poor communication of design	Medium high(MH)	Medium	Medium(M)
Poor understanding of instructions	High (H)	High (H)	Medium(M)
Late delivery of machine/material at construction site	Medium high(MH)	Medium(M)	Medium(M)
Unsuitable weather conditions	Medium high(MH)	Medium	Medium(M)
Labor disputes and strikes	High (H)	High (H)	High (H)
Accidents at site	Medium(M)	Medium	Medium(M)
Earthquake	High (H)	Medium	High (H)
Landslide	High (H)	Medium(M)	Medium
Wind	Medium(M)	Medium(M)	Medium(M)
Flood	Medium high(MH)	Medium(M)	Medium(M)

Table 5.7: Responses of Expert 5

Expert-5 / Alternatives	Probability of Occurrence	Impact on Cost	Impact on Time
Low productivity of man/machine	Medium low(ML)	Medium(M)	High(H)
Defective construction	Medium high(MH)	Very high(VH)	Very high(VH)
Unavailability of man/machine/ material	High(H)	Medium low(ML)	Medium(M)
Poor coordination among subcontractor	Medium high(MH)	Low(L)	Low(L)
Conflict with subcontractor	Medium high(MH)	Very low(VL)	Medium(M)
Bureaucracy and sluggish governmental process	Medium(M)	Low(L)	High(H)
Financial instability of sub-contractor	Low(L)	Medium low(ML)	Medium(M)
Inadequate cost estimations	Medium(M)	Very high(VH)	Very low(VL)
Inflation of construction material/labor cost	Very high(VH)	Very high(VH)	Low(L)
Prosecution by third party	Medium(M)	Medium low(ML)	High(H)
Design change request by client	Very high(VH)	Very high(VH)	Very high(VH)
Defective design by designer	Medium high(MH)	High(H)	High(H)
Inadequate site information	Medium(M)	Medium(M)	Medium(M)
Poor communication of design	Medium(M)	Medium(M)	Medium low(ML)
Poor understanding of instructions	Very low(VL)	Medium low(ML)	Medium low(ML)
Late delivery of machine/material at construction site	Medium low(ML)	Medium low(ML)	Medium high(MH)
Unsuitable weather conditions	Medium low(ML)	Medium(M)	Medium(M)
Labor disputes and strikes	Medium high(MH)	Medium low(ML)	Medium
Accidents at site	Medium(M)	High(H)	Medium
Earthquake	Very low(VL)	Very low(VL)	Very low(VL)
Landslide	Very low(VL)	Very low(VL)	Very low(VL)
Wind	Very low(VL)	Very low(VL)	Very low(VL)
Flood	Very low(VL)	Very low(VL)	Very low(VL)

Table 5.8: Responses of Expert 6

Expert-6 Alternatives	Probability of Occurrence	Impact on Cost	Impact on Time
Low productivity of man/machine	Medium high(MH)	High(H)	Very high(VH)
Defective construction	Medium high(MH)	Medium	Very high(VH)
Unavailability of man/machine/ material	Medium low(ML)	Medium low(ML)	Medium
Poor coordination among subcontractor	Medium low(ML)	Medium low(ML)	Medium
Conflict with subcontractor	High(H)	Very low(VL)	High(H)
Bureaucracy and sluggish governmental process	High(H)	Medium	High(H)
Financial instability of sub-contractor	Medium low(ML)	Medium low(ML)	Low(L)
Inadequate cost estimations	Medium low(ML)	Very high(VH)	Low(L)
Inflation of construction material/labor cost	Medium low(ML)	High(H)	Low(L)
Prosecution by third party	Medium low(ML)	Low(L)	Low(L)
Design change request by client	Very high(VH)	Medium low(ML)	Medium
Defective design by designer	Medium(M)	High(H)	High(H)
Inadequate site information	Medium(M)	Low(L)	Low(L)
Poor communication of design	Medium low(ML)	Medium(M)	Medium low(ML)
Poor understanding of instructions	Low(L)	Medium	High(H)
Late delivery of machine/material at construction site	Very high(VH)	Medium low(ML)	Very high(VH)
Unsuitable weather conditions	Medium low(ML)	Medium(M)	Medium(M)
Labor disputes and strikes	High(H)	Medium low(ML)	Medium low(ML)
Accidents at site	Medium high(MH)	High(H)	Medium(M)
Earthquake	Very low(VL)	Very low(VL)	Very high(VH)
Landslide	Very low(VL)	Very low(VL)	Medium
Wind	Very low(VL)	Very low(VL)	Medium low(ML)
Flood	Very low(VL)	Very low(VL)	Medium low(ML)

5.2. FGTOPSIS Results and Discussion

Six responsible from the company were the responders of the survey given to the company, 3 of them were ‘Managers’ and 3 of them were ‘Site engineers’. Questionnaire outputs are aggregated and processed with the designed Excel spreadsheet. The steps and the result of the FGTOPSIS method applied for decision is as below:

Step 1: Decision makers assign linguistic evaluations to the criteria (Questionnaire outputs)

Table 5.9 shows the decision of each expert on each criterion as Linguistic Variables.

