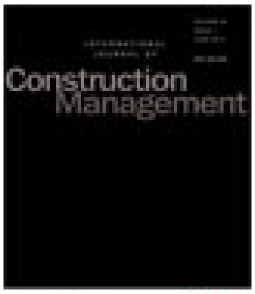

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# Risk management workshop application: a case study of Ahwaz Urban Railway project

Mehdi Tavakolan and Amir Mohammadi

Department of Construction Engineering and Management, School of Civil Engineering, College of Engineering, University of Tehran, Tehran, Iran

**ABSTRACT**

Effective risk management is a vital part of project management. The previous workshops in the construction industry have shown to suffer from the lack of a comprehensive risk management techniques. This paper aims to investigate the capacity of a workshop as a risk management approach through the analysis of risk management for Ahwaz Urban Railway project. The analysed workshop uses brainstorming, the combination of fuzzy and failure mode and effect analysis and multiple-choice questions to identify, evaluate and determine the best responses to risks, respectively. The workshop examination shows that a workshop gives the organization an opportunity to identify critical risks. Furthermore, it helps the organization staff to have a better understanding of the project's environment and provides chances to improve teamwork. Despite the strengths of the workshop, it has several limitations of its own. The participants should be the project's major stakeholders and the workshop requires time and money. Two of the major limitations of the analysed workshop are time limitation, and lack of risk monitoring and controlling experience. In addition, this study does not investigate the relationship between risks. However, more attempts are needed to address challenges and barriers of risk management implementation in construction industry.

**KEYWORDS**

Project management; risk management; risk analysis; fuzzy sets; case study

## Introduction

The nature of various activities involved in construction projects is determined by many risks and inherent uncertainties in every phase of the project lifecycle (Imbeah & Guikema 2009; Abdelgawad & Fayek 2012; El-Sayegh & Mansour 2015). The increasing complexity and dynamism of construction projects, however, have led to substantial uncertainties and the revitalization of subjectivities in the risk analysis process (Nieto-Morote & Ruz-Vila 2011; Gan & Xu 2013). This aside, the environment in which construction industry operates is usually exposed to a high degree of risks and faces a significant number of uncertainties (Tserng et al. 2009; Marle & Vidal 2014). Having these impeding features in mind, one would not find it surprising that, over the past decade, many projects have experienced large variations in cost and schedule which, of course, greatly contributes to their failure (Liu et al. 2011; Chen et al. 2012). In order to increase control in the area of such projects, risk management (RM), as the art and science of anticipating and planning for future uncertain events, is vital to understand and mitigate or control risks (Alarcon et al. 2011; Yoon et al. 2014). RM also necessitates a comprehensive project surveillance and monitoring since it is imperative that project managers should consider all possible risks to establish corrective actions in the right time in order to improve the chance of success and minimize the risks of project failure (Ahmed et al. 2007; Skorupka 2008; Imbeah & Guikema 2009; Kuo & Lu 2012; Choudhry & Iqbal 2013; Mohammadi & Tavakolan 2013;Wambeke et al. 2014). Therefore, in both preemptive and inventive senses, RM is essential for any given construction project to fulfil its objectives (Ezeldin & Orabi 2006; Hwang et al. 2014). Furthermore, when it comes to cost and profit analysis, which is, of course, the keystone of any given construction project, and, in these lines, to enhancing the profitability of a construction company, those risks that affect the profit of the company must be controlled as part of their long-term business planning (Wang et al. 2009; Allan & Yin 2010; Yoon et al. 2014). Hence, given all the previously mentioned dimensions and aspects involved in it, the construction company is one of the major beneficiaries of the RM implementation simply because it is exposed to the highest degree of risks (Mohamed et al. 2015). As a result, RM is important for each stakeholder benefits from

**CONTACT** Mehdi Tavakolan mtavakolan@ut.ac.ir

project's success. Therefore, every stakeholder in the project expects that project risks be managed properly.

## Literature review

So far, several RM approaches have been proposed such as project risks analysis and management (Chapman 1997); AS/NSZ framework (AS/NZS 4360 2004); shape, harness and manage project uncertainty approach (Chapman & Ward 2003); a risk management standard developed by the Institute of Risk Management (Institute of Risk Management 2002) and the framework proposed by the Project Management Institute (PMI) (PMBOK 2008). Despite the differences among these approaches in terms of number of processes and contents, they nevertheless share a common paradigm and provide more or less the same insight into the question of RM. However, for the sake of the necessary specifications needed here, it is important to properly select RM tools and techniques for a successful RM implementation (Goh et al. 2013).

Some of the RM tools currently used in the construction industry are comparatively mature, such as fault tree analysis (FTA), event tree analysis (ETA), Monte Carlo analysis and sensitivity analysis (Zeng et al. 2007; Goh et al. 2013). Despite the fact that high quality data are prerequisite for effective applications of such sophisticated quantitative techniques as Monte Carlo analysis and sensitivity analysis, such data are, unfortunately, difficult to be acquired or even sometimes are not available in the construction industry (Zeng et al. 2007). To give a telling instance, according to Abdelgawad and Fayek (2010), estimating the probability distributions for basic events in FTA is an immensely difficult task for lack of sufficient data on construction projects. In addition, as Ferdous et al. (2011) put forward, FTA and ETA processes basically depend upon two assumptions. First, the probability of events is assumed to be exact, which is not very often true. Second, the interdependencies of events proposed by FTA and ETA are assumed independent, which is an inaccurate assumption. For one thing, a probability and impact matrix fail to provide sufficient risk planning and risk response processes. For another thing, this technique cannot examine the relationships between and among the risks (Goh et al. 2013). For Perry and Hayes (1985), sensitivity analysis as a defining feature has limited efficacy in assessing the combined effects of various risk variables. In addition, a further disadvantage is that it provides no indication of the probability of risk occurrence (Zou & Zhang 2009). Moreover, checklist or brainstorming individually does not provide themselves the capacity to prioritize and evaluate risks by assessing the likelihood and impact of the risks (Loosemore 2009; Goh et al. 2013).

