Risk Contingency Evaluation in International Construction Projects (Real Case Studies)

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Abstract: - **Most construction companies operating in the global construction industry would undertake international projects to maximize their profitability through benefitting from the new attractive markets and reducing the dependence upon local markets. As a result of the nature of construction works the company and project's conditions actually include massive risks and uncertainty. So the risk sensitivity of projects costs should be assessed in a realistic manner.**

The comprehensive risk assessment method was introduced as a decision making supporting tool to be employed for international constructive projects through applying a risk model that will aid the procedures of evaluating risks and prioritizing such projects and assessing risk contingency value. Both the Analytic Hierarchy Process (AHP), applied for evaluating risk factors weight (likelihood), and FUZZY LOGIC approach, applied for evaluating risk factors influence (Risk consequences) employing software aids such as EXECL and MATLAB software, were used for developing the risk model.

The reliability of the developed software has been verified by applications on a real construction projects. The proposed methodology and decision support tool have been proved to be reliable for the estimation of cost overrun resulting from risk on basis of actual final reports of projects.

Six actual case studies from different countries were chosen to determine the highest risk factors and to implement the designed models, test their results and evaluate risk cost impact.

The proposed models result showed that: the highest and lowest risk contingency percentage of 48 % and 16 % were in Project no (5), (6) respectively in Egypt. On the other hand, the projects no (1, 2, 4,7) in Saudi Arabia, UAE, Libya and Jordan, the risk contingency of 29%, 39%, 20% and 28% respectively. The actual results are close to those of the proposed program.

Keywords: **Risk Management, International construction, risk factors, Analytic hierarchy process (AHP), FUZZY LOGIC approach, MATLAB software and Validation process.**

I. INTRODUCTION

Risks result in cost overrun and delays of schedules in many projects. The risk management effectiveness becomes a major aspect in project management [15]. The exact impact of qualitative decision factors on the project risk cannot be determined using subjective judgment, yet it can only help in constraining or excluding possible strategies in order to improve the qualitative decision. Making the decision to participate in an international construction project required a thorough study of many simultaneous dimensions; e.g., project revenues maximization, project risks allocation and minimization, funds availability, etc. Thus in order to assess the factors influencing the company's analysis a multi factor decision making methodology should be applied [4, 13, 1, 10]. Such decisions are extremely complex due to the fact that they are deeply affected by many parameters and most of the parameters are subjective and non- quantifiable ones. Dias (1995) tackled the issue of evaluating infrastructure projects from the contractors' position, and managed to identify to main objectives of a risk model: 1. To provide a logical, reliable and consistent process to facilitate a company's decision to carry on with a project by the means of analyzing different parameters, 2. To allow performing a sensitivity analysis so companies will be able to assess different scenarios; e.g., risk mitigation strategies. [4,13, 6, 7].

This study describes a tool representing a system capable of finding the correlations between such decision factors, as well as, the impact every factor introduces to the total project risk. It deploys a modeling technique operates on the basis of Analytical Hierarchy Process (AHP), Fuzzy logic. Statistic methods were used to verify the model and the results were compared to the actual ones from projects' final reports.

II. BACKGROUND

Construction projects are influenced by uncertain environment because of their extremely huge sizes (physical, required manpower and fiscal value), complex designs and external elements involvement. According to such uncertainties facing the projects, many changes in the projects' scopes take place during the execution phase. If such changes were not controlled properly; goals like time, cost and quality may never be accomplished. [16].

Of the essential elements required for any managerial work is the ability of situations analysis and decision making. The process of making decisions includes a number of tasks; planning, finding alternatives, defining priorities, selecting the best policy, allocating resources, identifying requirements, anticipating outcomes, designing systems, evaluating performance, securing system stability and settling conflicts. [20, 21, 22, 23]. The Decision Support System (DSS) is defined in early definitions as a system aiming to support managerial decision makers in semi-structured decision situations. DSS is intended to be associated to decision makers, in order to expand their abilities and not to substitute decision makers' judgment [4]. A DSS is an interactive, flexible, and adaptable Computer Based Information System (CBIS) that utilizes decision rules, models, and model base coupled with a comprehensive database [6, 7, 11, 19]. The decision makers often hesitate in alternative selection due to the complicated nature of construction engineering. Fuzzy risk assessment is a promising tool that measures risk ratings if the risk consequences are not clear and their definition is based on subjective judgment and not objective data. In addition to that Fuzzy is an optimum technique to handle the uncontrolled factors such as; location, manpower, equipment, weather, unpredictable circumstances, time- based situations and rules [14].