Table 5.9: Linguistic variables of each expert on each criterion

Decision maker	Probability of occurrence	Impact on Cost	Impact on Time
EXPERT1	Medium low(ML)	Medium high(MH)	Medium high(MH)
EXPERT2	Medium high(MH)	High(H)	Medium low(ML)
EXPERT3	Medium low(ML)	High(H)	High(H)
EXPERT4	Medium low(ML)	Medium high(MH)	High(H)
EXPERT5	Medium high(MH)	High(H)	Medium high(MH)
EXPERT6	Medium(M)	Medium high(MH)	Medium(M)

Step 2: Linguistic variables are converted to fuzzy numbers to compute criteria weights.

Table 5.10: Fuzzy weights of each expert on each criterion

Decision maker	Probability of occurrence			Impact on Cost			Impact on Time		
EXPERT1	0.1	0.3	0.5	0.5	0.7	0.9	0.5	0.7	0.9
EXPERT2	0.5	0.7	0.9	0.7	0.9	1.0	0.1	0.3	0.5
EXPERT3	0.1	0.3	0.5	0.7	0.9	1.0	0.7	0.9	1.0
EXPERT4	0.1	0.3	0.5	0.5	0.7	0.9	0.7	0.9	1.0
EXPERT5	0.5	0.7	0.9	0.7	0.9	1.0	0.5	0.7	0.9
EXPERT6	0.3	0.5	0.7	0.5	0.7	0.9	0.3	0.5	0.7

Step 3: Group weights of the decision makers are identified (according to their experience).

Among the respondents of the questionnaire, 3 of them were 'Managers' and 3 of them were 'Site engineers'. The fuzzy weights are assigned to the respondents considering the experiences given in Table 5.1. The experts worked in different sections on the project of the Tramway of Casablanca with Yapi Merkezi as the project has many lines to be delivered.

Table 5.11: Fuzzy weights for experts

Responder	Fuzzy Weights		
Expert 1	0.3	0.5	0.7
Expert 2	0.3	0.5	0.7
Expert 3	0.3	0.5	0.7
Expert 4	0.5	0.7	0.9
Expert 5	0.3	0.5	0.7
Expert 6	0.1	0.3	0.5

Step 4: Aggregated fuzzy group weights are calculated for criteria

The results are aggregated by using the equation in the step 4 of the FGTOPSIS method. This step is explained in details below:

Initially, a combined matrix is constructed by multiplying each decision-maker criterion's fuzzy number with the fuzzy number of the year of experience. As the minimum number of the criterion's fuzzy number with the minimum Years of experience's fuzzy number, the middle number with the middle, and the maximum with the maximum.

Then, the weight of each criterion is computed. Each criterion will be in fuzzy number by taking the minimum value of all the decision-makers for the first value of the fuzzy number, the average of all the decision-makers of the second value of the fuzzy number, and the maximum value of all decision-makers for the third value of the fuzzy number.

Table 5.12 Aggregated weights of experts for criteria

	Probability of occurrence			Impact on Cost			Impact on Time		
Weighs of each criteria	0.03	0.227	0.630	0.050	0.400	0.810	0.030	0.347	0.900

Step 5: Decision makers rate the alternative risk factors with linguistic variables. (Questionnaire outputs)

Step 6: Linguistic variables are converted to fuzzy numbers to compute criteria weights.

Step 7: Constructing the decision matrix.

Table 5.13: Combined decision matrix

Risk Factors (Alternatives)	Probability of Occurrence			Impact on Cost			Impact on Time		
Low productivity of man/machine	0.10	0.78	1.00	0.30	0.88	1	0.50	0.92	1
Defective construction	0.10	0.70	1	0.50	0.92	1	0.70	0.93	1
Unavailability of man/machine/ material	0.10	0.72	1	0.10	0.40	1	0.30	0.63	0.9
Poor coordination among subcontractor	0.10	0.55	0.90	0.10	0.33	0.90	0.10	0.43	1
Conflict with subcontractor	0.50	0.82	1	0.10	0.37	1	0.30	0.73	1
Bureaucracy and sluggish governmental process	0.30	0.73	1	0.10	0.57	1	0.50	0.87	1
Financial instability of sub-contractor	0.10	0.60	1	0.10	0.50	1	0.10	0.57	1
Inadequate cost estimations	0.10	0.57	1	0.70	0.98	1	0.10	0.35	1
Inflation of construction material/labor cost	0.10	0.75	1	0.30	0.80	1	0.10	0.30	1
Prosecution by third party	0.10	0.43	0.90	0.10	0.45	1	0.10	0.57	1
Design change request by client	0.50	0.93	1	0.10	0.57	1	0.10	0.73	1
Defective design by designer	0.30	0.77	1	0.10	0.80	1	0.10	0.67	1
Inadequate site information	0.30	0.70	1	0.10	0.70	1	0.10	0.67	1
Poor communication of design	0.10	0.50	0.90	0.30	0.60	1	0.10	0.47	1
Poor understanding of instructions	0.10	0.35	1	0.10	0.60	1	0.10	0.63	1
Late delivery of machine/ material at construction site	0.10	0.68	1	0.10	0.37	1	0.30	0.75	1
Unsuitable weather conditions	0.10	0.67	1	0.10	0.53	0.90	0.30	0.63	1
Labor disputes and strikes	0.10	0.63	1	0.10	0.37	1	0.10	0.63	1
Accidents at site	0.10	0.57	1	0.10	0.73	1	0.10	0.50	0.9
Earthquake	0.10	0.23	1	0.10	0.35	1	0.10	0.68	1
Landslide	0.10	0.23	1	0.10	0.32	1	0.10	0.50	0.90
Wind	0.10	0.17	0.7	0.10	0.27	0.90	0.10	0.30	0.70
Flood	0.10	0.20	7	0.10	0.23	0.70	0.10	0.30	0.70

To construct the combined fuzzy decision matrix, the minimum fuzzy number from all the fuzzy numbers of the decision-makers are taken as the first number of each alternative, the average value of all the fuzzy numbers of the decision-makers as the second number of each alternative, and the maximum value of all the fuzzy numbers of the decision-makers as the third number of each alternative.