Furthermore, almost every RM technique evaluates risks by considering two risk parameters, namely, the risk likelihood and risk impact (Zeng et al. 2007). However, it should be noted that a particular risk is highly dependent on many other factors involved, e.g. human factors, workplace factors, material factors and equipment factors, and these factors should also be considered in the project risk assessment process to obtain a reliable result (Zeng et al. 2007). However, fuzzy and failure mode and effect analysis (FMEA) provides increased value to the RM processes and expands the concept of risk prioritization by adding a detection parameter (Carbone & Tippet 2004). Such inclusions and considerations have made FMEA recommendable by reliable sources such as United States Department of Defense and the Society of Automotive Engineers as an authentic RM approach (Rhee & Ishii 2003; Hu et al. 2009; Chang & Wen 2010). In traditional FMEA, before the current modifications, the priorities of failure modes are specified by using risk priority numbers (RPN), which is the product of the occurrence (O), severity (S) and detection (D) scores for each risk. However, the traditional FMEA still has some limitations (Chin et al. 2009; Chang & Wen 2010; Xiao et al. 2011; Liu et al. 2013 ). Therefore, regarding such limitations, a number of attempts have been made to exploit the combination of fuzzy sets and FMEA within the construction RM domain (Sharma et al. 2005; Chang & Cheng 2011; Mohammadi & Tavakolan 2013; Samaras et al. 2014). The combination of fuzzy sets and FMEA thus can be said to eliminate several limitations of traditional FMEA. For example, different sets of O, S and D ratings may produce exactly the same value of RPN in traditional FMEA, but their hidden risk implications may be totally different because of the different severities of the failure consequences (Liu et al. 2013; Jin & Zuo 2011). This is because hidden risk implication represents the real position of the risk (Chileshe & Kikwasi 2014). Project managers expect that top priority risks include special risks, but sometimes it does not happen in the way expected. These risks are, nevertheless, important for project managers, yet they are not considered enough due to inappropriate risk assessment techniques commonly applied (Perera et al. 2014). Furthermore, another decisive limitation is that the relative importance among O, S and D is not taken into consideration in traditional FMEA. The three factors are assumed to have the same importance (Chang & Wen 2010). However, unlike FMEA, the use of fuzzy inference system considers hidden risk implications. Moreover, fuzzy rules have the extra advantage of having

**Table 1.** Comparison of RM techniques in terms of five steps of Project Management Institute (PMI) approach.

| Techniques | Risk planning | Risk identification | Risk analysis | Risk response | Risk monitoring |
|---|---|---|---|---|---|
| Monte Carlo simulation | ✓ | ✓ | ✓ | | |
| Sensitivity analysis | | ✓ | ✓ | | |
| Fault tree analysis | | ✓ | ✓ | | |
| Event tree analysis | | ✓ | ✓ | | |
| Probability and impact matrix | | ✓ | ✓ | | |
| Brainstorming | ✓ | ✓ | | ✓ | |
| Checklists | ✓ | ✓ | | | |
| Workshop | ✓ | ✓ | ✓ | ✓ | ✓ |
| FMEA | | ✓ | ✓ | ✓ | |

the potential to consider the relative importance among O, S and D.

Furthermore, besides addressing the limitations of traditional FMEA, there is a need to systematically investigate the overall aspects of RM on the perspectives of various project participants. In so doing, workshop is one of the integrated approaches that can provide a platform for various project participants to have a joint RM practice (Goh et al. 2013). The workshop also has the further advantage of including various RM tools. Utilizing the most appropriate RM tool for each process of the RM provides an integrated approach which allows the project manager to use the maximum capacity of the RM for the project. The RM workshop prepares a comprehensive RM approach by simultaneously addressing risk planning, identification, analysis and response. A comparison of the RM techniques in terms of five processes of PMI approach is shown in Table 1.

A few researchers studied the workshop application as an RM tool. Wood and Ellis (2003) discussed applying a workshop in the RM. The workshop can serve as an opportunity for members of the project team to gather, discuss potential risk issues and improve team building skills. Goh et al. (2013) have also used an RM workshop for a public construction project in practical terms. They stated that the use of an RM workshop can fill gaps in the current application of RM techniques. More to this, they used a probability and impact matrix for risk assessment, but the matrix was, unfortunately, unable to produce rigorous results. This can be explained by the fact that the focus of the study by Goh et al. (2013) was on the impact and probability of risk factors without considering the manageability of the risk which depends on the project and organization type. Furthermore, another problem with this model of workshop-design was that the execution of their workshop lacked risk planning.

One of the challenges and difficulties in this area, however, is that there are a few research validating the application of RM workshop in construction domain. Hence, this paper aims to investigate the capacity of the workshop as an RM tool by analysing an RM workshop for Ahwaz Urban Railway project and then explain the practice of RM processes utilized in the workshop. It is worth mentioning that the workshop output is important for all stakeholders of Ahwaz Urban Railway project. So, in order to ensure compatibility with the project, the workshop processes should be chosen meticulously regarding their advantages and disadvantages. Practically speaking, the workshop participants used brainstorming and discussion to identify risks, fuzzy FMEA to assess risks and multiple-choice questions to determine the best responses for each registered risk in the workshop.

In order to achieve the research objective, this paper is structured as follows. Next section describes Ahwaz Urban Railway project. In 'Risk management of the pre-workshop section', RM of the pre-workshop is presented to show the establishment of Fuzzy FMEA Risk Analyzer. The workshop implementation and sequences of the RM steps are presented in 'The risk management workshop implementation section'. The output of the RM workshop and discussion is presented in 'The output of the risk management workshop and discussion section'. It investigates the reliability of the results, the ability of the Fuzzy FMEA Risk Analyzer to eliminate the traditional FMEA limitations and the changes in the project plan regarding the workshop output. 'The RM workshop examination' section investigates the workshop strengths and weaknesses as an RM technique. Conclusions and future work are summarized at the end.

## Project description

As far as the preliminary considerations for the project's start-up are concerned, the Ahwaz Urban Railway project in Iran, with a contract sum of US$ 780.22 million, has been studied. The date of site possession for mobilization was 26 June 2006, and the project was estimated to be completed by 26 June 2008. However, in practice, the site mobilization took 11 months to accomplish due to the diversity of the project locations. Line 1 of Ahwaz Urban Railway project is more than 23 km long, in addition to depot and parking, and also consists of two separate

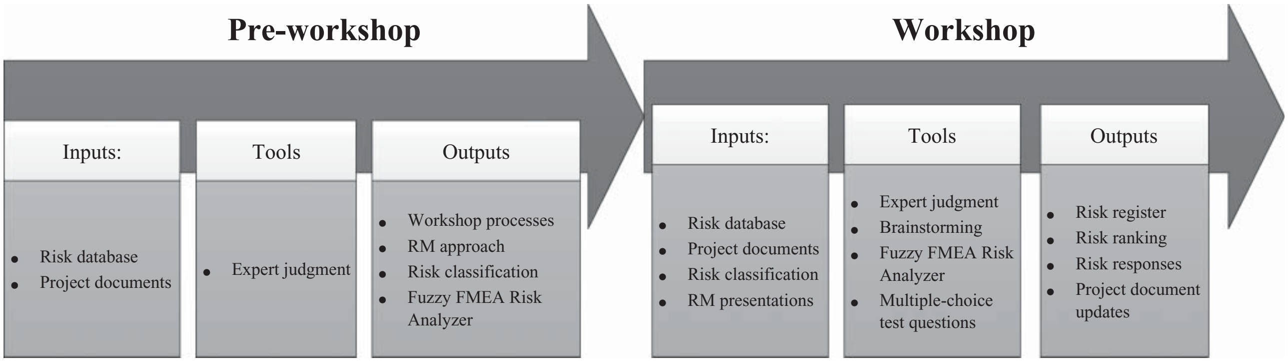


**Figure 1.** Inputs, tools and outputs of pre-workshop and workshop.

tunnels and 23 stations. On the other hand, the project's scope of work includes provision of engineering; supply of equipment and materials; construction and installation of works; commissioning and training in various areas such as tunnelling; construction of railway stations and related access roads, depot buildings, wagon parking facilities, central control building, inter-tunnel ventilators, laying rails, electrical and mechanical equipment and locomotives and wagons for the entire line. When executed and brought to resolution, it is calculated that the travel time, including stops at stations, will be about 44 minutes. At peak travel times, the trains will operate on the line with the headway of 210 seconds and the maximum speed of trains will reach 80 km/h. It is worth mentioning that there is a risk assessment methodology for tunnelling activities. This information thus supports us to set up the workshop, but the risk assessment methodology results are not used in the workshop itself.

