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Quantifying Owner-Builder's Risks in Egyptian Construction Projects using AHP and Multilevel Fault Tree and Event Tree

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Abstract: This paper presents a framework for quantifying Owner-Builder's risks in the Egyptian construction projects. The framework combines three approaches to assess the risks and their root causes: 1) the Analytical Hierarchy Process (AHP) and Relative Importance Index (RII) prioritization techniques; 2) Fuzzy Fault Tree Analysis; and 3) Fuzzy Event Tree Analysis. First, literature review and experts' interviews are conducted to identify critical risk events and their root causes for Egyptian construction projects. Second, the AHP combined with RII identifies and prioritizes the critical risk events. Third, the fuzzy fault tree calculates the fuzzy probability of failure of critical risk events affecting the Egyptian construction industry and detects their root causes and probability of occurrence. Fourth, the fuzzy event tree calculates the Expected Monetary Value (EMV) of each critical risk event. Consensus on root causes of critical risk event and logical representation of the fault tree are achieved through a two-step Delphi technique with experts. Different root causes of critical risk event are prioritized according to their importance to its probability of occurrence, using fuzzy importance analysis. The concepts forming this framework can be generalized and applied to other countries by changing related risk events and their relative experts' opinions. The framework solves a major problem that faces construction project teams in prioritizing and assessing risk events, linguistically, in their projects prior to the start of construction phase, using fuzzy set theory.

Keywords: Fuzzy Sets, Fuzzy Fault Tree, AHP, Risk Management, and Fuzzy Importance Analysis.

1 Introduction

Project Management Institute (2008) defined a project risk management process as an integrated cycle of risk identification, qualification, quantification, and response planning and control. The importance of risk management is magnified in an industry that has a significant level of uncertainty, such as the case of building construction. Construction industry plays an important role in flourishing the economy of developing countries. For instance, the Turkish Construction Industry grew large in the year 2011 and reached60.5 Billion USD, which was about4.7% of the national Growth Domestic Product (GDP) in 2011 (The World Bank, *2011*). The Indian building construction sector contributed to 6% of its GDP in 2011 (Sahni2012). The Indian building construction market grows annually at14 %. Unlikely, there is no adequate research that addresses the process of quantification of Owner-Builder's construction risks in most developing countries, especially in Egypt. Thus, there is a demand to develop a framework to assess those risks in developing countries with specific focus on Egypt case in order to avoid the imprecision and vagueness inherited in the risk analysis process.

Few research studies were conducted to model general risks in the Egyptian construction industry. For example, Zabaal (2007) studied risk management for infrastructure projects in Egypt. Also, Eraky (2011) studied risk management of Ministry of Interior construction projects in Egypt. The research area of risk assessment using the fault tree analysis has been tackled by many international researchers. For example, Abdelgawad and Fayek (2011) studied the risk assessment process in the construction industry using fuzzy fault tree analysis by considering two main analysis stages. The first stage involved performing qualitative fault tree analysis to determine the minimal cut set equations of basic events. The second stage applied fuzzy arithmetic operations to calculate the probability of occurrence of top events through assessing the probability of occurrence of basic events. This work; however, is criticized because it did not provide a clear methodology for calculating experts' importance weights, which impacts the quality of their risk prioritization decision. Similarly, Captuo et al. (2004) studied water supply risks using dynamic fault tree analysis. Kim et al. (2005) studied risk assessment of Liquefied Natural Gas (LNG) storage tanks in Korea using fault tree. Liang et al. (2012) assessed and classified risks of pipeline projects in China using fault tree analysis.