Step 8: Assessment of the normalized fuzzy decision matrix.

Table 5.14: Normalized fuzzy decision matrix

Risk Factors (Alternatives)	Probability of Occurrence			Impact on Cost			Impact on Time		
Low productivity of man/machine	0.10	0.13	1	0.10	0.11	0.33	0.10	0.11	0.20
Defective construction	0.10	0.14	1	0.10	0.11	0.20	0.10	0.11	0.14
Unavailability of man/machine/ material	0.10	0.14	1	0.10	0.25	1	0.11	0.16	0.33
Poor coordination among subcontractor	0.11	0.18	1	0.11	0.30	1	0.10	0.23	1
Conflict with subcontractor	0.10	0.12	0.20	0.10	0.27	1	0.10	0.14	0.33
Bureaucracy and sluggish governmental process	0.10	0.14	0.33	0.10	0.18	1	0.10	0.12	0.20
Financial instability of sub-contractor	0.10	0.17	1	0.10	0.20	1	0.10	0.18	1
Inadequate cost estimations	0.10	0.18	1	0.10	0.10	0.14	0.10	0.29	1
Inflation of construction material/labor cost	0.10	0.13	1	0.10	0.13	0.33	0.10	0.33	1
Prosecution by third party	0.11	0.23	1	0.10	0.22	1	0.10	0.18	1
Design change request by client	0.10	0.11	0.20	0.10	0.18	1	0.10	0.14	1
Defective design by designer	0.10	0.13	0.33	0.10	0.13	1	0.10	0.15	1
Inadequate site information	0.10	0.14	0.33	0.10	0.14	1	0.10	0.15	1
Poor communication of design	0.11	0.20	1	0.10	0.17	0.33	0.10	0.21	1
Poor understanding of instructions	0.10	0.29	1	0.10	0.17	1	0.10	0.16	1
Late delivery of machine/ material at construction site	0.10	0.15	1	0.10	0.27	1	0.10	0.13	0.33
Unsuitable weather conditions	0.10	0.15	1	0.11	0.19	1	0.10	0.16	0.33
Labor disputes and strikes	0.10	0.16	1	0.10	0.27	1	0.10	0.16	1
Accidents at site	0.10	0.18	1	0.10	0.14	1	0.11	0.20	1
Earthquake	0.10	0.43	1	0.10	0.29	1	0.10	0.15	1
Landslide	0.10	0.43	1	0.10	0.32	1	0.11	0.20	1
Wind	0.14	0.60	1	0.11	0.38	1	0.14	0.33	1
Flood	0.01	0.50	1	0.14	0.43	1	0.14	0.33	1

The results are aggregated by using the equation in the step 8 of the FGTOPSIS method. This step is explained in details below:

Normalized fuzzy decision matrix is constructed by dividing the minimum fuzzy number of each alternative in the combined fuzzy decision matrix by the maximum fuzzy number of the same alternative, the middle value of each alternative in the combined fuzzy decision matrix by the middle fuzzy number of the same alternative, and the maximum value of each alternative in the combined fuzzy decision matrix by the minimum fuzzy number of the same alternative.

Step 9: Calculation of the weighted fuzzy normalized matrix: the normalized fuzzy values of factor's fuzzy weights* are calculated and given in Table 5.15.

Table 5.15: Weighted fuzzy normalized matrix

Risk Factors (Alternatives)	Probability of Occurrence			Impact on Cost			Impact on Time		
Low productivity of man/machine	0.003	0.029	0.63	0.005	0.045	0.27	0.003	0.038	0.18
Defective construction	0.003	0.032	0.63	0.005	0.044	0.162	0.003	0.037	0.129
Unavailability of man/machine/ material	0.003	0.032	0.63	0.005	0.1	0.81	0.003	0.055	0.3
Poor coordination among subcontractor	0.003	0.041	0.63	0.006	0.12	0.81	0.003	0.08	0.9
Conflict with subcontractor	0.003	0.028	0.126	0.005	0.109	0.81	0.003	0.047	0.3
Bureaucracy and sluggish governmental process	0.003	0.031	0.21	0.005	0.071	0.81	0.003	0.04	0.18
Financial instability of sub-contractor	0.003	0.038	0.63	0.005	0.08	0.81	0.003	0.061	0.9
Inadequate cost estimations	0.003	0.04	0.63	0.005	0.041	0.116	0.003	0.099	0.9
Inflation of construction material/labor cost	0.003	0.03	0.63	0.005	0.05	0.27	0.003	0.116	0.9
Prosecution by third party	0.003	0.052	0.63	0.005	0.089	0.81	0.003	0.061	0.9
Design change request by client	0.003	0.024	0.126	0.005	0.071	0.81	0.003	0.047	0.9
Defective design by designer	0.003	0.03	0.21	0.005	0.05	0.81	0.003	0.052	0.9
Inadequate site information	0.003	0.032	0.21	0.005	0.057	0.81	0.003	0.052	0.9
Poor communication of design	0.003	0.045	0.63	0.005	0.067	0.27	0.003	0.074	0.9
Poor understanding of instructions	0.003	0.065	0.63	0.005	0.067	0.81	0.003	0.055	0.9
Late delivery of machine/material at construction site	0.003	0.033	0.63	0.005	0.109	0.81	0.003	0.046	0.3