For launching the process of the realization of this project, two construction companies, from Iran and China, founded a Joint Venture (JV) company to accomplish this project as an Engineering, Procurement and Construction (EPC) contract. The payment is paid directly to the JV parties by the owner, that is, a member of the Iranian government.

However, it was mentioned earlier that there are often important tasks to be undertaken before the actualization of the targeted workshop. So, it is obligatory to undertake such tasks by a pre-workshop (Wood & Ellis 2003). The pre-workshop has significant participatory role in starting up a workshop in a project since it could save the workshop time and expense by accomplishing primary processes. It would also improve the workshop performance by filling out the initial processes since it will actually facilitate workshop processes, especially in case of time limitation and preliminary arrangements which can be hindering tasks at the time of the actual workshop formation. Furthermore, making important decisions such as selecting RM approaches, determining the formation of the workshop participation and choosing the participants can be performed in the pre-workshop. A pre-workshop is thus conducted for this project for better implementation of the workshop. The contractor, owner and consultant were asked to introduce their own representative to participate in the pre-workshop. Twenty experts were pre-selected from the representatives based on their experience and involvement in the project. Finally, seven experts with more experience were selected to participate in the pre-workshop processes. The pre-workshop uses expert judgment to reach the pre-workshop outputs using the risk database and project documents needed for holding the actual workshop. The pre-workshop outputs include workshop processes, the RM approach, risk classification and Fuzzy FMEA Risk Analyzer. The workshop is then expected to use some of the pre-workshop outputs such as Fuzzy FMEA Risk Analyzer as workshop tools and apply the rest as inputs. The inputs, tools and outputs of pre-workshop and workshop are shown in Figure 1. The following parts describe the pre-workshop and workshop implementation.

## Risk management of the pre-workshop

For the provision of a reliable database, a comprehensive database of definitions and concepts of the risk, risk identification techniques, construction project risks and risk assessment approaches was created by collecting the data from the project management literature. To being the pre-workshop process, two sessions were conducted with seven participants from the selected workshop participants. Five participants were chosen from the contractor's body of recommended experts, one participant from that of the owner's organization and, finally, one from that of the consultant.

The initial goal of the first session was to determine the process of workshop implementation and selection of the RM approach (according to advantages and disadvantages of the techniques recorded in the database), and to explore the RM conditions in the project. In the second session, consequently, the RM assessment tools and their pros and cons were discussed. The participants adopted Project Management Body of Knowledge (PMBOK 2008) framework as the workshop RM approach including five processes: risk planning, risk identification, risk analysis, risk response and risk monitoring and control. The reason for selecting PMBOK (2008) framework as the workshop RM approach was, first and more importantly, the application of PMBOK (2008) as the project management standard in the contractor's company. Furthermore, the other reason was that almost each participant of the workshop was familiar with the concepts and definitions of the PMI. These attributes then significantly grounded and facilitated the implementation of the workshop. PMBOK (2008) argued that risk planning begins when the project is conceived and should be completed earlier than the initial project planning. However, considering the outputs, two major outputs of the risk planning are risk categories and risk methodology. Therefore, in one side, the experts decided to classify project risks into three categories: technical risks, external risks and management risks. Risk methodology, on the other side, involves tools and techniques that will be used to perform the RM in the project.

Furthermore, the participants decided to employ brainstorming and multiple-choice questions for risk identification and risk response. Moreover, they determined FMEA for risk assessment providing the elimination of traditional FMEA limitations. In order to establish the workshop risk assessment tool, several group interviews were conducted with the same experts who participated in the pre-workshop. The output of these interviews was Fuzzy FMEA Risk Analyzer developed by the combination of FMEA and fuzzy sets. The processes to establish the Fuzzy FMEA Risk Analyzer are briefly shown in Figure 2. The following section explains these processes in detail.

### *Fuzzy FMEA Risk Analyzer establishment*

*Step 1: Linguistic definition of likelihood (L), impact (I) and detection (D)*

A group interview was conducted with the participants of the pre-workshop to define the linguistic terms involved in the body of the questions. The first goal of the meeting was to introduce the Fuzzy FMEA Risk Analyzer. Using the database, the experts were asked to answer the open-ended questions. The experts decided to use five linguistic terms to define the likelihood (L), detection (D) and impact (I). The definitions of L, I and D are described in Table 2.

*Step 2: Membership functions establishment of likelihood (L), impact (I), detection (D) and risk priority numbers (RPNs)*

Subsequently, the meeting continued to define the membership functions (MFs). The MF of a fuzzy set is a generalization of the indicator function in classical sets. In fuzzy logic, it represents the degree of truth as an extension of valuation. A MF for a fuzzy set A on the universe of discourse $X$ is defined as $\mu_A: X \to [0,1]$, where each element of $X$ is mapped onto a value between 0 and 1. MFs allow us to graphically represent a fuzzy set. The $x$ axis represents the universe of discourse, whereas the $y$ axis represents the degrees of membership in the [0,1] interval. During this step, the experts were asked to define MFs for L, I, D and RPNs according to the definitions shown in Table 2. Afterwards, the trapezoidal and triangular MF shapes were chosen to present the L, I, D and RPNs linguistic terms. Furthermore, the experts intended to use nine linguistic terms to represent the RPNs. The direct method with the experts was then used to elicit the MFs ranges. With this aim in mind, the experts were asked questions like 'What is the degree of membership of 10 in "very high"?' Figure 3 shows the MFs of L, I, D and RPN. The MFs of I and L are identical and the MFs of D have the reverse order of linguistic terms as compared to L and I. So, on one hand, if a risk has a higher likelihood or impact, it is expected that it