Schachner (1994) defined an Owner-Builder as a person who owns the property and acts as a general contractor on the job, and either does the work himself or has employees (or subcontractors) working on the project. He also stated that an Owner-Builder has a full responsibility of all relevant risks to sub-contractors, suppliers, project schedule, and project financing, which necessitates conducting a detailed risk quantification process to ensure minimizing risk impact on the project goals. Most often, Owner-Builders have difficulty in evaluating construction risks quantitatively in construction projects. They need to assess the cost of their projects in different scenarios when the probability of occurrence of a risk event is uncertain. Thus, the expected monetary value (EMV) of each risk event is assessed to accommodate the consequences of risk events. This paper proposes a fuzzy quantitative risk analysis framework, which combines the Analytical Hierarchy Process (AHP), Relative Importance Index (RII) ranking, and fuzzy fault and event trees analysis to assess construction risk events in building construction projects for Owner-Builders. The framework assists Owner-Builders in identifying the critical root causes of risk events and conducting fuzzy importance analysis using fault trees. It also helps building construction teams in determining experts' importance weights in prioritizing critical risk events. Moreover, it assists risk management experts in determining the allowance of the mitigation strategy of the potential risk event by computing the expected monetary value (EMV) of each risk event, using event tree analysis. Also, instead of using Uniform membership functions to determine the linguistic probability of occurrence of risks (Abdelgawad and Fayek 2011), the proposed framework introduces the Guassian Membership Function because it is simpler in implementation, it allows for a variety of shapes, and it provides more flexible representation of fuzzy values.

2 Risk Quantification Framework

The proposed framework combines three approaches to assess the Owner-Builder Construction risks and their root causes: the Analytical Hierarchy Process (AHP) and Relative Importance Index (RII) ranking, Fuzzy Fault Tree, and Fuzzy Event Tree (Figure 1).

2.1 Analytical Hierarchy Process (AHP) and Relative Importance Index (RII) Ranking

The Analytical Hierarchy Process combined with Relative Importance Index (RII) ranking are used to identify and prioritize critical Owner-Builder risk events impacting building construction projects in Egypt. This component of the framework is composed of three steps: identify critical risk events and their groups, create linguistic scale and develop questionnaire to collect expert opinions, and apply AHP and RII algorithms to prioritize construction risk events.

2.1.1 Identify Critical Risk Events and their Groups

Twenty Two construction risks relevant to Owner-Builder were identified using literature review and interviews with ten experts each of them had twenty years of experience in building construction projects. Experts also agreed that Owner-Builder's risks can be divided into six categories: geo-technical risks, area conditions risks, governmental risks, management risks, labour risks, and financial overburden risks (Table 1).

2.1.2 Create Linguistic Scale and Collect Experts' Opinions

In this step, a survey-based questionnaire was designed to assist experts in ranking risks based on their probability of occurrence in building construction projects, using a five-point Likert scale (Saaty 1980). The scale ranged between (1) *Very Low* and (5) *Very High*, while the term (3) *Medium* was placed as a midterm value on the scale. Moreover, the questionnaire included a section that contained experts' demographic information that defined five qualification criteria of experts: Q1: Years of experience in building construction projects, Q2: Years in Conducting Risk Management, Q3: Role in company, Q4: Academic record, and Q5: Diversity of experience. Table 2 illustrates experts' qualifications criteria and their weights, while Table 3 lists experts' qualifications and their attributes.