Therefore, Fuzzy logic and computation is employed in many engineering tasks such as risk evaluation, risk pricing algorithm, construction time- cost trade off and the building elements' whole life costs. The following sections shall specify examples for applying fuzzy theory in construction industry:

Hyun-Ho et al., (2004) managed to develop a risk assessment method for underground construction projects. The main tool of this method was a risk analysis software. The risk analysis software was based on an uncertainty model built by fuzzy concept. The fuzzy-based uncertainty model was designed to examine the uncertainty range of degrees related to: 1. The probability parameter estimations, and 2. Subjective judgments. They also concluded that the proposed method for risk assessment shall provide both the insurance companies and contractors with process and tools that are of flexible and easy to follow nature and shall improve the ability to model uncertainty. [8] As for Sou-Sen et al. they proposed an optimal construction time-cost trade-off method concerned with the time period of the uncertain activity and the time-cost trade off. The uncertainties of activity durations were modeled using the Fuzzy set theory. The method showed the perfect balance of time and cost in the presence different risk levels according to decision makers [25].

a generic elemental whole life costing model was developed by Wang et al. (2004). The model used the fuzzy logic model. Experts' linguistic data were used to model the correlation between the context of application and the cost items. As Fuzzy logic approach uses experts' knowledge, this model proved that fuzzy manages to resolve the problem of lacking data and uncertain future events prediction.

Dikmen I et al (2007) developed a Fuzzy based model rating approach which is used to estimate cost overrun risk in international projects during the bidding stage. The step-wise procedure was developed for this approach and this procedure was applied during the development of the fuzzy risk rating tool. [5]

Cardona and Carreño (2004) [2] proposed fuzzy linguistic values that represent factors risk performance, such linguistic values are the same as a fuzzy set that have a membership function of the bell function. They also suggested that effectiveness obtained by the defuzzification of the linguistic values has the same as a function of the Sigmoidal. Therefore, the risk effectiveness is nonlinear; as a result of complexity. [2]

QammazA (2007) proposed "Structure of the International Construction Project Risk (ICPRR) Software Application, an application that was composed using "Oracle Forms"[28]. (Dias, 1995), (Salman A, 2003) and (Zayed ,2008) introduced risk models on both company and project levels based on equation (1) that represent the probability multiplied by consequences. They used a questionnaire for identifying the expected risk performance of each factors and liner equation for assessing risk effectiveness [4, 27, 24]. Salman A, 2003 [24] managed to prove that the risk consequences drive the action as the model results are very sensitive for any variation in risk effectiveness more than importance weight. The conclusion derived upon this was that the value scores are the driving forces of this model rather than the importance weights [24], therefore this paper applied fuzzy logic in order to evaluate risk performance and nonlinear Function (sigmoidal function) to evaluate risk effectiveness.

III. STUDY OBJECTIVES

The current study has the following goals:

(1)- Determine main risk and uncertainty factors and their sub-factors influencing projects on both company level and project level in international projects.

(2)- determine risk and uncertainty values for each factor using evaluation model based on analytic hierarchy process (AHP), determine the risk performance for each factor based on developed program based on (fuzzy logic approach) instead of depending on questionnaire applied in the previous methods

(3)- Determine the value score (effectiveness) of each of the risk factors using nonlinear function.

(4)- Design flexible assessment model in order to measure the cost impact of risk and proposed appropriate risk contingency value.

(5)- Applying the proposed model in real construction projects to assess the proposed risk contingency value and compare the proposed risk contingency value with its actual risk value.

IV. STUDY METHOD

This research had different method stages to accomplish its goals in determining the risk index (R). Fig. 1 shows these stages and their correlation. The stages are described in detail across the whole paper and can be briefly listed as follows:

Stage 1: Literature Review:

This stage of the study revolved about exploring the previous decision making supporting systems in the field of risk assessment, as well as, the components of risk models.

Stage 2: Analytical study.

A stage consisting of:

(1). Exploring the risk evaluation models for both the company level and project level. (developing a Risk hierarchy model)

(2). Two risk index (R) models, on both the company and project levels, were developed in order to evaluate the impact of risk sources and uncertainty on construction project based on equation (1) probability theory which is adapted from Dias [4].

Final project Risk Index (R) = Risk Index for Company level (R1) * Risk Index for project level (R2)

Risk Index 1, 2 =Likelihood X Consequence

$$R1,2 = \sum_{i=1}^{n} W(xi) * E(xi) \quad \text{Equation (1)}$$

R	:	Risk index of construction projects.
R1	:	Risk index of projects in company level.
R2	:	Risk index of projects in project level.
Wi (xi)	:	Weight for each risk area i using Eigen value method.
Ei (xi)	:	Effect score for each risk area (xi).
Xi	:	Different risk areas i.
I	:	1, 2, 3,. . .. ., n.
N	:	Number of risk areas.

(3). Two models composed to define the risk index (R) and the risks factors distributed among two levels (company level and project level). Each model includes two parts: risk factors weights (W) and their value score (E).

AHP will be used for determining risk factors weights; while four different approaches shall be used for assessing the risk impact, these are; Dias approach [4], Value curve approach according to Zayed T [27], New approach according to Salman [24] and proposed model using Fuzzy logic approach to evaluate Expected risk performance and sigmoidal function to evaluate risk factors effectiveness.