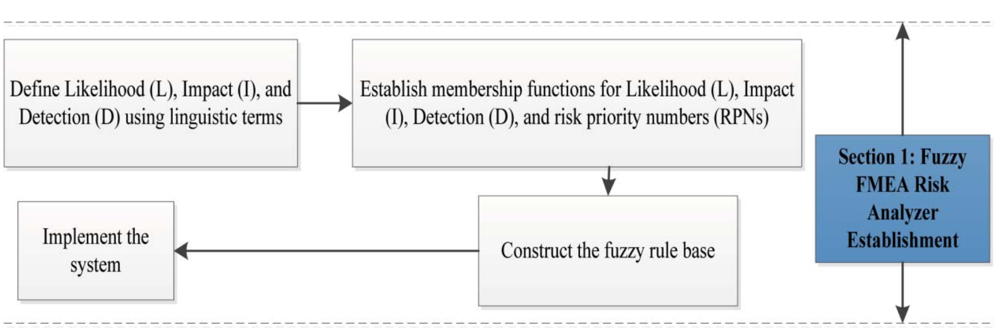


**Figure 2.** Fuzzy FMEA Risk Analyzer establishment.

**Table 2.** Linguistic definition of impact (I), likelihood (L) and detection (D).

| | Impact categories | | | | |
|---|---|---|---|---|---|
| Description | Cost | Schedule | Quality/technical | Likelihood | Detection |
| Very high | ≥20% of project cost | ≥20% of project duration | The project does not meet business expectations. | Risk will definitely occur. | The risk will definitely be detected and controlled. |
| High | Cost increase is <20% and ≥10% of project cost | Time increase is <20% and ≥10% of project duration | The project changes or quality are unacceptable to project sponsor. | Risk will likely to occur. | There is a likely chance to detect and control risk. |
| Medium | Cost increase is <10% and ≥5% of project cost | Time increase is <10% and ≥5% of project duration | Major areas of project are affected. | Risk may occur. | There is a medium chance to detect and control risk. |
| Low | Cost increase is <5% and ≥2% of project cost | Time increase is <5% and ≥2% of project duration | Few areas of project are affected. | Risk is unlikely to occur. | There is an unlikely chance to detect and control risk. |
| Very low | <2% of project cost | <2% of project duration | The effect on project is negligible. | Risk is highly unlikely to occur. | The risk will not be detected and controlled. |

has a higher value of RPN. On the other hand, if a risk has a higher chance to be detected, it is expected that it has a lower RPN. As a result, the MFs of D have the reverse order of linguistic terms as compared to L and I.

*Step 3: Construction of fuzzy rules base*

In this case, the fuzzy rule base connects the L, I and D inputs to the RPN. The fuzzy rule base entails 'If-Then' rules. Here, the 'If' part shows the different scenarios that can occur in the system, and the 'Then' part shows the output scenarios related to inputs accordingly. For example: If likelihood (L) is 'Very high' and impact (I) is 'Medium-High' and detection (D) is 'Low' then RPN is 'High.' If the input factors are L (10), I (6) and D (7), the RPN would not be exactly 420. However, if the RPN of a risk is 420, it would be in both Medium and Medium-High area as shown in Figure 3. Besides, if a vertical line is drawn from 420, it intercepts with both Medium and Medium-High MFs. There were three inputs and each of which had five linguistic terms. In total, $5^3 = 125$ rules should have been created to consider all the input combinations. The rules were then elicited from group interviews using multiple-choice questions. For the operational arrangements of the process, the minimum operator was used for aggregation; the product operator was used for implication; the maximum operation was used for rule aggregation and, the centre of area was used for defuzzification.

*Step 4: System implementation*

MATLAB program was applied to establish the Fuzzy FMEA Risk Analyzer using the graphical user interface and the fuzzy set toolbox platform of MATLAB R.2010. The user can insert the risk data at the Fuzzy FMEA Risk Analyzer both manually and automatically. Using the 'Load Data' button, the user can insert risk data from