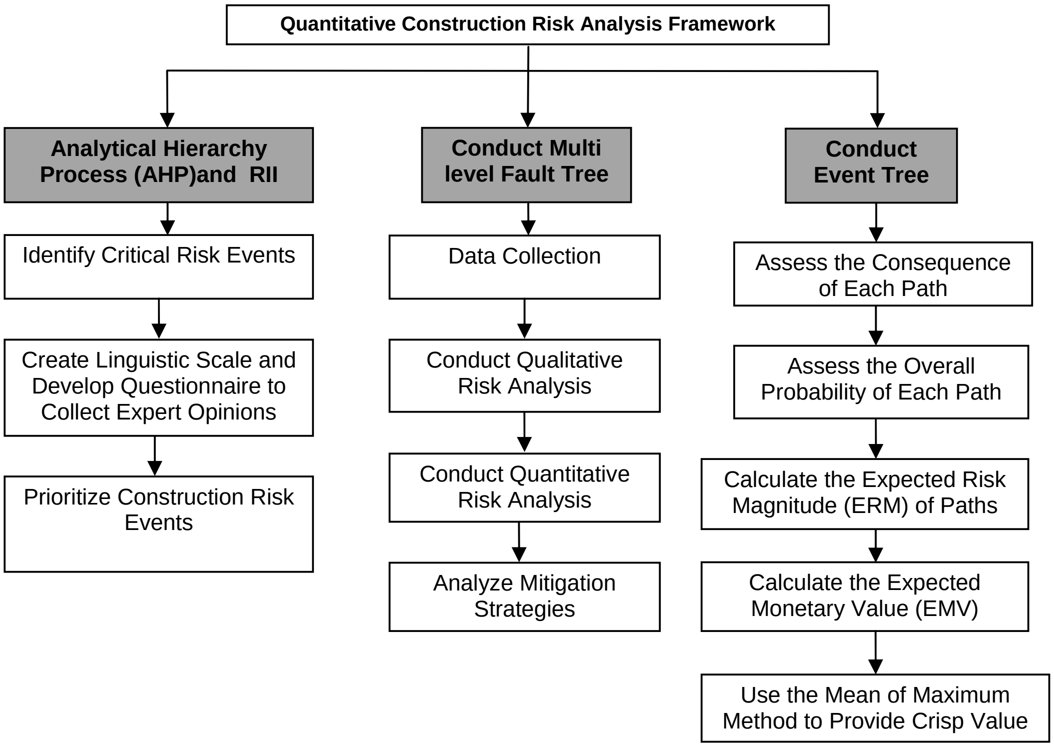

Figure 1: General Methodology and Detailed Steps of the Framework

Table 1: Owner-Builder Critical Risk Events

Risk ID	Risk Category	Risk ID	Risk Category
Group (1): Geo-Technical Risks		11	Damage or Failure Risks.
1	Unexpected Sub-Surface Conditions.	12	Safety and Health Risks.
2	Inadequate Experience of Geo-technical Consultant.	13	Insufficient Time to Execute the Project.
Group(2): Area Conditions Risks		*Group(5): Labour Risks*	
3	Bad traffic Conditions around the site.	14	Low Skill Level of Labour.
4	Restrictive Conditions on the site.	15	Shortage of Labours
Group(3): Governmental Risks		16	Poor Labour Productivity
5	Failure to Obtain Approvals and Permits.	17	Unavailability of Qualified Subcontractors.
6	Project Delayed or Stopped or Abandoned.	*Group (6): Financial Overburden Risks*	
7	Difficulty to Transfer or Obtain Utilities.	18	Increase in Labour Wages
Group (4): Management Risks		19	Increase in the Price of Raw Materials.
8	Defective Works.	20	Increase in the Cost of Equipment.
9	Improper Data and Information.	21	Increase in the cost of purchasing Land
10	Lack of Project Management.	22	Shortage of Financially Credible subcontractors.

Table 2: Experts' Qualifications Criteria and their Respective Weights

Q1: Years of Experience	Q2: Years of Experience in Risk Management	Q3: Role in Company	Q4: Academic Record	Q5: Diversity of Experience
16-20 Years(1.0)	16-20 Years(1.0)	Site Engineer (0.2)	Ph.D. (1.0)	Very High (1.0)
11-15 Years(0.8)	11-15 Years(0.8)	Senior Engineer (0.4)	Master(0.6)	High(0.8)
6-10 Years(0.6)	6-10 Years(0.6)	Project Manager (0.6)	Bachelor (0.4)	Medium(0.6)
1-5 years(0.4)	1-5 years(0.4)	Consultant (0.8)	Diploma(0.2)	Low(0.4)
Less than 1 year(0.2)	Less than 1 year(0.2)	Principal (1.0)		Very Low(0.2)

Table 3: Experts' Qualifications (Attributes)

Expert No.	Q1: Years of Experience	Q2: Years in Risk Management	Q3: Role in Company	Q4: Academic Record	Q5: Diversity of Experience
1	16-20	16-20	P.Manager	Master	V .High
2	1-5	1-5	S.P.Engineer	Bachelor	V .High
3	16-20	16-20	P.Manager	Master	Average
4	16-20	16-20	P.Manager	Master	Average
5	16-20	16-20	S.P.Engineer	Master	Average
6	11-15	11-15	S.P.Engineer	Bachelor	V .High
7	16-20	16-20	P.Manager	Bachelor	V .High
8	16-20	16-20	P.Manager	Master	V .High
9	11-15	11-15	P.Manager	Bachelor	V .High
10	6-10	6-10	P.Manager	Master	Average
11	6-10	6-10	S.P.Engineer	Bachelor	Average
12	11-15	11-15	P.Manager	Bachelor	Average
13	11-15	11-15	P.Manager	Bachelor	Average
14	16-20	16-20	S.P.Engineer	Master	Average
15	16-20	16-20	P.Manager	Master	Average
16	16-20	16-20	P.Manager	Bachelor	V .High
17	6-10	6-10	P.Manager	Master	V .High
18	6-10	6-10	P.Manager	Bachelor	V .High
19	6-10	6-10	P.Manager	Bachelor	V .High
20	1-5	1-5	S.P.Engineer	Bachelor	V .High
21	1-5	1-5	S.P.Engineer	Bachelor	V .High
22	1-5	1-5	S.P.Engineer	Bachelor	V .High
23	16-20	16-20	P.Engineer	Master	V .High
24	1-5	1-5	S.P.Engineer	Bachelor	V .High
25	6-10	6-10	P.Manager	Bachelor	V .High