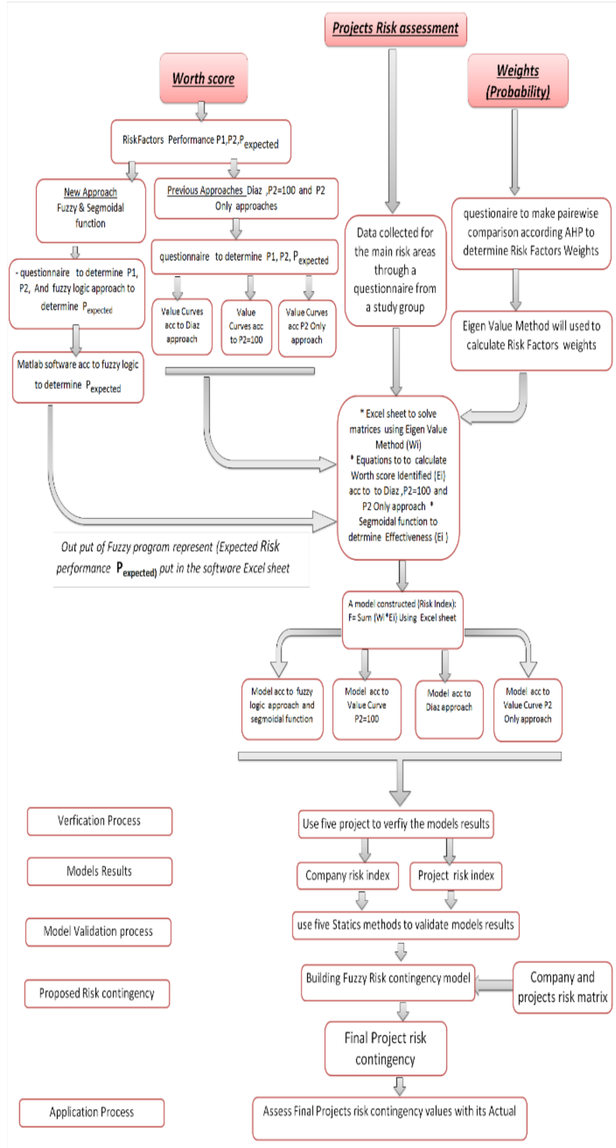


Figure (1) : Study method flowchart.

(4). A new software, deploying excel sheet, was developed for the purpose of evaluating the risk factors weights busing AHP concepts and Eigen value method. Also, excel software will receive **Expected Risk Performance ($P_{Expected}$)** value from fuzzy program in order to calculate risk effectiveness using sigmoidal function hence the overall risk can be determined through equation no (1) on both level of the company and the project.

Stage 3: Case studies (Verification, validation and application processes).

(1). The study used six case studies to verify the suggested model using questionnaire as a data collecting tool, to collect data about sources of risk in international construction projects, as well as, risk factors from a study group.

(2). Validation was undertaken in order to assess different methods through comparing their results and applying four statistical evaluation methods.

(3). The proposed model will be applied to assess the suggested risk contingency value in real construction projects and match the proposed risk contingency value with its actual risk value from its close out reports of the projects.

V. MODELS DEVELOPED THROUGH RESEARCH

Four models were developed throughout research stages. Table 1 shows the description and the objectives of each model. Hierarchy risk models on both company and project levels are displayed in fig.2, 3, 4 that will be used throughout the study to evaluate the projects risk. The main Hierarchy risk model shown in figure (2) represents level 1 which is divide into two main groups company and project, each class divided into main categories representing main risk factors divided to sub factors as shown in figures (3,4).

Table (1) : Developed models which were used through study stages.

Model No	Description	Objectives
Module 1	Hierarchy Risk model factors	Building risk model factors for both company and project level
Module 2	Expected risk performance based on fuzzy logic approach	Identifying Expected risk performance using MATLAB software instead of using questionnaire in the previous methods
Module 3	Overall Excel sheet model	Receive output results from expected performance FUZZY program, calculate each risk factor effectiveness using sigmoidal function, solving AHP matrices and calculate final project risk index
Module 4	Fuzzy risk contingency model	Receive output results of risk indexes for both company and project risk contingency using MATLAB software

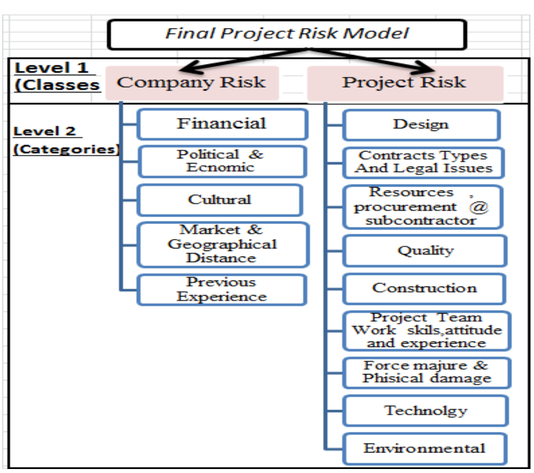


Figure (2) : *Risk hierarchy model in company and project Levels.*

In order to assess the risk sources impact, as well as, the uncertainty in a construction project from contractor's (company) point of view a risk index (R) model was designed. The model offers a logical, reliable and consistent method for evaluating and prioritizing potential projects, in addition to, facilitating decision making on company's party. The various risk sources and uncertainty of the project are characterized through the risk index (R) which is based on equation 1. The R-index includes two parts, these are; weights of risk factors and sub-factors and their impact score. AHP developed by Saaty shall determine Weights of risk areas [20, 21, 22, 23], while, the impact score shall be assessed using utility function for previous approaches and fuzzy logic approach for the suggested model. Four approaches are used in developing risk worth score (Impact) of the risk factors; these approaches are shown in table 2.

