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USING MULTI-CRITERIA DECISION MAKING (MCDM) METHODS IN EGYPTIAN CONSTRUCTION PROJECTS

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Abstract: Construction project risks are generally defined as the possible variations of the actual outcomes from the planned scenarios which expose the various stakeholders to monetary losses and time-wise delays. Construction projects in Egypt always experience a high level of risks and uncertainties due to their complex and dynamic environments. This, in turn, impacts projects in both time and cost and causes numerous disputes between parties. Usually, project participants in Egyptian construction projects allocate risks by aversion where owners tend to shift risks to the primary contractor, who in turn transfers them to the subcontractors. As a result of this, risks are not necessarily allocated/ re-allocated to the party that is best able to manage them efficiently and effectively. This also increases the dispute and disagreement level between project parties which consequently cause losses in both time and budget. Accordingly, this paper appraises the need for an efficient framework that allocates project risks to the most suitable party through utilizing a systematic risk analysis approach that identifies the dominant risks in the Egyptian construction industry and evaluates their relative importance, interdependency and possible effects and frequency of occurrence. Hence, multi-criteria decision-making techniques are used to develop a framework that mitigates the possible risks and decreases their negative effects through optimizing the project risk allocation process. Previous researches have not considered the application of MCDM and optimization techniques in the process of project risk allocation which is considered a novelty of this research. Experts from the Egyptian construction industry were involved in several stages of the study, to assess the perceptions of various stakeholders of construction projects and to ensure and validate the public acceptance and approval of the proposed framework. The proposed framework was tested by industry specialists and applied on Egyptian construction projects to validate its efficiency by comparison to the real situation and approach implemented. The result of applying the developed framework on the case studies was in favor of the proposed model as it proved reduction in money losses and time-extensions due to proper allocation of the construction risks and therefore, this resulted in a declination in the dispute level between project participants.

1 INTRODUCTION

Risk management is a project management practice that is considered of great importance as Royer (2000) stated that: "Experience has shown that risk management must be of critical concern to project managers as unmanaged or unmitigated risks are one of the primary causes of project failure". Risk management is thus in direct relation to the successful project accomplishment as it helps ensure a project is completed on time, within budget and with the sought-after performance (Turner 1999).

The most widely-accepted risk management process is basically constructed from four iterative phases as shown in Figure 1: risk identification, risk estimation, risk response planning, execution and monitoring.

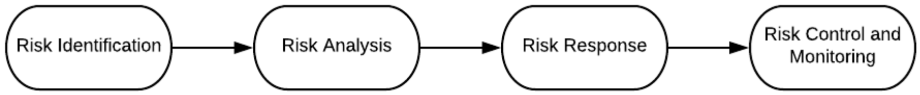

Figure 1 Risk Management Process (Ahmed and Nassar 2016)

When dealing with risks, the potential for improvement should also be taken into account, for example, to undertake the project with fewer resources or to make use of an unexpected window of opportunity. Risks are at the very core of the business: risks and opportunities are linked; there are no opportunities without risks related to them. Thus, risks raise the value of a project; usually, higher risks bring greater opportunities (Miller 2001)

One of the most important decisions in a project is the allocation of risks: who carries which risks. This is directly linked to this research; as this study will examine how risks are mitigated and handled in project networks and which party takes responsibility for risk management. Before the decisions of risk allocations are ready to be made, the attitude that project actors have towards the risk has to be determined. Before a project starts, every player's strategy, as well as the ability to bear and manage risks, has to be known before risks are assigned to them (Klemetti, 2006).

In this context, this research would first review the practices followed in the literature for risk transfer and allocation purposes, identify and analyze the most commonly experienced risks in construction projects especially in areas similar to the Egyptian dynamic environment and hence develop a risk allocation framework that aims to decrease dispute levels in construction projects between the various parties.

2 BACKGROUND

Many efforts have been conducted in the filed of construction project risks identification, assessment and allocation, however, almost none of the projects integrated the multi-criteria decision making concepts into their analysis approach.