2.1.3 Prioritize Owner-Builder Construction Risk Events

In this step, The Analytical Hierarchical Process (AHP) in Multi Criteria Decision Making (Saaty, 1980) was used to determine the importance weights of experts participating in the risk evaluation process, while RII ranking was utilized to prioritize the risks, based on both the risk rating of the experts (step 2) and their computed importance weights that is determined by the AHP approach. The two approaches are simple and can provide subjective and objective assessments of multiple factors (Elbarkouky et al., 2012).

Five specialists in the field of human resource (HR) management and recruitment in Egypt helped conducting the pair-wise comparison method to determine the relative importance weight (r_k) of each of the five qualification criteria. A five-point preference scale was introduced to the HR experts to rank the factors relative to each other, using a standard preference matrix. The cardinality values of the scale ranged between (1) Equal Preference and (5) Extremely Preferred. The terms: (2) Slightly Preferred, (3) Preferred, and (4) Very Much Preferred were used as intermediate values. Table 4 illustrates the the eigenvector elements of the matrix that represents the average ratings of the five experts, where n is the number of rows or columns of the matrix computed using the n^{th} root of product method (Saaty, 1980).

Table 4: Values of the eigenvectors of the AHP method

Criteria	Q1	Q2	Q3	Q4	Q5	nth root of product	Eigenvector
Q1	4	4	5	4	4	4.183	0.237
Q2	4	4	4	4	4	4.000	0.227
Q3	3	4	4	3	3	3.366	0.191
Q4	4	3	3	3	3	3.178	0.180
Q5	4	3	3	2	3	2.930	0.166
Total						17.657	1.000

In order to calculate the relative importance weight factor (w_i) of an expert (i), the subjective weights (g_{ji}) of his or her attribute values are multiplied by the relative importance weights (r_k) of each respective criterion and the sum of the products is normalized to determine w_i, which ranges between 0 and 1as illustrated in Equation 1.

$$[1]\mathrm{W}i = \sum_{k=1}^{n} rk * \ gji$$

Where *gji* is the subjective weight of expert's *(i)* individual attributes (*j*) and r_k is the relative importance weight of each respective criterion. This value is normalized within the *Wi* values of any set of experts participating in the evaluation process of risk events to obtain a relative importance weight value *wi* of each of these experts. For example, Expert 1 (project manager) who has a Master degree; 16 to 20 years of experience; the same number of years in risk management; and whose diversity of experience is very high, his importance weight can be assessed using Equation 2 as follows:

[2] *W1*=1*0.237+1*0.227+0.6*0.191+0.6*0.18+1*0.166=0.889.

Table 5 illustrates the importance weights and relative importance weights for experts participated in the risk analysis process.

Table 5: Importance Weights and Relative Importance Weights

Expert No.	**Importance Weight**	**Relative Importance Weight**	**Expert No.**	**Importance Weight**	**Relative Importance Weight**
1	0.889	0.050	14	0.784	0.044
2	0.360	0.020	15	0.822	0.047
3	0.822	0.047	16	0.853	0.048
4	0.822	0.047	17	0.703	0.039
5	0.784	0.044	18	0.667	0.038
6	0.814	0.046	19	0.667	0.038
7	0.814	0.046	20	0.536	0.020
8	0.889	0.050	21	0.536	0.020
9	0.760	0.043	22	0.536	0.020
10	0.640	0.036	23	0.812	0.046
11	0.562	0.032	24	0.536	0.030
12	0.693	0.039	25	0.667	0.038
13	0.693	0.039	Total	17.659	0.968

The average rating of the twenty five experts (Table 3) who participated in the process of prioritizing risk events was computed. Equation 4 illustrates the RII_j computation to rank the twenty two risks (j).

$$[3] RIIj = \sum_{i=1}^{n} Wi\ yj/z$$

Where, W*i* is the relative importance of experts participated in the process of determining the Owner-Builder Construction Risks y_j is the rating score assigned to each risk event (*j*) by each expert (*i*) on the Likert scale from 1 to 5, and *z* is the highest possible rating value of the Likert scale (Saaty 1980), which is 5 in this case. The *RII* value has a range between 0 to 1 (0 not inclusive), such that the higher its value, the more important the risk event is. Table 6illustrates the average rating of the construction risk events and their *RII* rank.