Table (2) : Performance and Effectiveness evaluation approaches.

Approach	*Performance evaluation*	*Effectiveness evaluation*
Diaz Approach	Questionnaire-based	Diaz value curve
P2=100 Approach	Questionnaire-based	According to Zayed value curve P2 = 100
P2 Only Approach	Questionnaire-based	According to Salman, A. value curve P2 = 100
Proposed model based on Fuzzy Logic and Sigmoidal function Approach	Based on Fuzzy Logic	Sigmoidal function

- Diaz Value Curve deploys two points P1, P2's to describe the value curve. P1 is the minimum risk performance level, P2 the maximum risk performance level. These questionnaire- abstracted two points; feature the generic form of a value curves through dividing the performance scale into three regions [4].
- P2= 100 Value Curve. The performance value of P1 was always zero in P2 =100 approach in contrast of Dias and loannon approach. This is the result of considering all project's decision factors significant and influencing the outcome of the total project's risk. Even in case of minimum impact of the decision, its performance should be taken into consideration in evaluating according to Zayed approach [27].
- P2 Only Value Curve. P2 Only Approach" which shall deploy P2 value provided by the respondents as the maximum performance and P1 shall be neglected. [24].
- Suggested Model to Assess Expected Risk Performance According to Fuzzy Logic

Applying Fuzzy Logic and MATLAB software, the new suggested model to evaluate the Expected Risk Performance will be deployed and shall be explained in the following sections (section 7, 8).

VI. DATA COLLECTION

Personal interviews; during which questionnaire survey were used, were performed with 93 respondents, in order to, identify the risk factors and sub factors in international projects. 36 respondents provided positive responses. The experts were selected on the basis of their participation in pipeline projects across the country, as well as, their actual or intended participation in international projects. Experts' positions were variable, e.g.; project manager, project planner, proposal developers, quality control officials, estimators and site and cost control engineers. Table (3) shows the two phases of research data collection process.

Table (3) : Study Questionnaires.

Questionnaire No	***Description***	***Objectives***
A. General Data		
Questionnaire 1	Criteria Development	Developing a risk model
B. focused Data		
Questionnaire 2	1. AHP, Risk Performance surveys for six projects on company level.	Model verification and application
	2. AHP, Risk Performance surveys for six projects on project level.	Model verification and application
Questionnaire 3	comprehensive evaluation surveys for six projects	Model Validation
Questionnaire 4	Company and projects risk matrix	Fuzzy Risk contingency model

A. First general data.

Based upon managers, users and experts' opinions, to develop a risk factors model, as presented in questionnaire No. 1. The first questionnaire focused on the general data regarding setting criteria for developing risk hierarchy models. The first stage was specifying the numerical and linguistic variables affecting the project. This was accomplished by gathering all the related variables from database of previous projects and the project environment (host country conditions, project's characteristics and location). The process of collecting project risk decision factors was based upon assessment of a wide range of risk decision factors and their sub factors extracted from the literature.

The second stage aimed at identifying such variables, excluding the redundant variables, and classifying them. Then, categorizing these decision factors into main categories according to their relevance for the purpose of saving both efforts and time spent in determining their interrelationships and evaluating them. This requires a group of experts in the field. As for the third stage, it is about applying mathematical methods for processing the data. Analyzing the gathered data sample showed a wide variety in estimating the important weights in each of the factors due to the fact that each project has its own unique risks and different policies may be applied to allocate and mitigate the same risks among different projects as a result of the different countries' conditions. Thus this is the main reason of including all the factors in both models and dividing the attributes into categories, in order to compare the attributes in a more meaningful manner by only comparing attributes of the same nature and also in order to reduce the size of comparison matrix. Figures 2, 3, 4 show final risk hierarchy models.