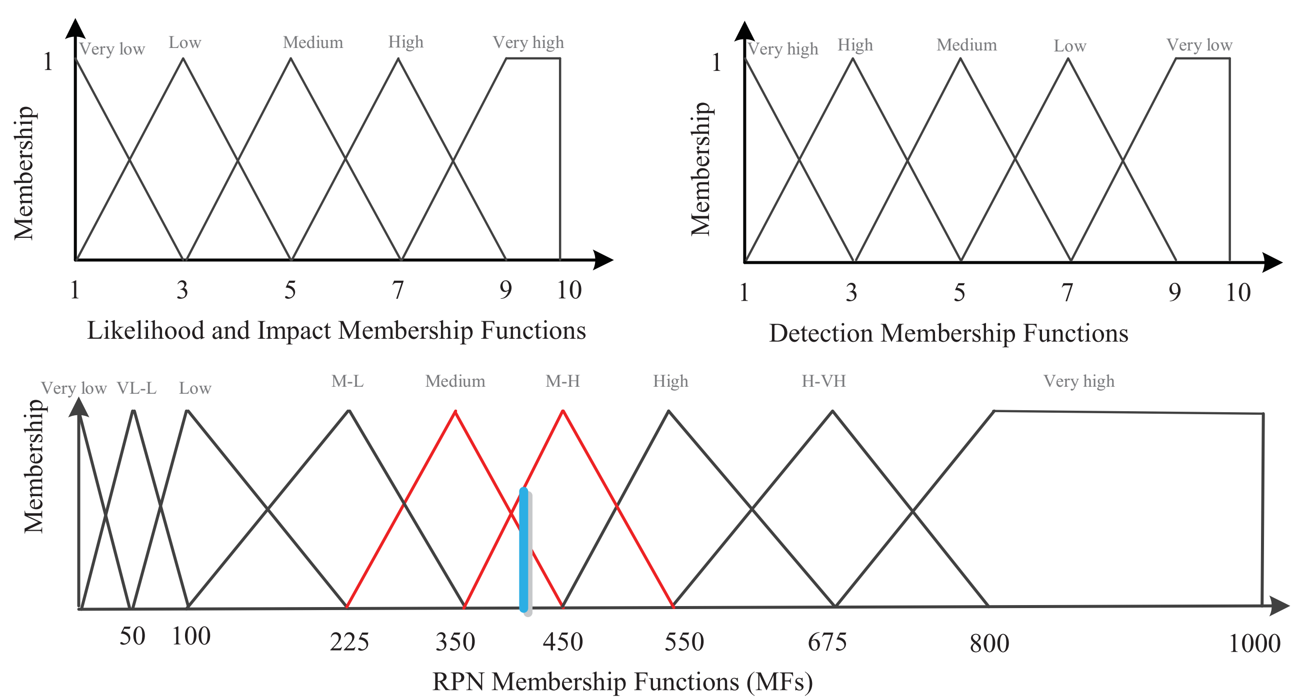


**Figure 3.** Likelihood, impact, detection and RPN MFs.

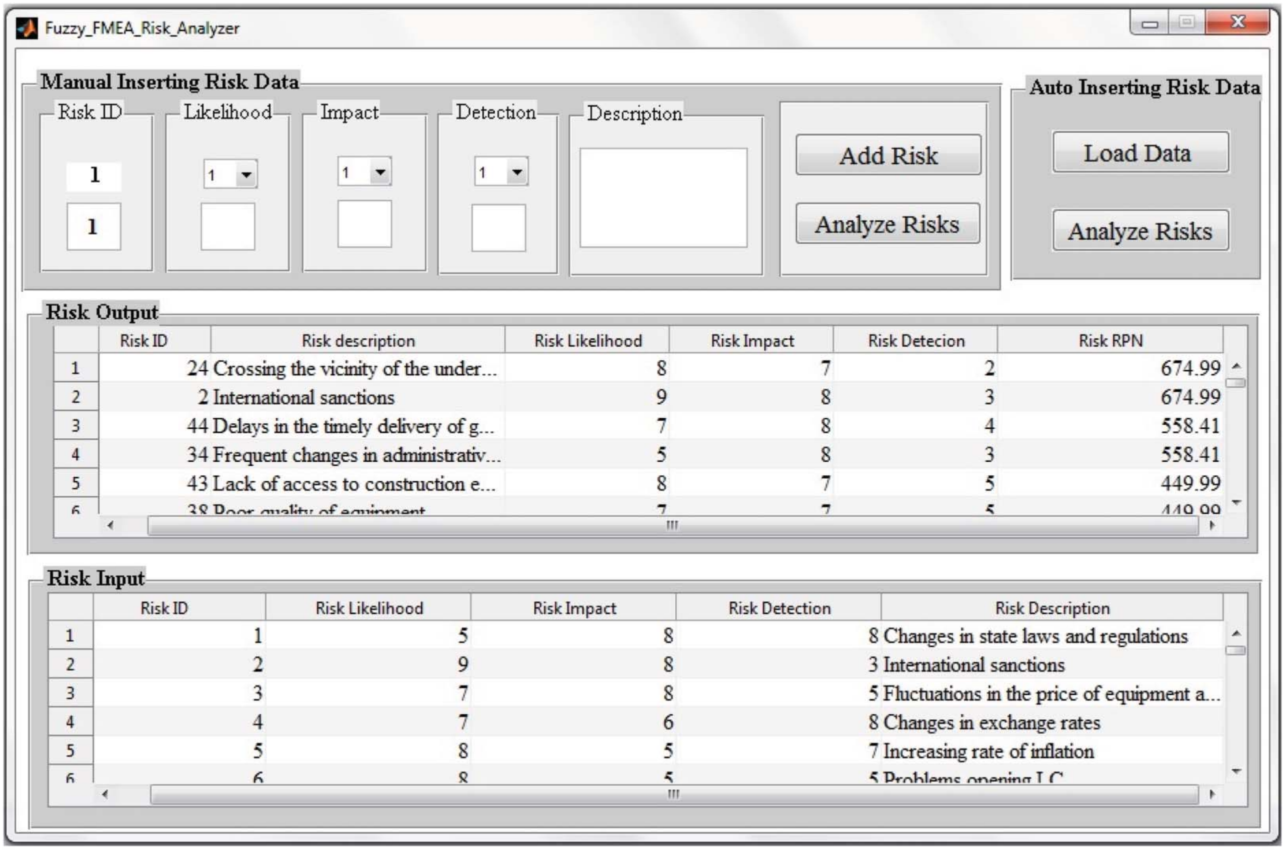


**Figure 4.** Fuzzy FMEA Risk Analyzer.

Microsoft Excel. The inserted risk data will be thus shown on the 'Risk Input' table and the user can check the validity of the data and, if needed, correct the mistakes. After inserting the risk data, the risk assessment process can be performed by pushing the 'Analyze Risk' button. The risk ranking based on the RPN values will be presented on the 'Risk Output' table. The Fuzzy FMEA Risk Analyzer is shown in Figure 4.

## The risk management workshop implementation

The length of time allotted to the workshops tends to range from a half day to two entire work days depending on the nature of the project and the willingness of the client to pay and cover the expenses involved (Wood & Ellis 2003; Samaras et al. 2014). Normally, an isolated venue is always preferred for the organization of workshops in order to gather all involved key players in one place for discussion (Goh et al. 2013; Mohamed et al. 2015).

With taking such time-allocation necessities and principles into consideration, a one and a half day workshop was held in the meeting room of the central site in Ahwaz. The project was already under construction when the workshop started. There were 20 participants present in the workshop. The participants comprised the project manager (1), the project technical assistant (2), machinery manager of railway transportation division (3), two project management Office (PMO) experts (4–5), two planning experts (6–7), the head of the project planning and controlling (8), two experts of the project health, safety and environmentoffice (9–10), the head of the tunnel boring machine (TBM) technical office (11), the head of the quality assurance and management representative of the project (12), the head of the quality control and project support (13), PMO manager (14), planning and developing deputy of railway transportation division (15), two experts from the consultant company (16–17) and, finally, three experts from the owner's company (18–20). There were more participants from the contractor's company in comparison with that of the owner and consultant's companies because, as stated previously, the project was under construction and the contractor's experts were directly dealing with the project issues. Moreover, the project type was EPC and, as commonly known, there are more risks in this type of the contract for the contractor. Four facilitators and administrators were assigned to facilitate the workshop. Regarding the expenses, the workshop costs

**Table 3.** RM workshop timeline.

| | Timeline | Processes |
|---|---|---|
| Day 1 | 8:00 am–8:30 am | Opening ceremony |
| | 8:30 am–9:30 am | RM introduction |
| | 9:30 am–10:30 am | Presentation and discussion on the adopted RM approach |
| | 10:30 am–11:00 am | Break |
| | 11:00 am–11:30 am | Presentation on the project status by project manager |
| | 11:30 am–12:00 pm | Participants divisions according to risk categories |
| | 12:00 pm–12:30 pm | Break |
| | 12:30 pm–14:30 pm | Risk identification |
| | 14:30 pm–15:00 pm | Discussion on the output of risk identification process |
| | 15:00 pm–15:30 pm | Break |
| | 15:30 pm–18:00 pm | Risk evaluation |
| Day 2 | 8:00 am–8:45 am | Discussion on the output of risk evaluation process |
| | 8:45 am–10:15 am | Discussion and determination risk response |
| | 10:15 am–10:45 am | Break |
| | 10:45 am–12:00 pm | Presentation on the risk monitoring and controlling by RM facilitator |

were undertaken by the Iranian contractor. The RM workshop timeline is shown in Table 3.

Regarding the workshop schedule and its time management, the workshop commenced with an opening ceremony (8:00 am–8:30 am). Afterwards, a comprehensive presentation was given introducing the RM concepts and expressing the RM processes implementation in an organization (8:30 am–9:00 am). The presentation explained the risk definitions, general processes of the RM and the RM tools and techniques. Additionally, project manager discussed the selected RM approach and RM tools determined in the pre-workshop (9:30 am–10:30 am).

The project manager then presented a summarized status of the project to level the information of the participants after a break (11:00 am–11:30 am). When the workshop started, the project was already behind schedule and had overrun the budget. It had achieved a progress of 42% compared to the initially planned progress of 99%. The project manager stated the several factors that, in his view, had caused the current situation, such as international sanctions, subcontractor's disqualification, delays in timely delivery of the goods and materials to the project, workers' strike, changes in the owner's body of authorities and decision-makers, inappropriate soil conditions, lack of access to construction equipment and, finally, the complexity of the construction approach. Risk planning process was already carried out during the pre-workshop for saving the workshop time. Subsequently, the participants were divided to three groups to concentrate on the project risk categories: technical risk, external risk and management risk (11:30 am–12:00 pm). As with the members of each group, the technical group consists of participants with the following IDs: 4-6-7-10-11-17. The external group consists of participants with these IDs: 3-5-8-9-13-15-16-20. Subsequently, management group consists of participants with the following IDs: 1-2-12-14-18-19.

Each group was then assigned to identify the risks of the project and analyse them according to their risk category. In the beginning, the participants started to brainstorm and initiated discussions among the group members to come to create a list of the risks. The identification process took two hours (12:30 pm–14:30 pm).