Table 6: Prioritization of Critical Risk Events

Risk ID	Risk Events	Average Rating	RII	Rank
20	Increase in the Cost of Equipment	4.818	0.933	1
19	Increase in the Price of Raw Materials	4.727	0.916	2
18	Increase in Labour Wages	4.636	0.898	3
22	Shortage of Financially Credible Contractors	4.454	0.863	4
15	Shortage of Labours	4.363	0.845	5
16	Poor Labour Productivity	4.090	0.792	6
7	Difficulty to Transfer or Obtain Utilities	4.000	0.775	7
12	Safety and Health Risks	3.727	0.722	8
4	Restrictive Conditions on the site	3.454	0.669	9
6	Project Delayed or Stopped or Abandoned	3.181	0.616	10
14	Poor Labour Skill Level	3.181	0.616	10
1	Unexpected Sub-Surface Conditions	3.090	0.598	11
3	Bad traffic Conditions around the site	2.909	0.563	12
5	Failure to Obtain Approvals and Permits	2.818	0.546	13
11	Damage or Failure Risks	2.454	0.475	14
17	Unavailability of Qualified Contractors and Sub-contractors	2.454	0.475	14
2	Inadequate Experience of Geo-technical Consultant	2.000	0.387	15
13	Insufficient time to execute the project	2.000	0.387	15
21	Increase in the Cost of Purchasing Land	1.900	0.369	16
8	Increase in Defective Works	1.818	0.352	17
9	Improper Data and Information	1.727	0.334	18
10	Lack of Project Management	1.272	0.246	19

Based on the (20/80) Pareto Principle, which states that roughly 80% of the impact can be derived from 20% of the causes (Fernández-Sánchez and Rodríguez-López 2010), the highest five critical risk are introduced to subsequent stages of risk quantification (Multilevel Fault tree and Event Tree).

2.2 Conduct Multilevel Fault Tree

The main aim of the Multilevel Fault Tree model is to compute the probability of failure of a risk event and select the most critical root cause that leads to the failure of the risk event. Moreover, the model allows establishing mitigation strategies for critical root causes in order to determine the probability of failure or success of mitigation strategies. The model is composed of four main stages as it is described below.

2.2.1 Data Collection Stage

The first stage of the Multilevel Fault Tree is data collection. This stage is divided into two steps: collect root causes for each critical risk event, and establish linguistic term to assess the probability of occurrence of each critical risk event. The collect root causes step is concerned with defining the root causes for each critical risk event and the failure of mitigation strategies using various techniques, such as interviews, Delphi, brainstorming and checklists. The two-step Delphi technique is used to achieve consensus among experts to establish linguistic terms to assess the probability of occurrence of each critical risk event. Fuzzy linguistic terms were defined through interviews with fifteen experts each of them had an experience of twenty years in Building Construction Development Projects. Experts agreed to utilize a five point scale: Very Low (VL), Low (L), Medium (M), High (H), and Very High (VH) in order to assess the probability of occurrence of each risk event and suggested using the standard quasi-Gaussian Membership Function to represent the linguistic terms of the scale, which was also recommended by Stefanini and Sorini (2009). Figure 2 illustrates the final shape of the membership function for the probability of occurrence as proposed by experts.