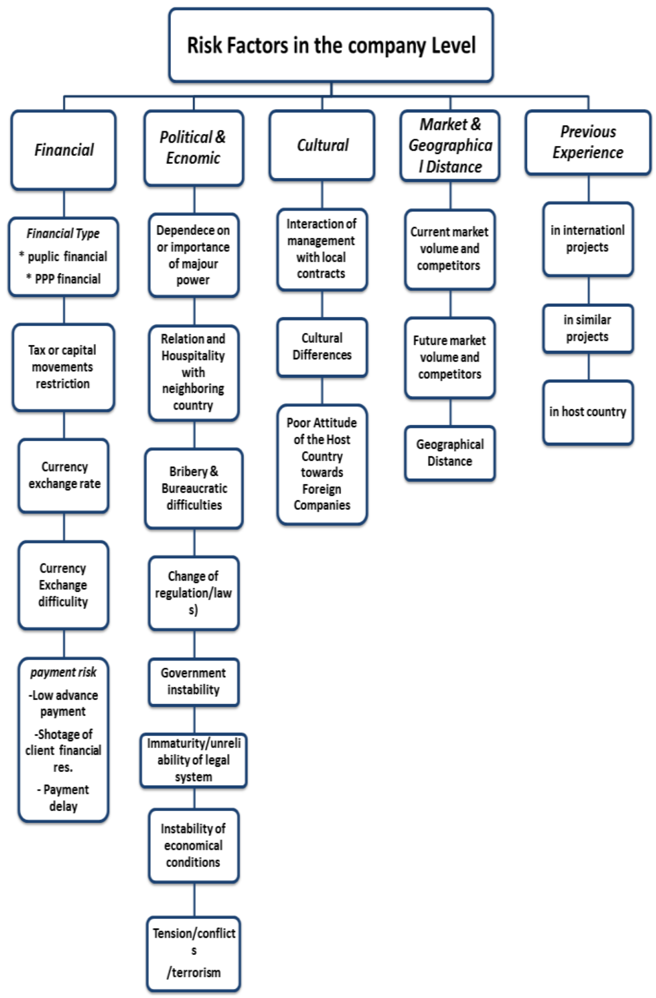


Figure (3) : *Risk factors on company Level.*

B. Second focused data.

These are measurements taken to evaluate the whole performance of the model based on six case studies of six different projects.

1. Questionnaire No. 2, essential for model verification, validation and application processes. Each project questionnaire consists of two parts
   - Part 1: Factors and sub factor weights (AHP survey) for company risk level.

Factors and sub factor risk Performance (Impact) for company risk level.

- Part2: Factors and sub factor weights (AHP survey) for project risk level.

  Factors and sub factor risk Performance (Impact) for project risk level.

2. Questionnaire No. 3, Holistic evaluation for both company and project level, essential for model validation process.
3. Questionnaire No. 4, impact of company and project Risk on the overall project risk (Risk matrix), essential for Risk contingency model.

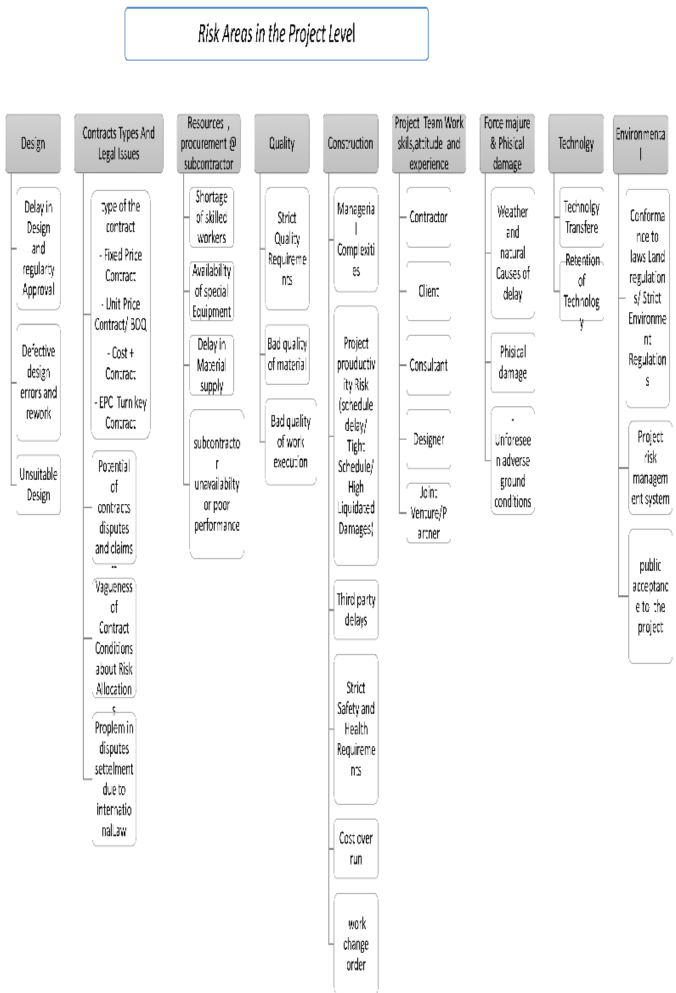


Figure (4) : *Risk factors on project Level*

VII. SUGGESTED EXPECTED RISK PERFORMANCE ASSESSMENT MODEL ACCORDING TO FUZZY LOGIC

The fourth approach introduces a new model to determine the anticipated risk factors performance as per fuzzy logic approach, instead of questionnaire applied in the previous method, in addition to, determining risk factors effectiveness according sigmoidal function instead of linear functions deployed in previous methods. The reason for using Fuzzy logic is that it is conceptually easy to understand because the mathematical concepts behind fuzzy reasoning are very simple. It is also flexible with any given system and it is capable of modeling nonlinear functions of arbitrary complexity. Fuzzy logic can be developed basing on experts' experience, as contrasting to neural networks that take training data and generate opaque, impenetrable models, fuzzy logic relies on the experience of people who already understand the system. Fuzzy logic is based on natural language. The basis for fuzzy logic is the same as for human communication. [16], [29].

7.1 Modeling a Fuzzy Problem:

The first Fuzzy model was developed in order to evaluate expected risk performance. Input data were two elements (minimum risk performance and maximum risk performance). The inputs are crisp (non- fuzzy) numbers limited to a specific range provided through questionnaire No. 1. All the results were evaluated in parallel by fuzzy reasoning using 10 rules system. The results of the rules were combined and defuzzified, the result is a crisp number representing the output expected risk performance.