Unsuitable weather conditions	0.003	0.034	0.63	0.006	0.075	0.81	0.003	0.055	0.3
Labor disputes and strikes	0.003	0.036	0.63	0.005	0.109	0.81	0.003	0.055	0.9
Accidents at site	0.003	0.04	0.63	0.005	0.055	0.81	0.003	0.069	0.9
Earthquake	0.003	0.097	0.63	0.005	0.114	0.81	0.003	0.051	0.9
Landslide	0.003	0.097	0.63	0.005	0.126	0.81	0.003	0.069	0.9
Wind	0.004	0.136	0.63	0.006	0.15	0.81	0.004	0.116	0.9
Flood	0	0.113	0.63	0.007	0.171	0.81	0.004	0.116	0.9

The results are aggregated by using the equation in the step 9 of the FGTOPSIS method. In this step weighted normalized fuzzy decision matrix is computed by multiplying each alternative's fuzzy number with the fuzzy number of each criterion. As the minimum number of the criterion's fuzzy number with the minimum number of the criterion's fuzzy number, the middle number in the middle, and the maximum to the maximum.

Step 10: Calculating of FPIS and FNIS.

The results are computed by using the equations in the step 10 of the FGTOPSIS method: Initially, Weights of the Fuzzy Positive Ideal Solution (A-) for each criterion is computed by taking the maximum value of all the alternatives in the weighted normalized fuzzy number matrix. Then, weights of the Fuzzy Negative Ideal Solution (A-) for each criterion is computed, by taking the minimum value of all the alternatives in the weighted normalized fuzzy number matrix. The results are given in Table 5.16.

Table 5.16: FPIS and FNIS values

	Probability of Occurrence			**Impact on Cost**			**Impact on Time**		
A^+	0.003	0.029	0.63	0.005	0.045	0.27	0.003	0.038	0.18
A^-	0.003	0.032	0.63	0.005	0.044	0.162	0.003	0.037	0.129

Step 11: Determining the distance measure of each alternative from the FPIS and FNIS.

D+ and D- values are computed and provided in Table 5.17. To calculate the distance from the FIPS, all the criteria from the FPIS matrix should be summed up for each alternative. To calculate the distance from the FNIS, all the criteria from the FNIS matrix should be summed up for each alternative.

Table 5.17: Distance of all the alternatives from the FPIS and FNIS

Alternatives	**D+**	**D-**
Low productivity of man/machine	0.800092	0.409812
Defective construction	0.88884	0..317803
Unavailability of man/machine/ material	0.449707	0.79282
Poor coordination among subcontractor	0.104976	1.140679
Conflict with subcontractor	0.68228	0.504428
Bureaucracy and sluggish governmental process	0.726173	0.479627
Financial instability of sub-contractor	0.140919	1.138182
Inadequate cost estimations	0.472884	0.737946
Inflation of construction material/labor cost	0.381374	0.827927
Prosecution by third party	0.127398	1.138851
Design change request by client	0.395711	0.848125
Defective design by designer	0.356972	0.894965
Inadequate site information	0.352455	0.895171
Poor communication of design	0.393772	0.827475
Poor understanding of instructions	0.136755	1.138552
Late delivery of machine/material at construction site	0.444101	0.792934
Unsuitable weather conditions	0.462761	0.791872
Labor disputes and strikes	0.128995	1.139352
Accidents at site	0.149617	1.137828
Earthquake	0.092895	1.142559
Landslide	0.075214	1.143669
Wind	0.012406	1.15152
Flood	0.013275	1.151066

Step 12: Computing the Closeness coefficient of individual alternative

The CC* is the value of each risk factor's Relative distance from Ideal.

The risk factor has a higher impact and effect when the value of CC* is higher. To get the closeness coefficient, a division should be made of the distance from (FNIS) by the sum of (the distance from FNIS and the distance from FPIS).

Step 13: Alternatives ' ranking regarding the closeness index.

The results for Steps 12 and 13 are given below in Table 5.18.

Table 5.18: Results of FGTOPSIS for risk factors

	Relative distance from Ideal	**Ranking from most to less**
Alternatives	**C****	**Rank**
Low productivity of man or machine	0.3387	2
Defective construction	0.2634	1
Unavailability of man, machine or material	0.6381	7
Poor coordination among subcontractor	0.9157	19
Conflict with subcontractor	0.4251	4
Bureaucracy and sluggish governmental process	0.3978	3
Financial instability of sub-contractor	0.8898	15
Inadequate cost estimations	0.6095	5
Inflation of construction material/labor cost	0.6846	11
Prosecution by third party	0.8994	18
Design change request by client	0.6819	10
Defective design by designer	0.7149	12
Inadequate site information	0.7175	13
Poor communication of design	0.6776	9
Poor understanding of instructions	0.8928	16
Late delivery of machine/material at construction site	0.6410	8
Unsuitable weather conditions	0.6312	6
Labor disputes and strikes	0.8983	17
Accidents at site	0.8838	14
Earthquake	0.9248	20
Landslide	0.9383	21
Wind	0.9893	23
Flood	0.9886	22

Table 5.18 indicates the final results of the FGTOPSIS method and shows each alternative’s closeness coefficient, and they are ranked according the relative

distance from the ideal. When we look to the results the most impacted risk factors were ‘Defective construction’ and ‘Low productivity of man/machine’ as the table shows. They should be considered for further analysis to get rid of the consequences that may come along. There are some risks that are not affecting the project during its phases as the methodology showed. These risk factors would be neglected as: Wind, Flood, and Landslide.