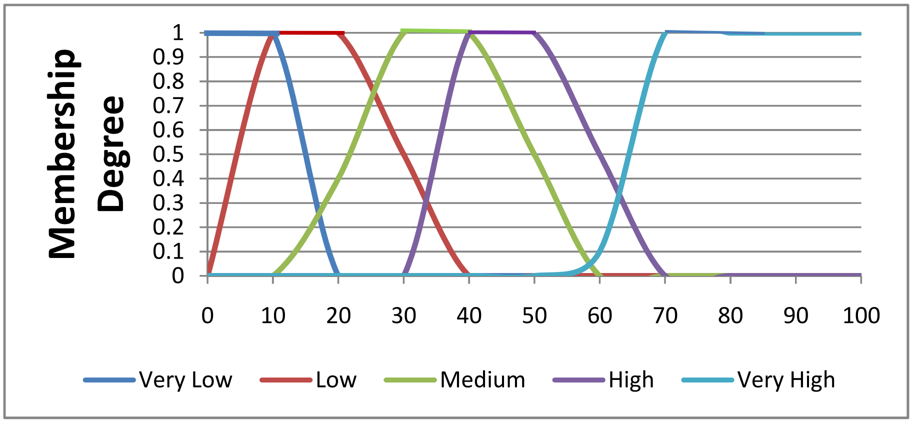

Figure 2: Final Shape of the Membership Function "Probability of Occurrence"

2.2.2. Conduct Qualitative Risk Analysis

This stage assesses the fuzzy probability of occurrence of basic events, obtained from Stage 1, and identifies the minimal cut sets (MCS), using Hauptmanns' (1988) algorithm. Ayyub (2003) defined a minimal set (MCS) as *"a cut set with the condition that the non-occurrence of any one basic event from this set results in the non-occurrence of the top event."* The minimal cut set equation is determined using the following two main rules:

1- If the top event is connected by an OR gate with its basic events then insert each event from the CL into a separate row in a Working Boolean Matrix.

2- If the top event is connected by an AND gate with its basic events, then insert all the events from the CL into a single row in a Working Boolean Matrix. For further details on Qualitative Risk Analysis using Fault Tree, please refer to Abdelgawad and Fayek (2011).

2.2.3 Conduct Quantitative Risk Analysis

The objective of this stage is to determine the Fuzzy Probability of risk events and determine the most critical root cause that contributes most to the failure of risk event. The procedure to achieve that is as follows:

1- Convert the Membership Function in Figure 2 into a triangular membership function using expert judgment by interviewing the fifteen experts. Experts were asked "*Based on your experience in Owner-Builder Construction Project, what are the ranges of elements (xi) that may represent this linguistic term on the attached membership function? Please circle as many answers as applicable*".

2- Compute a value for m, where m is the mean value of the triangle (Stefanini et al.2006).

3- Find the major and minor triangle fuzzy numbers using the criterion of dominance (Kaufman and Gupta 1988).

4- Select m*, which is a major triangle fuzzy number, and m_*, which is a minor Fuzzy number of the triangle.

5- Calculate the pessimistic possibility of failure (m_F) of risk event (OR case) associated with m* using Equation 4, where A,B, and C are different root causes.

[4] $m_F=1-(1-m_A)(1-m_B)(1-m_C)$

6- Calculate the optimistic possibility of failure (m_F) of risk event (AND case) associated with m_{*}, using the Equation 5:

[5] $m_F= m_{A*}m_{B*}m_C$

7- Defuzzify the top event fuzzy probability using the mean of maximum (MOM) method since the mean of maximum can be viewed as the most suitable method to estimate the fuzzy probability of top event (Abdelgawad 2011). The Fuzzy Possibility of top event can be computed as the value of the optimistic value plus the value of the pessimistic value divided by 2.

8- Conduct a fuzzy importance analysis to identify the most critical root causes (Basic Events) using Equation (6) (Khan and Abbasi 1999):

[6]$FIM=((TE_1-TE_2)/TE_1)*100$

Where TE_1 is the top event fuzzy possibility, assuming that all root causes will occur, and TE_2 is the top event fuzzy possibility, assuming each root cause is eliminated in turn (Abdel gawad and Fayek 2011).