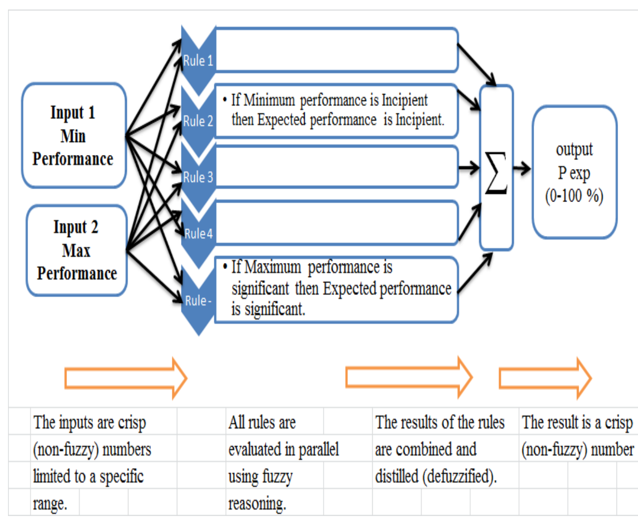


Figure (5) : Expected Risk Performance model (Pexp)

7.2 Fuzzy Inference Process:

Fuzzy inference is the process of the mapping formulation from given input into output using fuzzy logic. Such mapping offers the basis upon which decisions making or patterns discerning can rely.

In the Fuzzy Logic, there are five parts of the fuzzy inference process: [1,2].

1. Step 1. Fuzzifying Inputs: That is to fuzzify the input variables and to determine the membership function of the input and output variables, for example; figure 6 shows the input and output Membership functions.
2. Step 2. Fuzzy Operator application: applying the fuzzy operator (AND or OR) to the antecedent.
3. Step 3. Applying implication method. Implication from the antecedent to the consequent.
4. Step 4. Aggregate All Outputs. Aggregation of the consequents across the rules.
5. Step 5. Defuzzified Process.

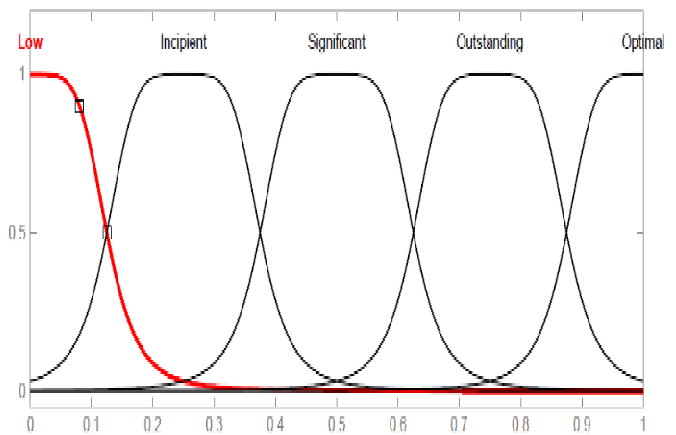


Figure (6) : *Membership functions of input variables*

VIII. SYSTEM DEVELOPING USING MATLAB SOFTWARE

A new model was provided to determine expected risk factors performance, thus representing best estimation of risk impact according to fuzzy logic approach instead of questionnaire used in previous method

Membership functions for fuzzy sets are defined, representing the performance levels for the input factors (P1, P2) and are used in information processing, P1 represent Minimum Risk Performance that is, representing maximum Ineffective risk performance and P2 represents maximum risk performance that is, representing maximum effective risk performance. These two points were explained by experts in the questionnaire method.

The performance values of the factors are provided on the x-axis and the membership degree for each level of performance is shown on the y-axis, where 1 is the total membership and 0 is the non-membership. Equation No. 2 presents Membership functions as represented by bell function, as proposed by [6].

$$bell(x,a,b,c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}}$$

Equation 2

Where the parameter b is usually positive.

Figure 7 shows input Membership Function for point P1 and another input P2 and output Membership Function for the same membership function. The Rule Editor represented with ...and then.... As for the rule variables, they are considered as independent of each other in order to simplify the procedure. The steps followed to develop the program based on fuzzy approach using MATLAB software are presented in details [1,2].