The members of the first and third groups were enthusiastic to get involved and accomplish their tasks. On the contrary, the second group was less motivated but their performance was still acceptable. Subsequently, each group presented their outputs of the risk identification process and the participants discussed the identified risks (11:30 pm–12:00 pm). The facilitator of the workshop then gave some ideas and comments to smooth the path to the offset of the risk identification process. In this process, it was found that some risks can be categorized into two categories, for example, providing commissioning equipment could be classified as a management risk and external risk, simultaneously. This problem was solved for some risks and participants then managed to put them in more appropriate categories.

After the break, the participants tried to determine each risk factor including risk likelihood, risk impact and risk detection using the definitions shown in Table 2. The evaluation process took two and a half hours and 48 risk items of the project were identified and evaluated (15:30 pm–18:00 pm).

In its given form, the concept of risk detection was vague and the facilitator was asked for more explanation. Afterward, the facilitator analysed the risks using the Fuzzy FMEA Risk Analyzer which was previously established during the pre-workshop.

It should be noted that all participants attended the two-day workshop. On the second day, however, the workshop started with the presentation of the risk ranking list and continued with the results put to discussion (8:00 am–8:45 am). Past experience of the risks was investigated to verify the results and the participants looked over the ranking list to prevent the risks from being ignored. Subsequently, the participants answered the multiple-choice questions to determine the best responses for each risk (8:45 am–10:15 am). The possible answers introduced in the questions at issue included tools and techniques to plan risk responses according to PMBOK (2008).

In the end, the facilitator presented the risk monitoring and controlling processes to finalize the RM processes after a break (10:45 am–12:00 pm). The RM processes should be performed regularly during the project life cycle to identify and track new, changing and outdated risks. Also, it is shown that each risk characteristics, risk responses and the effectiveness of the applied risk response should be registered accurately for being used in the future to prevent from making similar mistakes.

## The output of the risk management workshop and discussion

Risks of the case study were identified and evaluated. The RM workshop output was then briefly registered in a risk register table which contains the risk description, risk factors, critical risks, risks responses and helpful comments on risk monitoring and controlling. Among the aforesaid items, the critical risks are shown in Table 4. The risk register table itself is shown in the Appendix. To show how the risk evaluation process works, assume that the parameters of the international sanction risk are determined in the workshop. Next, the likelihood, impact and detection are 9, 8 and 3, respectively. These values are used as inputs to the Fuzzy FMEA Risk Analyzer. Next, for each individual risk, the fuzzy inference process fires the proper rules, aggregates the inputs, performs rule implication and aggregation, and, finally, defuzzifies the result to obtain a value of RPN equal to 674.9.

The problems that occurred during the project, however, were thoroughly inspected to check the reliability of the results. Concerning the expenses and costs, the mechanical, electrical and controlling systems consist of 55% of the project costs and it was expected that related risks to the equipment be present in the critical risks. Crossing the vicinity of the underground utilities happened several times during the tunnel excavation. Some problems were direct or indirect consequences of the insufficient information provided in the basic technical documentation and, in addition, the lack of information about the network distribution of water and sewage which resulted in the deprivation of some areas of freshwater. Also, the main fibre optic got disconnected once and thus brought up repair costs and caused disorder in the communication systems and internet access for a while. International sanctions during the project construction increased the project time and cost. The first plan in the tunnelling was to use four sets of TBM, although political conflicts eventually caused the project manager to change the planning. It was decided to buy two sets of TBM while, unfortunately, the cost of these

**Table 4.** Critical risks of the project.

| Ranking | Risk description (workshop) | (L, I, D, RPN) | Recommended Action | Project plan changes | Risk Description (Traditional FMEA) | RPN | Risk ranking in the workshop output |
|---|---|---|---|---|---|---|---|
| 1 | Crossing the vicinity of the underground utilities | (8, 7, 2, 674.99) | Avoidance | Further boring tests | International sanctions | 504 | 2 |
| 2 | International sanctions | (9, 8, 3, 674.99) | Avoidance/ transfer | Ordering equipment from inside | Crossing the vicinity of the underground utilities | 448 | 1 |
| 3 | Delays in the timely delivery of goods and equipment to the project | (7, 8, 4, 558.41) | Avoidance/ transfer | Increasing human resources in the procurement office | Delays in the timely delivery of goods and equipment to the project | 336 | 3 |
| 4 | Frequent changes in the administrative authorities | (5, 8, 3, 558.41) | Avoidance/ transfer | ——— | Lack of access to construction equipment | 280 | 5 |
| 5 | Lack of access to construction equipment | (8, 7, 5, 449.99) | Mitigation/ transfer | Changes in buying orders | Fluctuations in the price of equipment and materials | 280 | 7 |
| 6 | Poor quality of equipment | (7, 7, 5, 449.99) | Mitigation/ transfer | Assigning experts to investigate the quality of the equipment | Frequent changes in administrative authorities | 280 | 4 |
| 7 | Fluctuations in the price of equipment and materials | (7, 8, 5, 449.99) | Mitigation/ transfer | Pre-purchasing needed materials | The complexity of the stations' construction approach | 252 | 10 |
| 8 | Provision of commissioning equipment | (6, 5, 5, 341.59) | Mitigation/ transfer | Purchasing equipment by Kayson Company | Lack of technical knowledge and experience required for designing | 252 | 18 |
| 9 | Dependence on certain suppliers | (6, 7, 6, 341.59) | Mitigation/ transfer | Increasing human resources in the procurement office | Inappropriate soil conditions in the tunnel | 252 | 20 |
| 10 | The complexity of the stations' construction approach | (7, 6, 4, 341.59) | Mitigation/ transfer | Using the top-down method | Poor quality of equipment | 245 | 6 |

machines was greater than the original planning. Moreover, the arrival of the TBMs and some equipment were not on schedule due to political conflicts and also strict import regulations.

Administrative changes, too, caused some difficulties in the project, especially, in the owner's organization. These changes made certain obstacles such as unexpected delays in the notification of the contract and less coordination between the owner and the JV parties. Another impediment to the project was raised by quality and availability of the equipment. The poor quality of the equipment, on the other hand, caused certain reworks and decreased the project quality in some cases. Fluctuations in the price of equipment and materials played the role of a major constraint for the procurement team because the market instability spurred sharp and unpredictable rises in prices. Therefore, the project faced complicated issues, not taken into account previously, during the construction phase. For example, lack of access to cement was a serious problem for a period of time. The contract type was EPC and contained providing commissioning equipment, but the availability of this equipment became a serious issue due to the political conflicts and overshadowed the whole facilitation of the projects being carried out as an extraneously affecting factor. These problems made the project dependent upon certain suppliers who took advantage of the conditions and rallied up the prices. Furthermore, as discussed earlier, the soil condition of the stations made the construction approach more complicated. The level of the ground water was very close to the surface in the Ahwaz. Thus, the sealing of the tunnels and stations required further arrangements. Inspections revealed that some risks can have interactions and one might cause or intensify another. Hence, international sanctions affected the price of materials and equipment and caused lack of access to certain equipment. These problems might also have caused the poor quality of the equipment or certain previously unaccounted for delays in the process of the projects being carried out. However, sometimes the circumstances may and in fact will make some risks inevitable. In this case, political conflicts intensified other risks' impacts while the project required importing technologies and equipment. Naturally, the project management team could not completely avoid the international sanctions and responded to this risk by other replaceable tools and tactics like mitigation. Accordingly, the project had fallen behind schedule by 57%.