In the United States of America, studies related to risk importance and allocation were conducted by Kangari (1995). He created a survey questionnaire based on a previous survey done by ASCE with the basic idea of trying to analyze if any significant changes had taken place in the contractor's perception towards risk allocation. One hundred large contractors were surveyed, and their responses showed their perceptions on rating the importance of given risks and how they could be allocated to either the owner, the contractor, or shared between both. Safety in construction projects proved to be the most serious risk for the contractors followed by quality of work while the least important risk was the changes in governmental regulations.

Kartam and Kartam (2001) conducted a research study on risk allocation in the Kuwaiti industry. The survey tool used for their research was a questionnaire comprising of three sections. The first section gave insight into risk identification and allocation while the second section assessed the significance of various risk categories. The third section asked for practical actions to be taken in cases of risk occurrence. Thirty-five contractors were surveyed, who represent a 57% response rate. Out of twenty-six total risks, four risks were allocated to the owner, thirteen to the contractor and four were shared between both of them. The remaining risks were left undecided.

In the study of Hameed and Woo (2007), both questionnaires and in-depth interviews were used for data collection as tools to test the views of construction industry participants in issues related to risk importance and risk allocation. The questionnaire was divided into three sections. Section one included the general information about the respondent and the company while section two assessed the importance of various risks in term of their impact on the project delay, and section three was related to risk allocation to either the contractor, the owner, or shared by both parties. The number of respondents used for the data analysis was 57, most of which were very experienced in the construction field. The ten top significant risks identified in the results of data analysis are 1. Delays in resolving contractual issues, 2. Delayed payment on contracts, 3. Political uncertainty, 4. Financial failure, 5. The scope of work definition, 6. War threats, 7. Suppliers/Subcontractors poor performance, 8. Change in work, 9. Defective design, 10. Labor and equipment productivity.

In Yemen, Issa et al. (2015) directed a research study on risk allocation and importance in the Yemeni construction industry. For the purpose of this study, fifteen experts and practitioners with more than 20 years of experience were selected to fill the questionnaire designed using the Delphi method. The Delphi method utilized in this research consisted of two rounds and all the selected experts participated in both rounds. The assessment had three purposes: to test the criticality of various risks according to their respective WRF, allocate each risk to the corresponding party and decide what action should be taken to face those risks. The risk factors were organized from the most to the least critical.

Despite the extensive literature available on the areas of risk management in projects and especially construction projects, the applicability of the integration between Fuzzy Logic and Multi-Criteria Decision-Making techniques remain questionable.

Multi-Criteria Decision-Making (MCDM) is a very important tool in the assessment and evaluation of various industry problems. MCDM is the process of evaluating all the alternative options and choosing one of them or prioritizing them based on their performance against preset criteria and attributes. Over the years, numerous methods have been developed to solve multiple attribute decision-making problems. One of the most significant tools in MCDM, and the one considered mostly used among all disciplines is the Analytic Hierarchy Process (AHP).

The AHP is a decision-making method developed by Thomas Saaty in 1971. It mainly aims at ranking alternatives in order to prioritize them. This is done by breaking down the problem into a hierarchy consisting of the goal sought-after, criteria and sub-criteria as well as alternatives. After that, the alternatives are evaluated against the multiple criteria identified by the means of pair-wise comparisons and accordingly each alternative is scored. Saaty suggested an appropriate scale for rating the human ability to measure subjective factors, ranging from 1-9 (Saaty 1982).

Another very important MCDM method is the Multi-Attribute Utility Theory (MAUT) which was first developed as an attempt to apply objective measurement to decision making. The basic hypothesis incurred in this method specifies that within any decision problem there is a real valued function or utility (U), defined by the set of feasible alternatives that the decision-maker seeks to maximize (Olson 1996). Each alternative results in an outcome, which may have a value on a number of different dimensions. MAUT seeks to measure these values, one dimension at a time, followed by an aggregation of these values across the dimensions through a weighting procedure. The simplest and most widely used aggregation rule is to take the weighted linear average. In this case, each weight is used in combination with each criterion value to produce the final utilities (Zietsman et al. 2006).