As ‘Defective construction’ ranked first as the most impacting risk in the project, a proper risk response strategy should be identified, to avoid the consequence that may come later in the stages of the project. Also ‘Low productivity of man/machine’ and ‘Bureaucracy and sluggish governmental process’ ranked respectively second and third.

The results show that the most impacted risk factors on the project have different risk categories. Thus, there may be many risk response strategies made based on each risk category as some of the risk factors could be reduced kind of 'Defective construction' and 'Low productivity of man or machine', others like 'Conflict with a subcontractor' and 'Bureaucracy sluggish governmental process' could be transferred to another party. While 'Late delivery of machine/material at the construction site' could be prevented, and others like 'Earthquake', 'Landslide', 'Wind', and 'Flood' could be accepted.

Based on the findings many risk responses could be affected to the top ranked risk factors as ‘Defective construction’ and ‘Low productivity of man/machine’, while mitigating them may be one of the best strategy, and this could be happen by intervening using ‘detailed strategy’ or ‘orderly inspections and control’, also preventing them could be happened by ‘giving training and skills enhancement’ to avoid these kind of risks.

Other risk factors like ‘Bureaucracy and sluggish governmental processes’ that was the third critical risk factors according to the decision makers, could be transferred to another party that has the governance and which is expert to make the operations related to this risk factor.

6. CONCLUSION

This is study is implemented with the aim of analyzing risk management practices in the daily operations of the construction companies via detailed examination of a specific case, a transportation project in Casablanca / Morocco, and prioritizing the project's risks using FG-TOPSIS in order to help the construction company for efficient risk management. With this motivation, 23 risk factors specific for the case are identified based on a thorough literature research. Six decision makers responded to the developed questionnaire. The respondents are also grouped based on their experiences before they evaluated the risk factors with a fuzzy scale. All the data is processed with Excel spreadsheet designed for FG_TOPSIS implementation. The results indicate 'Defective construction' and 'Low productivity of man/machine' as the most important risk factors of the case study.

Based on these findings, risk response strategies should be made by the decision makers from the company for an effective response. Risk avoidance by intervening using detailed strategy or orderly inspections and control, and risk transfer by sharing the risks with experts that may enable to use other resources and expertise of others, may be the most used risk response strategies in this case based on the result that has been computed according to the decision makers who made the survey.

To conclude, by using this methodology here some positive sights could be highlighted:

1) The approach picks up the most impacted risk factor in the project thus, the project manager could interrupt directly to the risk factor which ranked in the first.

2) The approach identifies the risk factors in the early phases.

3) Risk factors are quantified considering tree different impacts; in terms of probability of likelihood, time, and cost.

4) This approach gives a better risk assessment, while prioritizing risk factors, according to decision-makers who are also involved in the project and daily face various risks.

5) The assessment could help the stakeholders of the project to plan, manage, interrupt in time, and coordinate between them to avoid the risks that will occur at any time during the project duration.

Furthermore, taking into consideration the risk factors and their impact on the project, let the decision-makers such as project managers make their decisions under a fuzzy environment.

Future studies can continue based on the following suggestions;

- A FG-TOPSIS approach to this kind of problem can consider other groups such as 'Role that the manager taking on the project', ‘Gender, 'Local managers and foreign managers', and many other kinds of grouping to see the opinion of the decision-makers from many sides.

-Other MCDM could be taken into consideration and to be compared with the results of this method (FG-TOPSIS) to see the differences between the obtained results.

-There is some correlation between many risk factors while this methodology doesn't take it into consideration, and a future work could be overcoming these limitations and restrictions.

BIBLIOGRAPHY

Abd El Khalek H., Remon F.A., Kamel H., (2017). Uncertainty and risk factors assessment for cross-country pipelines projects using AHP. *American Journal of Civil Engineering 2016; 4(1): 12-23*

Abdul-Rahman H., Wang Ch., Y. L, (2013). Design and pilot run of fuzzy synthetic model (FSM) for risk evaluation in civil engineering, *Journal of Civil Engineering and Management 19(2):217-238DOI:10.3846/13923730.2012.743926*

Akintoyne A.S. and MacLeod M.J., (1997). Risk analysis and management in construction, *International Journal of Project Management 15*, 31-38

Autrey, T.D. (2015*). 6-Hour safety culture: how to sustainably reduce human error and risk.* Human Performance Association.

Aven, T. (2011). On the new ISO guide on risk management terminology. *Reliability Engineering and System Safety, 96: 719-726*

Baker S. , Ponniah D., and Smith S. (1999). Survey of risk management in major U.K. companies, *ASCE Journal of Professional Issues in Engineering Education and Practice, 125(3),* 94-102.