2.2.3.1 Numerical Example

To simplify the previous equations, let us assume that there are three experts E1, E2, and E3, and assume that experts' choices of the triangular fuzzy number memberships were as follows: E1(0.6,0.7,1.0), E2(0.4,0.45,0.52),and E3(0.7,0.8,0.85). Thus, $m_1=(0.6+0.7+1.0)/3=0.767$, $m_2=0.457$, and $m_3=0.783$. Then, the highest value of the three averaging values m*=0.783and the lower of the three averaging values $m_* =0.457$. Now assume that a risk event A has two root causes B and C. B is connected to the top event using OR Gate, and has two root causes D and E. C is connected to the top event using AND Gate and has two root causes F and G. Equations (7 through 10) illustrates the computations of the major and minor fuzzy numbers (m*,and m_*), and Fuzzy Probability of Failure of root cause (A):

[7]$m_D=0.767,m_E=0.788,m_F=0.45,m_G=0.457.$

[8] $m_fB=(1-(1-m_D)(1-m_E)) =(1-(1-0.767)(1-0.788))=0.951$

[9] $m_fC=(m_f*m_g)=(0.45*0.457)=0.21$

[10]$F_{pro}A=(m_fB+m_fC)/2=(0.951+0.21)/2=0.581=58.1\%$

The F_{Pro} (A) value indicates that the Fuzzy Probability of Failure of root cause (A) is 58.1%.

2.2.4 Analyze Mitigation Strategies

Each identified mitigation strategy is then analyzed by considering the possibility of failure of mitigation strategies to the top event, and repeating steps for stages of data collection, qualitative and quantitative Fuzzy Fault Tree.

2.3 Fuzzy Event Tree

After conducting quantitative fault tree analysis for the critical risk events under analysis, and to determine the failure of identified mitigation strategies, fuzzy event tree analysis for each risk event is performed to obtain a value of the Expected Monetary Value (EMV) as follows:

1- Define the linguistic term to assess the impact of the risk event. Interviews were held with fifteen experts, each of them had twenty years of experience in building construction Development Projects to define the linguistic term to represent the impact of the risk event. The modified horizontal approach with interpolation technique was used to build the membership function (Elbarkouky and Fayek 2011). Figure 3 illustrates the Membership Function of the Consequences.

2- Use the fuzzy probability of the critical risk event and the fuzzy probability of failure of each mitigation strategy according to the findings from the fuzzy fault tree analysis to compute the Expected Risk Magnitude (ERM) and the Expected Monetary Value (EMV) for risk events under analysis.

3- Define the fuzzy probability of success of each mitigation strategy, where the Fuzzy Probability of Success equals 1 minus the Fuzzy Probability of Failure.

4- Construct the event tree structure based on the findings of step 2, and 3.

5- Assess the consequence (C) of each path using the linguistic terms created in the first step.

6- Determine the overall probability (OP) of each path by multiplying the fuzzy probability of all events located on the same path.

7- Multiply the (OP) of each path with the estimated consequence (C) of each path to compute the Expected Risk Magnitude (ERM) of each path.

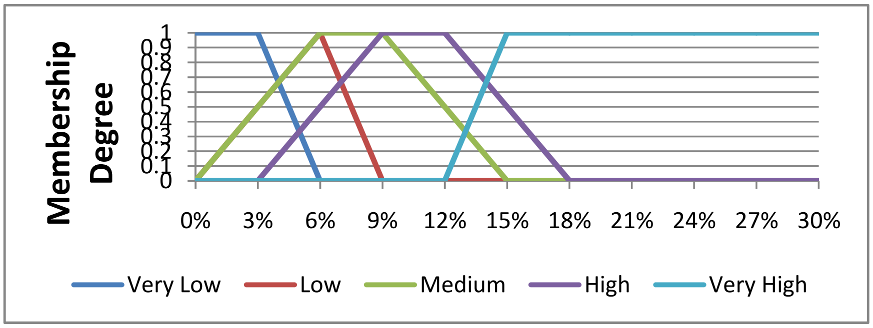

Figure 3: Final Shape of the Membership Function "Consequence"

Table 7 lists the Expected Monetary Value (EMV) for each risk event, and the Fuzzy Probability of Risk Events after conducting the previous approach.