MCDM methods are typically evaluated using Classic Logic which permits only Boolean values of decision either true (1) or false (0) . However, it has been greatly argued in previous researches that human decisions are usually made based on imprecise and non-numerical information, therefore, Fuzzy Logic was introduced by Zadeh (1965) to capture the vagueness and imprecise information provided by decision-makers. The Fuzzy Logic represents the degree of truth of a decision made on a scale from 0 – 1 representing the extreme boundaries of a decision being completely false or completely true. Applying Fuzzy Logic to MCDM has proved to be of great benefit and reliability in evaluating human responses rather than Classic Logic-based methods.

Therefore, this paper is realized to fill this gap and apply two methods into assessing construction project risks that are Fuzzy Analytic Hierarchy Process and Fuzzy Multi Attribute Utility Theory which is considered a novelty of this study. In the following sections, the framework developed for identifying and evaluating the project risks as well as the results of the risks' prioritization are elaborately discussed.

3 METHODOLOGY

The process followed in this research started with an extensive literature review to identify the main causes of disputes in Egyptian construction projects which resulted in recognizing the main potential risks for such projects. Proceeding the review phase, the detailed research design plan was sketched out, and it was decided that survey questionnaires and one-to-one interviews would be used for gathering the data and opinions of experts in the construction field. In this research, it was the various construction risks evident in the construction market, their level of importance in a construction project and their impact and frequency that hold prominence to frame the survey questionnaire and structure the interview process. Data management and analysis were planned after receiving the completed questionnaires from the respondents followed by drawing conclusions about findings brought from data analysis. After all these processes, data validation is done through carefully analyzing case studies from actual construction projects and comparing them to our proposed framework results.

A flow chart of the research methodology is demonstrated subsequently in Figure 2 to get a clearer picture of the procedure that has been followed.