Barghi B., Shadrokhsikari S. (2020) Qualitative and quantitative project risk assessment using a hybrid PMBOK model developed under uncertainty conditions *Heliyon 6 e03097.* Rerieved from *https://doi.org/10.1016/j.heliyon.2019.e03097*

Basahel A., and Taylan O., (2016). Using fuzzy ahp and fuzzy topsis approaches for assessing safety conditions at worksites in construction industry *Int. J. Of Safety and Security Eng. 6(4),* 728–745

Choudhry R.; Iqbal K. (2013). Identification of risk management system in construction industry in Pakistan, *Journal of Management in Engineering 29(1): 42–49.*

Cooper N.L., Cherry D.S., Scheller J.L., and Bidwell J.R. (2005). Potential effects of Asian clam. *Journal of the North American Benthological Society 24: 381-394.*

Courbage, C., Rey-Fournier, B., Treich, N. G. Dionne (Ed.), (2013). *Prevention and precaution*, in Handbook of Insurance, second edition.

Darnall, R. and Preston, J.M. (2010). Project management from simple to complex flat. *Version 2.0 ISBN (Digital): 978-1-4533-8676-7*

Dey P. K. (2011). Project risk management using multiple criteria decision-making technique and decision tree analysis: A case study of Indian oil refinery, *Production Planning and Control 23(12) :*1-19

Dziadosz A. and Rejment M., (2015) Risk analysis in construction project - chosen methods. *Procedia Engineering. Volume 122, 2015, Pages 258-265* Retrieved from *https://doi.org/10.1016/j.proeng.2015.10.034*

Enshassi A. & Mayer P. (2001) Managing risks in construction projects, *Ludwig burg, Germany.* Retrieved from *http://hdl.handle.net/20.500.12358/26607*

Fan, M., Lin, N.-P., & Chwen, S. (2008). Choosing a project risk-handling strategy: an analytical model, *International Journal of Production Economics, 112, 700-713.*

Fang C, Marle F and Zio E. (2010). An integrated framework for risk response planning under resource constraints in large engineering projects. *IEEE Transactions on Engineering Management (99), 1-13*

Flanagan, R. and Norman, G. (1993), Risk management and construction, *Wiley-Blackwell Science.*

Frimpong Y., Oluwoye J and Crawford L. (2003). Causes of delay and cost overruns in construction of groundwater projects in a developing countries; Ghana as a case study*, International. Journal of Project Management, 2,* 321–326

Gitinavard H., Mousavi S.M., Vahdani B., and Siadat A. (2017) Project safety evaluation by a new soft computing approach-based last aggregation hesitant fuzzy complex proportional assessment in construction industry, *Scientia Iranica E, 27(2), 983-1000*

Gładysz B., (2015). Project risk time management a proposed model and a case study in the construction industry. *International conference on project management. DOI:10.1016/j.procs.2015.08.459*

Goh C. S., Abdul-Rahaman H., & Abdul Samad, Z. (2013). Applying risk management workshop for public construction projects: case study. *Journal of Construction Engineering and Management, 139,* 572-580.

Gupta V.K. and Thakkar J.J. (2018). A quantitative risk assessment methodology for construction project. *Sādhanā 43, 116* Retrieved from *https://doi.org/10.1007/s12046-018-0846-6*

Hatefi, M.A., Seyedhoseini, S.M., (2012). Comparative review on the tools and techniques for assessment and selection of the project risk response actions (RRA). *Int. J. Inf. Technol. Project Manage*ment, 3, 60–78.

Hong E.S., Lee I.M., Shin H.S., Nam S.W., Kong J.S, (2009). Quantitative risk evaluation based on event tree analysis technique: Application to the design of shield TBM. *Tunneling and Underground Space Technology. 24 (3), 269–277*

HSE, (2014). *The health and safety toolbox: How to reduce risks at work*. Health and Safety Executive Books

Hubbard, D. W. (2009). *The failure of risk management*. Hoboken, New Jersey: John Wiley and Sons Inc.

Islam M.S., Nepal M.P., Skitmore M. and Attarzadeh M., (2017). Current research trends and application areas of fuzzy and hybrid methods to the risk assessment of construction projects. *Adv. Eng. Informatics 33, 112–131*

Jozi, S.A.; Shoshtary, M.T.; Zadeh, A.R.K. , (2015). Environmental risk assessment of dams in construction phase using a multi-criteria decision-making (MCDM) method. *Hum. Ecol. Risk Assess., 21, 1 16.*

Karimi A.A., Mousavi N., Mousavi F., Hosseini B.(2013). Risk assessment model selection in construction industry, Expert Systems with Applications. *Expert Systems with Applications 38, 9105–9111*

Kelly L.A, (2003). Quantitative risk analysis, lectures' notes, *University of StrathClyde*, Retreived from www.stams.strath.ac.uk/classes/53.411/notes.