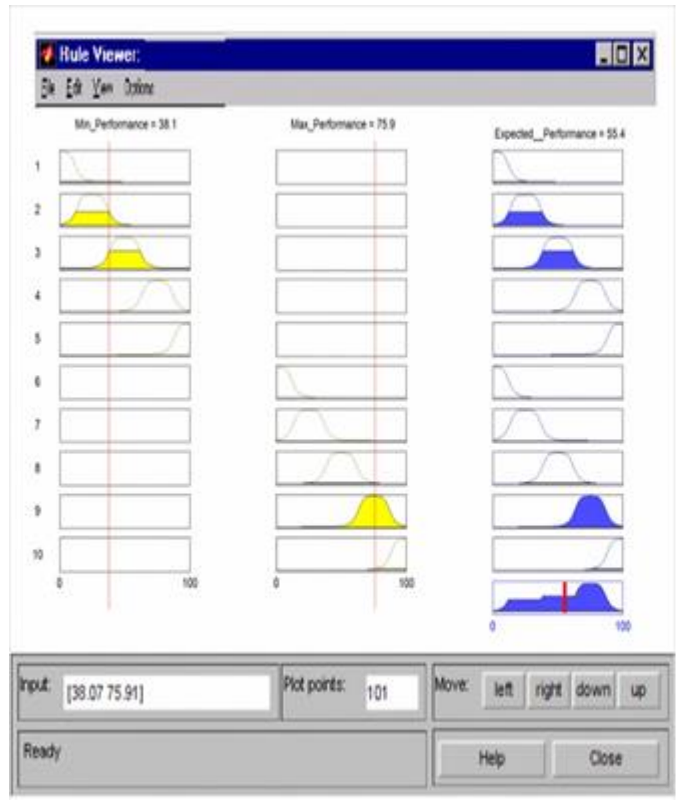


Figure (7) : Anticipated risk performance according to FUZZY LOGIC approach using MATLAB software.(Expected risk performance)

IX. DETERMINING RISK EFFECTIVENESS.

Equation No. 3 provides the Effectiveness of expected risk performance value (the value Obtained by the defuzzification of the linguistic values ($P_{\mathbf{Expected}}$)- obtained from previous section).

Effectiveness value is the value obtained by sigmoidal function type [2]. Figure 8 shows the Effectiveness degree of the risk performance value according to (Carreno 2004) using sigmoidal function type

$$sigmoidal(x,a,c) = \frac{1}{1+exp[-a(x-c)]} \qquad \text{Equation. (3)}$$

Where ***a***: controls the slope at the crossing point, 0.5 of membership and equal 0.104, X is Performance at X axis and C =50.

According to Carreño et al (2004) in order to characterize performance, whose shape corresponds to the sigmoidal function (Figure 8), the form and coverage of these membership functions follow a non- linear behavior in a sigmoidal form. As per figure (8) the effectiveness of the risk is represented as a function of the performance level.

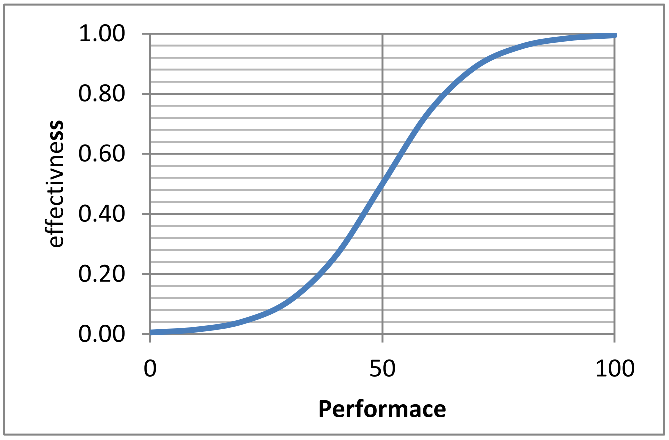


Figure (8) : Effectiveness degree of the risk performance. [6].

X. DEVELOPING AN EXCEL SPREAD SHEET PROGRAM.

The suggested model was designed using Excel Software Program to include the following features;

(1). The model shows all input data collected through a pair- wise process.
(2). Designed to resolve the matrices with AHP concepts and Eigen value method of assessing risk factors weights.
(3). The model calculates risk performance for each risk factor on the basis of each approach.
(4). The results obtained from fuzzy program represent (**Expected Risk Performance ($P_{Expected}$)**) put in the Excel sheet (Column 23) in order to calculate risk effectiveness using sigmoidal function.
(5). Therefore, the total risk index can be determined through equation No. (1), for both company and project levels. Figure 9 shows the Excel Software sheet, along with, the description of the properties and functions of each column. The right lower corner shows risk index of each approach.
(6). The main characteristic of the suggested model, that is, that the model has no limit as for the number of risk factors.

XI. VERIFICATION OF SUGGESTED MODEL RESULTS

Six projects in different countries, presented in table (4), were selected to verify model application as per study methodology flow chart shown in figure (1), the steps are as follows.

11.1 Part 1: Assigning Risk factors weights (AHP Survey)

Respondents were asked to make a pairwise comparison between risk factors and risk sub factors representing the relative significance between them of the basis of the numerical scale (1-9) using Analytical Hierarchy Process (AHP). Figure 10 provides an example to explain the pair wise process. The assignment of weights requires logical and analytical thinking, so it is preferred to focus on the respondents with good experience and knowledge as per each case study to participate in the AHP survey questionnaire as a guarantee that only valid and good quality data are collected. The group members should hold brainstorming sessions seeking consensus regarding the required tasks. In other words, instead of asking the same questions to individual members separately, the group shall provide only one response which represents the democratic majority point of view of the group [23,27].