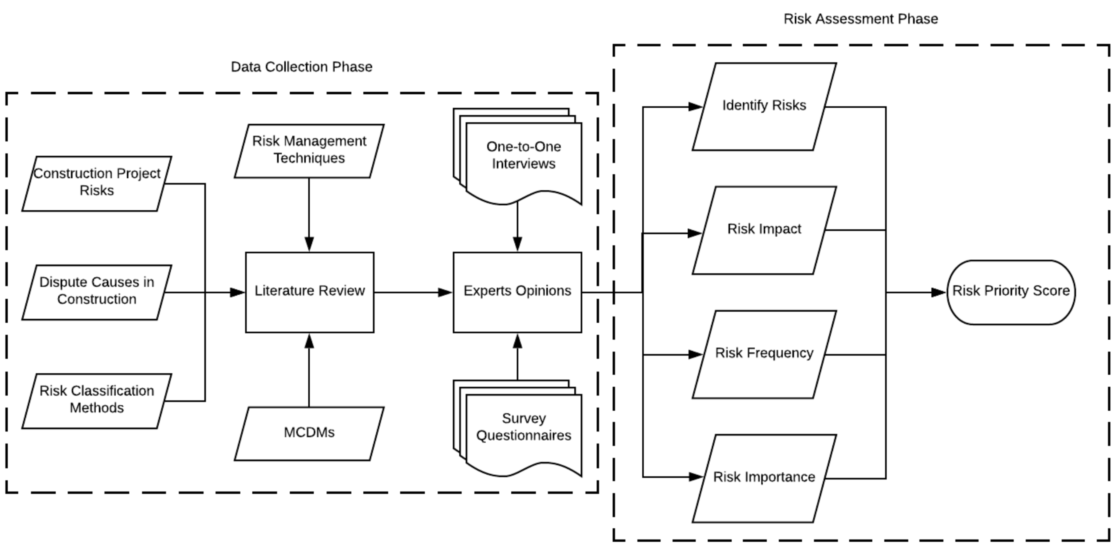

Figure 2 Overview of Research Methodology

3.1 Risk Identification

Based on the literature search and the opinions of the experts interviewed, the following risks were identified and grouped into six different clusters categorizing risks of relevant natures. The clusters developed are namely: Design Risks, External Risks, Organizational Risks, Project Management Risks, Legal Risks and Construction Risks. Those six clusters are further divided into a total of 37 risks that are most evident in Egyptian construction projects. A detailed illustration of the identified risks as well as the clusters they are part of is given in the following two tables, Table 1 and 2.

Table 1 Clusters of Risk Identified (Part 1)

Design	External	Organizational
- Change of design requirements by owners	- Stakeholders' improper intervention	- Delayed payment to contractors
- Defective design	- Acts of God	- Contractors' incompetence

- Deficiencies in drawings and specifications - Frequent changes in design by designers - Drawings and documents not issued on time	- War threats and political instability - Corruption and bribes - Criminal acts - Inflation and sudden changes in prices - Currency fluctuation - Unexpected inclement weather - Owner's sudden bankruptcy	- Lack or departure of qualified staff - Labor strikes and disputes - Conflicts due to differences in culture - Unfairness in tendering - Delays in resolving disputes - Owner's breach of contracts and disputes - Subcontractors' breach of contracts

Table 2 Clusters of Risks Identified (Part 2)

Project Management	Legal	Construction
- Lack of scope of work definition - Unreasonably imposed tight schedule - Poor quality of work - Delay of material supply by suppliers - Quality problems of supplier material	- Changes in laws and regulations - Delays in obtaining site access and right of way - Difficulty in claiming insurance compensation	- Accidents during construction - Low productivity of labor and equipment - Unpredicted technical problems in construction - Subcontractors' poor performance - Shortage in manpower supply and availability - Unforeseen site conditions

3.2 Risk Assessment Framework

The framework developed as part of this study helps identify the main risks evident and experienced in Egyptian construction projects and assess those risks according to several factors. In this section, the developed framework is discussed along with the methods used for calculation purposes of the various indicators for risk evaluation.

3.2.1 Risk Importance

The primary step in the framework presented in this study is to assess the importance index (II) of the risks identified in the literature search and the experts' survey. An importance index is generated for each identified risk based on the risks' significance in the construction project and its effect on causing disputes if not resolved and dealt with. This indicator is evaluated based on the perceptions of the surveyed experts from their point of view and experience in previous construction projects. Each expert is given a value representing the weight given to his answers to the survey, based on their experience, knowledge and background as shown in the equation below, Equation 1.

[1] II = $\sum_{i=1}^{n} ai\ x\ ei$

Where II: the Importance Index for each risk factor, n: Number of experts interviewed, a: the Level of Importance of the risk factor as perceived by Expert "i", and e: is the Weight given for Expert "i" based on his background and experience as compared by other experts included in this study.

The Importance Index for each risk factor is evaluated on a 5-point scale by means of a pair-wise comparison between the identified risk factors. And the final weights for the risk factors are calculated by means of a Fuzzy Analytic Hierarchy Process (F-AHP) method developed by Aydin and Kahraman (2013) as an improvement of the original AHP method developed by Saaty (1982). The scale used for the F-AHP method is presented in Table 3.

Table 3 Importance Index Pair-Wise Comparison Scale

Rating Scale		Linguistic Description
	(0,0,0)	Just Equal
1	(0,1,3)	Equally Important
3	(1,3,5)	Moderately More Important
5	(3,5,7)	Strongly More Important
7	(5,7,9)	Very Strongly More Important
9	(7,9,9)	Extremely More Important

After the weights are calculated, the consistency ratio is then determined in order to verify the assigned weights. Weights are assigned to components only if the Consistency Ratio (CR) has a value less than 0.1.