Koulinas G.K., Demesouka O.E., Marhavilas P.K., Vavatsikos A.P. and Koulouriotis D.E. (2019). Risk assessment using fuzzy TOPSIS and PRAT for sustainable engineering projects. *Open Access Journal, vol. 11(3), 1-15.*

Ling F. Y. Y. and Hoi L. (2006). Risks faced by Singapore firms when undertaking construction projects in India. *Int. J. Proj. Manag. 24*, 261–270

Lukas J.A., (2004). Real risk management for real projects. PMI, *Proceedings of the Project Management Institute Annual Seminars and Symposium (New York City).*

Merna T. and Stroch D. V., (2000). Risk management of an agricultural investment in a developing country utilizing CASPAR program, *International Journal of Project Management 18,* 349-360

Mojtahedi S. M. H., Mousavi S. M., Makui A. (2010) Project risk identification and assessment simultaneously using multi attribute group decision making technique *Safety Science 48*, 499–507

Muriana C and Vizzini G., (2017). Project risk management: A deterministic quantitative technique for assessment and mitigation. *Int. J. Proj. Manag. 35, 320–340*

Nguyen T.H., Marmier F. and Gourc D.,(2013). A decisionmaking tool to maximize chances of meeting project commitments. *Int. J. Prod. Econ. 142, 214–224*

Pangsri P., (2015). Application of the Multi Criteria Decision Making Methods for project selection. *Universal Journal of Management DOI: 10.13189/ujm.2015.030103*

Pfeifer J., Barker K., Ramirez-Marquez J. E. and Morshedlou N., (2015). Quantifying the risk of project delays with a genetic algorithm. *Int. J. Prod. Econ. 170, 34–44*

Piney C., (2002). Risk response planning: selecting the right strategy, *the 5th European Project Management Conference, PMI Europe 2002, France.*

PMBOK 6. (2017). *Practice Standard For Project Risk Management*, Project Management Institute, ISBN:978-1-933890-38-8.

PMI, Project Management Institute (2013). *A guide to the project management body of knowledge:* PMBOK. 5th edition. Pennsylvania: Project Management Institute, Inc

Potts H. ; Anderson J.E.; Colligan L.; Leach P., (2014). Assessing the validity of prospective hazard analysis methods: A comparison of two techniques. *BMC Health Services Research 14(1):41. DOI:10.1186/1472-6963-14-41*

Potts K., (2008). *Construction cost management, learning from case studies.* Abingdon: Taylor Francis Pb: ISBN 9780415286398

Pribadi K.S. and Pangeran M.H., (2006). Integrating qualitative and quantitative risk analysis for investment in public-private partnership scheme for water supply in Indonesia. *The tenth east Asia-Pacific Conference on structural Engineering and construction.*

Rayment, S. (2017) *Types of Construction Projects*. Retrieved from https://issuu.com/stephenraymentsystech/docs/types_of_construction_projects

Reddy A. S., (2015). Risk management in construction industry a case study, *International Journal of Innovative Research in Science, Engineering and Technology. ISBN(Online) :2319-8753. Vol. 4, Issue 10*

Rezakhani, P. (2012). Classifying Key Risk Factors in Construction Projects. *Bulletin of the Institute of Polytechnic Institute of Jassy, Construction Architecture section 58(2), 27-38*

Rippel, M., Teplý, P. (2010), Stress Testing and Scenario Analysis. *Journals published by VSE ISBN-10: - 3639234200.*

Ruijters E. , Stoelinga M. (2015). Fault tree analysis: A survey of the state-of-the-art in modeling, analysis and tools. *University of Twente,* Retrieved from http://dx.doi.org/10.1016/j.cosrev.2015.03.001

Saaty, T. (1980). The analytical hierarchy process: planning, setting priorities, resource allocation. *International Book Company*

Sabaghi M., Mascle C., Baptiste P.,(2015) Application of DOE-TOPSIS Technique in Decision-Making Problems *IFAC-PapersOnLine 48-3,* 773–777.

Saiful Islam, M. (2013). Risk Assessment of Construction Projects in Bangladesh. *International Postgraduate Research Conference*.

Sambasivan M and Soon Y W (2007). Causes and effects of delays in Malaysian construction industry. *Int. J. Proj. Manag. 25,* 517–526

Sato T. and Hirao M. (2013). Optimum budget allocation method for projects with critical risks. *Int J. Proj. Manag. 31, 126–135*

Shen, L. (1997). Project risk management in Hong Kong. *Int. J. Proj. Manag. 15: 101–105*

Shoar S. (2018). An Optimization framework for risk response actions selection using hybrid ACO and FTOPSIS. *Scientia Iranica,* DOI:10.24200/sci.2018.20225.

Smith N.J. , Merna T. and Jobbling, P. (2006). *Managing risk in construction projects.* 2nd edition Oxford: Blackwell Publishing

Taufik H.A. (2010). Risk management the quality of construction stage at the area of PT.X. *Indonesia University thesis, 185/F.01/TESIS/01/2010.*

Thomas P. (2009*)* Strategic Management. *Course at Chalmers University of Technology, Gothenburg.*

Tyler, Brian, Crawley, Frank & Preston, Malcolm. (2015). *HAZOP: Guide to Best Practice* (3rd ed.). IChemE, Rugby.

Wang J., & Yuan H. (2011). Factors affecting contractors' risk attitudes in construction projects: Case study from China. *International Journal of Project Management, 29, 209-219.*

Wang S. Q., Tiong R. L. K., Ting S. K. and Ashley D. (2000). Evaluation and management of foreign exchange and revenue risks in China's BOT projects. *Construct. Manag. Econ. 18, 197–207*

Wanjari S.P. and Dobariya G. (2016). Identifying factors causing cost overrun of the construction projects in India. *Indian Academy of Sciences, DOI 10.1007/s12046-016-0498-3*

Winch G. (2002). *Managing construction projects, an information processing approach.* Oxford: Blackwell Publishing.

Xanbo Z., Bon-Gang H., & Sui Pheng, L. (2012). Implementing enterprise risk management in a Chinese construction firm based in Singapore. *Proceedings World Construction Conference- Global Challenges in Construction Industry*. Colombo, Sri Lanka.