Theoretically, it can be concluded that the use of fuzzy sets will address the traditional FMEA limitations. The traditional FMEA and Fuzzy FMEA Risk Analyzer outputs with the use of the same inputs are shown in Table 4. A comparison between these two methods shows that the risks of 'provision of commissioning equipment' and 'dependence on certain suppliers' are removed from the critical risks index in the traditional FMEA. The project status yet clearly indicates that these two risks are influential in the project. There are some changes in the order of the risks. Moreover, the 'lack of technical knowledge and experience required for designing' and 'inappropriate soil conditions in the tunnel' are added in the traditional FMEA. Although, these two risks had been considerably compelling problems, they were solved by special arrangements. Particularly, after risk assessment was conducted by Amberg Engineering for tunnelling activities, the inappropriate soil conditions are to be mitigated. Regarding the comparison results and the project manager's presentation in the workshop, combining fuzzy sets with traditional FMEA practically improves the final output.

However, regarding the workshop output, the project management team made some changes to the project plan. Further boring tests were carried out for data collection to avoid incidents that might occur when TBM would cross the vicinity of the underground utilities. Furthermore, Iranian companies were ordered to manufacture some equipment to lower the risk of international sanctions in case of shortage of material and equipment in need; for example, an Iranian Company was committed to manufacture the wagons of the project. However, the wagons were a portion of the commissioning equipment. Additionally, the number of human resources in the procurement office was increased to successfully address the newly raised issues. This would decrease the delays in the timely delivery of goods and equipment to the project locations. Likewise, some experts were assigned to investigate the quality of the equipment before and during the purchase processes in order to mitigate the risk of poor quality of equipment. In order to prevent the fluctuations in prices and to secure a reliable budget strategy, some materials were pre-purchased. Furthermore, the primary stations were constructed using the bottom-up method. Then, it was suggested that the stations be built using the top-down method which was both simpler and had a better record of performance.

Regarding the procurement of certain equipment, some like the commissioning equipment was supposed to be bought by the Chinese Company. The Chinese Company yet failed to provide the equipment because the opening processes of the letter of credit (LC) were halted. This was owing to the fact that the Iranian bank did not agree to some terms of the LCs of the Chinese Company. The Iranian contractor then decided to purchase the equipment to mitigate the risks of the delays in the timely delivery of goods and equipment to the project location and provide the commissioning equipment in question.

Regarding the investment-related justifications for holding the workshop in question, the workshop cost was estimated to be 0.001% of the project's estimated cost. If one of the critical risks of the project was considered, it would be comprehended that the mitigation of just one of these risks can compensate the workshop's cost in its entirety. For example, if the project manager avoided or transferred the international sanctions risk, the project would save time and cost. This amount of saving is, in its own right, justifiable and adequate enough to convince project managers to implement preliminary RM in other projects. Consequently, the workshop would be considered a successful attempt.

## The RM workshop examination

The workshop was then carefully examined to find out the workshop strengths and weaknesses. The findings showed the validity of the studies performed by Perera et al. (2014) and Goh et al. (2013). The risk awareness of participants rose during the workshop and, in consequence, they achieved a shared understanding of the actual project risks. The workshop acts like a useful teambuilding opportunity and provides a mutually beneficial and communicative space for participants to brainstorm and discuss in order to reach a consensus and common understanding on the project risks (Low et al. 2013). Another advantage, however, is the capacity of a workshop to keep participants focused and encourage them to achieve a better performance of the workshop by the use of brainstorming technique in an intimate and friendly environment where new ideas are welcomed. The results indicated that the RM workshop can be indeed an important tool for project managers to identify and control risks by using strong and practical tools. Additionally, the participants of the workshop declare their viewpoint on the risks by specifying the risk factors including the likelihood, impact and detection. In so doing, the project manager can become preemptively aware of the risks by investigating the workshop results. The critical risks can be tracked down before they have a chance to turn into serious problems. A workshop also is capable of convening the stakeholders who have their own perspectives of the risks. Therefore, a workshop can inspect each risk rigorously due to the consideration level of the risk exposure to each stakeholder, hence alleviating investment-related worries. Furthermore, the workshop improves communication between and among the stakeholders by providing an intimate environment and helping them boost and widen the scope of their relationships.

Granted, it may have several limitations and weaknesses as well. In order to achieve some acceptable results, the participants should be the project's major stakeholders. It takes time and effort to coordinate professional experts as major stakeholders' representatives whose participation, no doubt, is essential in coming to a common perception of the risks, their imposition made by them on the budget management and the time issues they may raise. The workshop also takes time, and sometimes the participant would not attend the whole workshop and thus lose the necessary all-encompassing perspective. This can affect the output of the workshop. Moreover, the workshop has different costs including: experts' payment, coordination, reception, transportation, etc. Compared to the project cost combined and as a whole, the workshop does not cost much, but stakeholders should take care of the financial issues of the workshop. Accordingly, the workshop requires time, money and other resources like human resources and so on. Moreover, due to the participants' views on the risks, the studied workshop only considered and addressed the negative risks. Long discussions in every session can also cause the session to be less useful and bearing. The facilitators should thus be well-trained and aware of the human behaviour to properly motivate the participants. One of the major limitations of the analysed workshop was the time limitation. The time limitation prevented the full accomplishment of the PMBOK (2008) RM framework and because of that there is a lack of risk monitoring and controlling experience. The critical risks can be controlled and tracked during the project life cycle, but it requires more work and attention to the RM in the project. This study, however, does not investigate the relationship between the risks.

This research can also add the experience of an RM workshop implementation to the RM literature. The results and major critical risks can then aid the construction managers to develop systematical RM approaches and implement RM processes properly, especially, in the Middle East. Therefore, many construction companies can adopt the processes taken up and fulfilled here and take into the consideration the lessons learned from this paper in order to facilitate their RM and increase the RM performance rate. Furthermore, the studied workshop appropriate tools can be compared to other RM tools and techniques to introduce a broader scope for appreciating the situation involved in any project's multi-factorial process of materialization. The application of the workshops can be spanned to every type of projects in order to examine the workshop ability to handle the RM problems and issues.

## Conclusions and future works

Having this experience and study in mind, all organizations are strongly recommended to apply the RM proactively and consistently throughout a project's life cycle. An RM workshop provides an integrated approach which would prove to be apt to allow the project manager to use the maximum capacity of the RM for the project. The main purpose of this paper, however, was to investigate the application of an RM workshop as an RM approach. To do so, it has analysed an RM workshop for a large-scale construction project. It was shown and solidified that the previous workshops in the construction industry noticeably lacked the use of a comprehensive RM technique. This study has explained the need for the application of the RM workshop as a complex RM framework, which practically uses brainstorming, multiple-choice questions, risk register, fuzzy sets and FMEA. FMEA permitted the workshop participants to evaluate the likelihood (L), impact (I) and detection (D) of the risks by means of their judgments and experience put to a shared and practical dominion. The RM workshop outcome is also able to help the project managers to develop systematical RM approaches. In overall, project managers can put the processes taken up and the lessons learned from this workshop to use in order to facilitate the RM processes and increase the RM performance rate. Another constructive and generalizable result of this research is the experience of utilizing Fuzzy FMEA Risk Analyzer as the risk assessment tool. A sophisticated risk assessment tool requires pre-workshop sessions to facilitate the workshop tasks. Furthermore, by comparison, the results and project manager's presentation in the workshop, combining the fuzzy sets with the traditional FMEA practically will improve the final output.