3.2.2 Risk Impact

The second step in the risk assessment process adopted in this study is the evaluation of the impact value (IV) of each of the identified risks in the case of their occurrence in a construction project. This is done by means of a 5-point Likert scale that measures the effect of the risks on the project performance metrics and success factors on the basis of four different criteria, namely: Cost, Schedule, Safety and Quality as shown in Table 4.

Table 4 Risk Impact Rating Scale

Scale	Cost	Schedule	Safety	Quality
Catastrophic	> 20 %	> 15 %	Fatality	> 10 %
Major	15 – 20 %	10 – 15 %	Severe Injury	8 – 10 %
Moderate	10 – 15 %	5 – 10 %	Medical Treatment	5 – 8 %
Minor	5 – 10 %	1 – 5 %	First Aid	2 – 5 %
Negligible	< 5 %	< 1 %	No Injury	< 2 %

The method used in this fragment of the study is a Fuzzy Multi-Attribute Utility Theory (F-MAUT) method that is developed by Kahraman and Kaya (2012). The F-MAUT method used assesses the weights of each of the four criteria first using the traditional AHP method (Saaty 1982), and then gives fuzzy rating to each of the alternatives (risks) with respect to each of the four criteria/attributes.

3.2.3 Risk Frequency

The following step in the risk assessment framework developed is to assess the frequency value (FV) of each of the identified risks based on their probability of occurrence as per the experts judgements. The same F-MAUT method and the exact course of action of the Risk Impact Assessment is followed in this part as well. However, the measuring scale is different due to the different nature of the evaluation purpose. The rating scale for the frequency of each of the risks is given in Table 5.

Table 5 Risk Frequency Rating Scale

Scale	Frequency	Probability
Extremely Frequent	1 in 2 Projects	>= 50%
Frequent	1 in 4 Project	>=25%
Common	1 in 10 Projects	>= 10%
Unlikely	1 in 20 Projects	>= 5%
Extremely Rare	1 in more than 20 Projects	< 5%

3.2.4 Risk Priority Score

The final step in the risk analysis process is the calculation of a priority index for each of the identified risk factors based on their importance, impact and frequency levels as shown in Equation 2. The Risk Priority Score (RPS) is calculation by multiplying the previously attained indicators to get the RPS value for each risk.

[2] RPS = $II \ x \ IV \ x \ FV$

where RPS is the Risk Priority Score, II is the Importance Index, IV is the Impact Value and FV is the Frequency Value.

4 MODEL IMPLEMENTATION RESULTS

One hundred and eighty four key personnel were invited to participate in the surveying process. Project managers, contractors, consultants, contracts specialists, owner representatives, developers and planning engineers were requested to fill the survey questionnaire online as mailing the questionnaires didn't turn out to be a worthwhile option. The response rate initially was very lethargic and later on gained momentum as key personnel were met personally to get their responses. This study was concentrated in Cairo, Egypt as collecting responses from other areas in Egypt would have resulted in greatly variant responses due to the differences in environmental conditions between Cairo and other places as well as the variation in the business natures and conditions. A total response rate of 41.3% was achieved in the due course of data collection.

4.1 Risk Importance Weights

The importance of each of the thirty-seven identified risks is measured as per the pair-wise comparison between the different risk factors inside each category of the six identified categories. The importance weights are calculated using the F-AHP method where local and global weights are obtained. The global weights are further used in a later section to calculate the overall priority of each of the risk factors. A sample of the weights developed for the Project Management cluster and its constituents is given in Table 6.