Xianghui D. and Rui W. (2018). Risk Assessment of Tunnel Portals in the Construction Stage Based on Fuzzy Analytic Hierarchy Process. *Archives of Civil Engineering 64(4), 69-87*

Yoon K. and Hwang C. (1981). *Multiple attribute decision making–methods and applications*, A chapman and hall book.

Zhang J., Cai M., Li X. and Mu Z. (2011). Prioritizing highway tunnel risk factors with AHP method. *In: Inf. Sci. Technol. (ICIST), Int. Conf.* 1205–1207

Zhang Y.,(2016). Selecting risk response strategies considering project risk interdependence. *Int. J. Proj. Manag. 34,* 819–830

Zhao X., Hwang B-G., and GAO Y. (2016). A fuzzy synthetic evaluation approach for risk assessment: a case of Singapore's green projects. *J. Clean Prod. 115, 203–213*

Zhi He. (2015). Risk management for overseas construction projects. *School of Civil and Structural Engineering, Nanyang Technological University, Singapore 2263. 0263-7863 (95) 00015-1*

Zou P., Zhang G., and Wang J. (2007) Understanding the key risks in construction projects in China. *Int. J. Proj. Manag. 25, 601–614*

Zou P., Zhang G. and Wang, J., (2006). Identifying key risks in construction projects: life cycle and stakeholder perspectives. *A working paper submitted in the University of New South Wales, Sydney, Australia.*

APPENDIX A_ SURVEY QUESTIONS

Introduction:

This is a survey for a data gathering use, and it will be delivered to Managers and Site Engineers in Yapi Merkezi Company.

The data gathered will be used for Risk identification and risk factors will be ranked and prioritized, to know the most critical risk in a transportation project in order to let the Decision Makers choose the best risk response strategy.

The expected time to fill up the questionnaire is about to: 10 minutes.

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Name:

Surname:

1. Which role do you have in the project (Project Manager / Engineer)?

2. Which phase of the project do you take part in (Initiation, Planning, Execution / Implementation, or Closure please specify if there are many parts)?

3. How many years of experience do you have in transportation projects? (Please specify in years by number)

The questions coming are following the Risk Management Process so their results will be used as a data for Fuzzy-TOPSIS approach. Thus, the questions are constructed in a way that only those who have a <u>good level of engineering Management</u> could reply to them.

Assessment:

There are many risk factors that should be aware of in the risk management process and each risk factor has its own degree of Impact on the project.

For that reason, three criteria have been created as they are the most important criteria for making a risk management assessment in a transportation project, in order to give each risk factor a weight based on the criteria below:

1. The probability of occurrence

2. Impact on cost

3. Impact on time

1. Regarding the role, you have in the project, please define Please define the weight of each criterion affecting the project in the table below. The answer should be answering how much the criterion affecting the project and it should be in a scale in the range of (Very low, Low, Medium low, Medium, Medium high, High, Very high) respectively from the less to the most important one.

Probability of Occurrence	Impact on Cost	Impact on Time
Choisissez un élément.	Choisissez un élément.	Choisissez un élément.

2. How much each risk factor affecting the project based on the probability of occurrence, Impact on time, and Impact on Cost? The scale of each risk factor should be in the range of (Very low, Low, Medium low, Medium, Medium high, High, Very high) respectively from the less occurring risk to the most one.

Risk Factors	Probability of occurrence	Impact on Cost	Impact Time
Low productivity of man/machine	Choisissez un élément.	Choisissez un élément.	Choisissez un
Defective construction	Choisissez un	Choisissez	Choisissez
Unavailability of man/machine/ material	Choisissez un élément.	Choisissez un élément.	Choisissez un
Poor coordination among subcontractor	Choisissez un élément.	Choisissez un élément.	Choisissez un
Conflict with subcontractor	Choisissez un élément.	Choisissez un élément.	Choisissez un
Bureaucracy and sluggish	Choisissez un	Choisissez	Choisissez
Financial instability of sub-contractor	Choisissez un élément.	Choisissez un élément.	Choisissez un
Inadequate cost	Choisissez un	Choisissez	Choisissez
Inflation of construction	Choisissez un	Choisissez	Choisissez
Prosecution by third party	Choisissez un	Choisissez	Choisissez
Design change request by client	Choisissez un élément.	Choisissez un élément.	Choisissez un
Defective design by	Choisissez un	Choisissez	Choisissez
Inadequate site	Choisissez un	Choisissez	Choisissez
Poor communication of design	Choisissez un élément.	Choisissez un élément.	Choisissez un
Poor understanding of	Choisissez un	Choisissez	Choisissez
Late delivery of machine/material at	Choisissez un élément.	Choisissez un élément.	Choisissez un
Unsuitable weather	Choisissez un	Choisissez	Choisissez
Labor disputes and strikes	Choisissez un	Choisissez	Choisissez
Accidents at site	Choisissez un	Choisissez	Choisissez
Earthquake	Choisissez un	Choisissez	Choisissez
Landslide	Choisissez un	Choisissez	Choisissez
Wind	Choisissez un	Choisissez	Choisissez
Flood	Choisissez un	Choisissez	Choisissez

3. *Is there any other risk factor that you see is important that should be taken into consideration and is not mentioned above? (YES / NO) if yes, please specify*