Regarding the workshop output, the project management team of Ahwaz Urban Railway project has made some changes to the originally determined project plan. Further boring tests were carried out for data collection. Furthermore, Iranian companies were ordered to manufacture some of the equipment to lower the risk of international sanctions as a preemptive step taken for a better management of the risks at issue. Additionally, the number of human resources in the procurement office was increased to provide them with a higher chance of fulfilling the task to which the members of the office in question were assigned. Likewise, some more experts were assigned to investigate the quality of the equipment before and during the buying processes. In order to prevent fluctuations in the prices, some materials were prepurchased and thus secured budget strategy's success. The Iranian contractor decided to purchase the commissioning equipment. Furthermore, it was suggested that the stations be built using the top-down method which was simpler and had a better performance rate.

As mentioned earlier, an RM workshop provides a useful teambuilding opportunity and raises awareness of the RM. The workshop can thus lead participants to a focused attitude and also encourage them to identify the risks and achieve a collective understanding of the risks embodied in form a common perception and insight into the project ahead. A workshop is an incorporated technique that allows the participants to reach a satisfactory level of knowledge about risks by the brainstorming technique. It also helps the participants improve their knowledge of risk definitions and concepts, general processes of the RM and RM tools and techniques. More than anything else, the workshop improves communication between stakeholders and helps them boost their relationships and come to a better grasp of the investment-related issues needed to be addressed on way of dealing with the project's demands.

Despite the strengths of a workshop, the workshop participants should be the project's major stakeholders to achieve acceptable results. It logically means that the workshop requires time, money and other resources. Nonetheless, several limitations occurred in the proper and pre-planned application of the workshop. A difficult section of the workshop is unfortunately convening the main stakeholders to examine every perspective of risks. This study lacks the implementation of the RM in the risk monitoring and control processes. The risk monitoring and controlling process require applying RM throughout the project's life cycle and need more grounding work. It is thus safe to say that the results and findings of this study should be considered as part of the project planning phase. They cannot be generalized statistically and can only be generalized analytically in order to provide the necessary theoretical framework for further practical steps to be taken more properly.

As a final word, any given future research should cope with the experience limitations discussed above at length. Further implementation of workshops, as this study tried to concretely show, can help researchers understand the most effective mechanisms to implement a workshop.

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## ORCID

*Mehdi Tavakolan* http://orcid.org/0000-0002-2227-8009
*Amir Mohammadi* http://orcid.org/0000-0002-3586-7005

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## Appendix. List of registered risks in the workshop

| Risk description | L | I | D | RPN |
|---|---|---|---|---|
| Crossing the vicinity of the underground utilities | 8 | 7 | 2 | 674.99 |
| International sanctions | 9 | 8 | 3 | 674.99 |
| Delays in the timely delivery of goods and equipment to the project | 7 | 8 | 4 | 558.41 |
| Frequent changes in administrative authorities | 5 | 8 | 3 | 558.41 |
| Lack of access to construction equipment | 8 | 7 | 5 | 449.99 |
| Poor quality of equipment | 7 | 7 | 5 | 449.99 |
| Fluctuations in the price of equipment and materials | 7 | 8 | 5 | 449.99 |
| Providing commissioning equipment | 6 | 5 | 5 | 341.59 |
| Dependence on certain suppliers | 6 | 7 | 6 | 341.59 |
| Fast tracking | 6 | 5 | 5 | 341.59 |
| The complexity of the stations' construction approach | 7 | 6 | 4 | 341.59 |
| The complexity of the tunnel construction approach | 5 | 5 | 5 | 341.59 |
| Incompleteness of basic studies at the beginning | 6 | 6 | 6 | 341.59 |
| Lack of technical knowledge and experience required to design | 7 | 6 | 4 | 341.59 |
| Design complexity | 8 | 4 | 4 | 341.59 |
| Delays in shifting utilities (water, gas, fibre optic) | 8 | 5 | 5 | 341.59 |
| Changes in soil material in drilling the tunnel | 7 | 4 | 4 | 341.59 |
| Inappropriate soil conditions in the tunnel | 7 | 6 | 4 | 341.59 |
| Inappropriate soil conditions in the stations | 7 | 5 | 6 | 341.59 |
| Delays in issuing entry permits equipment to Iran | 7 | 6 | 6 | 341.59 |
| Delays in approval of design documents in the owner organization | 6 | 7 | 7 | 341.59 |
| Delay in the notification of contract by the owner | 7 | 5 | 5 | 341.59 |
| Delays in land acquisition | 5 | 6 | 6 | 341.59 |
| Unnecessary interference by the employer | 8 | 5 | 5 | 341.59 |
| Delays in receiving payment | 7 | 6 | 6 | 341.59 |
| Delays in getting paid in advance | 6 | 6 | 6 | 341.59 |
| Problems opening LC | 8 | 5 | 5 | 341.59 |
| Changes in state laws and regulations | 5 | 8 | 8 | 341.59 |
| Human injury resulting from failure to observe the HSE rules | 5 | 4 | 6 | 224.99 |
| Lack of access to appropriate knowledge for machinery maintenance | 5 | 4 | 4 | 224.99 |
| Workers' strikes | 5 | 4 | 4 | 224.99 |
| Lack of access to necessary technical and administrative experience | 6 | 4 | 4 | 224.99 |
| Failure to provide part and equipment for repairing machinery and TBM from Iran | 6 | 4 | 4 | 224.99 |
| Failure to provide part and equipment for repairing machinery and TBM from abroad | 4 | 5 | 5 | 224.99 |
| Disengagement guarantees from equipment vendors | 5 | 4 | 4 | 224.99 |
| Lack of clarity in the description of the subcontractors' contracts | 8 | 4 | 5 | 224.99 |
| Disqualification of subcontractor | 5 | 2 | 2 | 224.99 |
| Changes in the design of tunnels and stations | 3 | 5 | 5 | 224.99 |
| Traffic movement during construction | 6 | 4 | 4 | 224.99 |
| Incorrect information provided in the basic technical documentation | 7 | 5 | 7 | 224.99 |
| Poor management of leader company in JV | 4 | 5 | 5 | 224.99 |
| Ambiguities in contracts between JV members | 4 | 4 | 4 | 224.99 |
| Disagreement between the JV parties involved in the project management level | 4 | 5 | 5 | 224.99 |
| Changes in weather conditions such as flooding | 4 | 7 | 7 | 224.99 |
| Increasing rate of inflation | 8 | 5 | 7 | 224.99 |
| Changes in exchange rates | 7 | 6 | 8 | 224.99 |
| Theft and damage to equipment | 5 | 3 | 6 | 125.07 |
| Conflicts between the teams involved in the project due to different working cultures | 3 | 4 | 5 | 50.42 |