Table 6 Importance Weights for the Project Management Cluster

Cluster	Risk Factors	Local Weights	Global Weights
Project Management 18%	Lack of scope of work definition	28%	0.0504
	Unreasonably imposed tight schedule	17%	0.0306
	Poor quality of work	32%	0.0576
	Delay of material supply by suppliers	17%	0.0306
	Quality problems of supplier material	6%	0.0108

4.2 Risk Impact Results

The impact of each of the identified risks is evaluated based on the F-MAUT discussed in the methodology. Upon calculating the Impact Values (IV), it was evident that the most serious risk factor is the risk of War Threats and Political Instability, while the risk with the least effect on the construction project with respect to the four criteria of evaluation is the risk of Frequent Changes of Design by Designers. The next figure illustrates all the results developed as part of the Impact Value calculation process. (Figure 3)

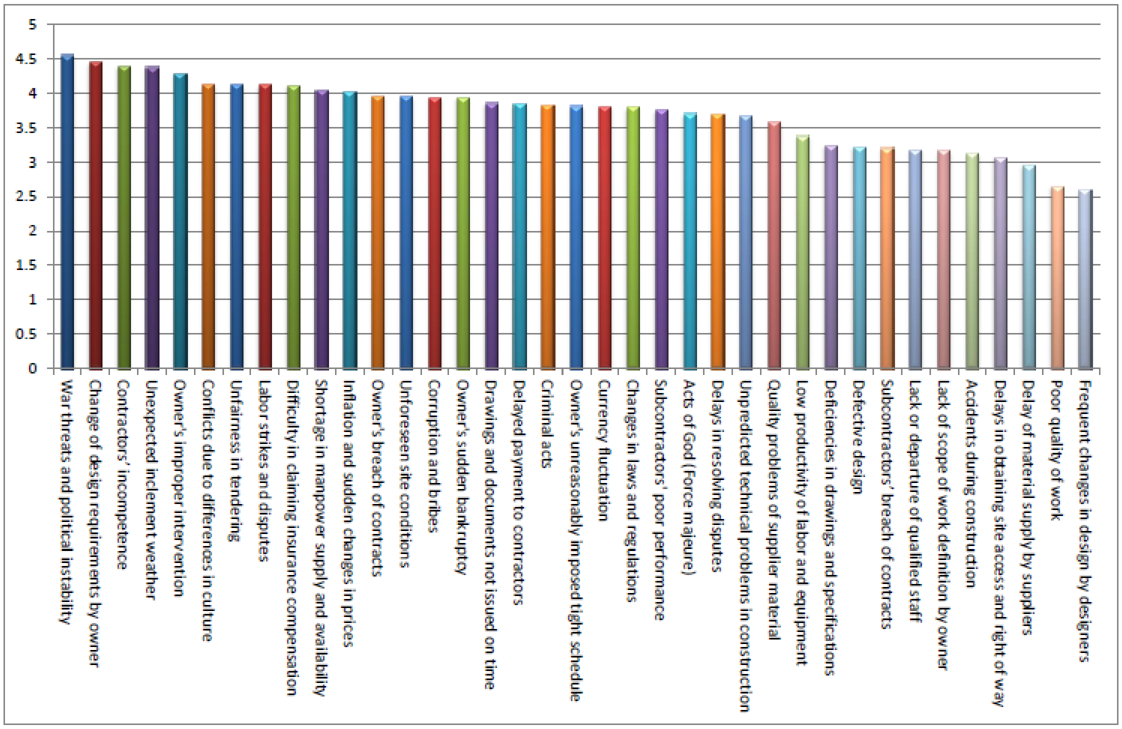

Figure 3 Impact Value Results for all the Risk Factors

4.3 Risk Frequency Results

Consequently, the frequency of occurrence of each of the identified risks is evaluated based on the F-MAUT discussed in the methodology. Upon calculating the Frequency Values (IV), it was evident that the most frequent risk factor in the Egyptian construction industry is the risk of Change of Design Requirements, while the risk with the least probability in the construction projects is the risk of a Force Majeure. The frequency predicted for all the risk factors is illustrated in Figure 4.