Table 7: EMV for Different Risk Events

Risk Event	**Percentage of EMV**	**Fuzzy Probability of Risk Events**
Increase in the Cost of Equipment	5.682	95%
Increase in the Price of Raw Materials	2.509	99%
Increase in Labour Wages	1.809	87%
Decrease in the Existence of Financially Credible Contractors	1.448	96%
Shortage of Labours	1.309	87%
Total	**12.757**	

2.4 Case Study

The Egyptian Real Estate market plays a vital and crucial role in raising the Egyptian national income. According to a recent study regarding the importance of the Real Estate market in Egypt (Alexandria

Bank Research Paper 2012), the Real Estate Sector contributed to the Egyptian Growth Domestic Product (GDP) with thirty four Billion Egyptian Pounds in 2011, which amounts to 2.63 percent. Also, the Egyptian Ministry of Housing and New Developing Societies announced that Egypt has a housing Deficit of five million units that need to be built sooner. As a result of the Egyptian Revolution of January 2011 and Egyptians' unrest, the Egyptian President and Cabinet were obliged to resign and the Egyptian Economy continued to further deteriorate. Rate of Inflation, Budget Deficit, Reduction in Local and Foreign Investment, Devaluation of Currency, Lending Interest Rates and Unemployment Rate continued to increase. Recently, the Egyptian Prime Minister announced that the new Budget Deficit for the Fiscal Year 2012/2013 is expected to reach 135 Billion EGP, which constitutes more than 10 percent of the Egyptian National Income. The current political and economic difficulties facing the Construction Projects after the Egyptian Revolution in 2011 affected the Construction Industry immensely. Thus, the Construction Project Owner-Builder's teams need to evaluate risks in their projects in order to produce a list of prioritized risk, which can help them address vagueness and uncertainty that they are currently facing. In order to achieve the previous objectives, a case study was conducted to assess major risk events that should have been realized by the Construction Project Owner-Builder's teams prior to the revolution, then, the allowance for these risk events was computed to enable categorizing the risks and computing the allowances for each group risk. Ten construction Projects were chosen in this case study. Interviews were held, using the indirect method and a two-step Delphi technique, with ten experts each of them had twenty years of experience in Construction Projects. Table 8 illustrates the projects costs, descriptions, total construction cost/m^2, EMV value/m^2, Owners 'profit, and the proposed price as computed, using the framework outlined in this paper.

Table 8: The proposed Model Price / m^2

Project No.	**Project Description**	**Project Cost to The Owner**	**Total Construction Costs/ m2(EGP)**	**Value EMV/m2**	**Owners' Profit**	**Proposed Model Price /m2**
1	Constructing 30 villas and 10 residential buildings	145 Million EGP.	2944.6	375.4365	588.92	3908.96
2	Constructing 70 Residential Building	350 Million EGP.	3073.8	391.9095	461.07	3926.78
3	Constructing 30 Residential Building	210 Million EGP.	2683.1	342.09525	670.775	3695.97
4	Constructing 20 Residential Building	100 Million EGP.	2893	368.8575	578.6	3840.46
5	Construction of 50 town houses and 100 residential building	650Million EGP.	2809	358.1475	702.25	3869.4
6	Constructing 35 Residential Building	600Million EGP.	3048	388.62	609.6	4046.22
7	Constructing 120 Residential Building	175Millon EGP.	3183.6	405.909	477.54	4067.05
8	Constructing 10 Residential Building	55 Million EGP.	2841.3	362.26575	568.26	3771.83
9	Construction and finishes of one commercial mall and 100 residential apartments	75Million EGP.	2738	349.095	547.6	3634.7
10	Constructing 20 villas and 30 residential buildings	210Million EGP.	2663.7	339.62175	665.925	3669.25

Based on the above results, the increase in the percentage due to the expected risks in the residential buildings and villas were about 10%, while the percentage increase in the commercial malls was about 12%.

3. Conclusion and Future Works:

A Quantitative Construction Risk Analysis Framework was developed in this paper to quantify risks encountered in Owner-Builder Construction projects. The objectives of the paper were accomplished by developing Analytical Hierarchy Process, Multilevel Fault Tree, and Event Tree models. Risks were identified and prioritized through the Analytical Hierarchy Process and Relative Importance Index. The most critical risks were introduced to Multilevel Fault Tree and Event Tree models to determine the fuzzy probability of failure of critical risk events affecting the Egyptian construction industry and detect their root causes and probability of occurrence. The fuzzy event tree calculated the Expected Monetary Value (EMV) of each critical risk event. The framework provided an improvement over previous quantitative models by incorporating the use of Fuzzy Fault and Event Tree to determine the allowance of mitigation of identified risk event. Other quantification methods, such as Fuzzy Arithmetic with parametric LR Fuzzy Numbers, and Fault tree with Fuzzy Gates can be used in the future for quantifying risk events and their results can be compared to the result of this model for validation purposes.

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