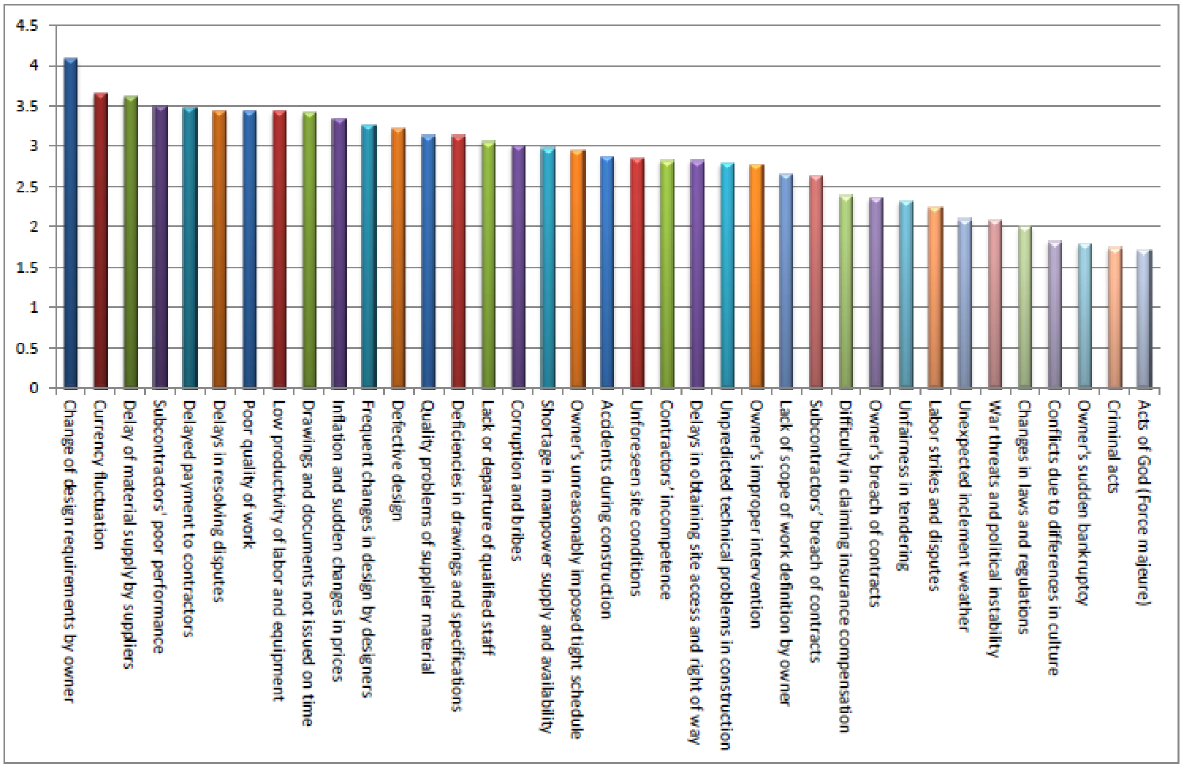

Figure 4 Frequency Value Results of the identified Risk Factors

5 CONCLUSION

To recall and sum up, the overall purpose of this study was to shed the light on practices of risk identification, assessment and management in the construction industry of various countries as a means to minimize disputes in the construction industry and applying them in Egyptian construction projects through a survey questionnaire aiming at key personnel in the construction field like owner representatives, contractors, consultants and contracts administrators. The survey questionnaire was developed for various reasons, to identify the most experienced risks in the Egyptian construction industry and assess the perceptions of the construction industry experts of risk frequency and impact evaluation as well as risk importance index calculation. The analysis of the results ranked the risks based on different factors by means of methods integrating the multi-criteria decision making techniques with fuzzy logic which has not been considered before in construction project risk assessment and analysis. A Fuzzy AHP method is used for weighing the importance of the different risk factors identified, while a Fuzzy MAUT method is used for assessing the risk frequency and impact values. This framework is expected to be a very useful tool for project managers and decision makers in controlling and mitigating the project risks as it presents an efficient prioritization tool for the project risks that can be beneficial for risk response process and risk avoidance and prevention as well.

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