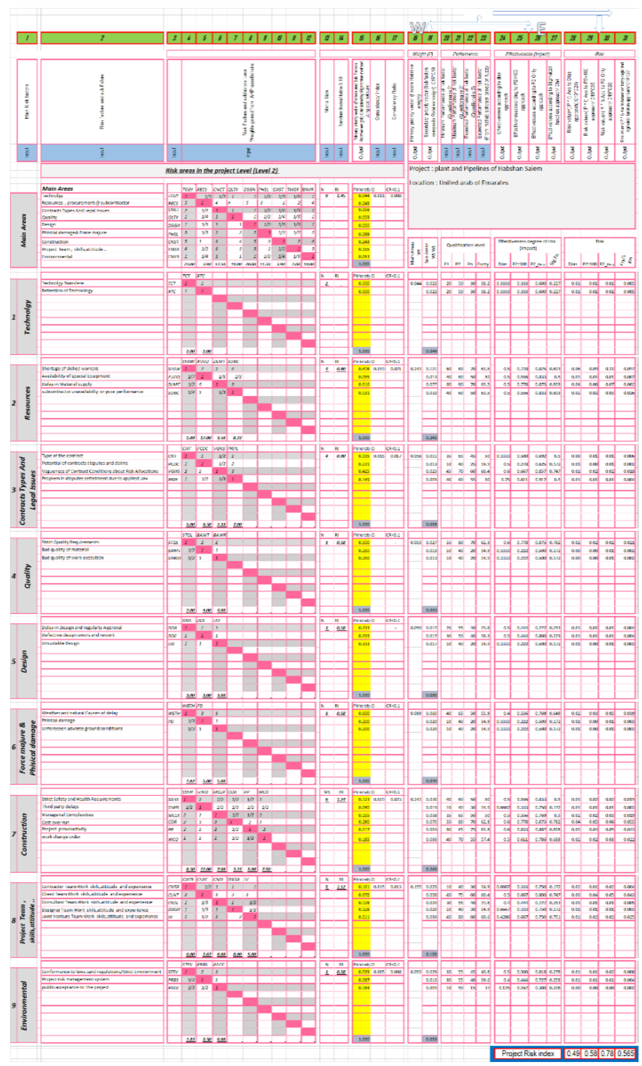


Figure (9) : Screen shot for Excel sheet program explaining each columns identification and demonstrate the input data and output results of the program for risks in the Project level in the project 2.

11.2 Part 2: Allocating Performance of Risk factors.

Respondents were asked to allocate 3 points representing low risk performance (P1), the high point of risk performance (P2) and the Expected risk performance ($P_{Expected}$) for all sub factors on both company and project risk factors on the basis of the numerical scale (1-9). Figure 10 provides an example explaining Allocating Risk Performance for each risk factor.

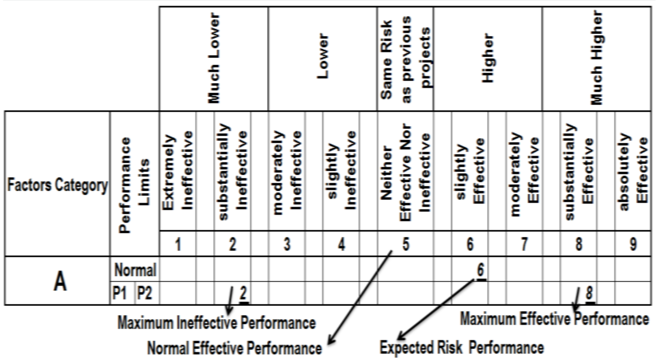


Figure (10) : Allocating Risk Performance for each risk factor on project level.

The performance scale has main points; these are:

- Minimum Risk Performance (P1): the point at which maximum Ineffective risk performance exists. It reflects the risk factor impact in the condition at which things go well (optimistic Impact).
- Maximum Risk Performance (P2): the point referring to maximum effective risk performance. It refers to the risk factor influence when things do not go well (pessimistic Impact).
- Expected Risk Performance ($P_{Expected}$): This is the point representing best estimate of the risk impact (most likely impact). This point was determined using FUZZY logic in new software instead of using questionnaire in previous methods.
- Ineffective point: The point of normal risk performance and it means that the risk is as same as previous projects.
- Extremely Ineffective: The lowest risk point in the performance scale, with the meaning that there is no risk at all.
- Absolutely Effective: The highest risk point on the performance scale. It is means that there is extremely high risk.

11.3 Part 3: Assessing effectiveness of risk factors.

Expected risk performance of risk factors were evaluated according previous approach using questionnaire and Matlab software for proposed FUZZY model as indicated in table (2), (Expected Risk Performance according FUZZY approach section and System Developing using MATLAB Software section). Effectiveness of risk factors were assessed using the relevant utility function for the previous methods (Dias, P2=100 and P2 Only approaches) and sigmoidal function to evaluate effectiveness of Expected risk performance ($P_{Expected}$) obtained by the new fuzzy model [8, 28, 1, 2].

XII. RISK MODELS RESULTS AND ANALYSIS

The detailed assessment of the four (Diaz, P2 Only, P2=100 and new software on the basis of FUZZY Logic) approaches for each project profile are shown in table 4. The calculations of the projects' detailed profiles evaluation results for each case study were undertaken in terms of the four approaches. They were also plotted according to comprehensive evaluations of the final risk index of the project. Figure 11 provides the results.

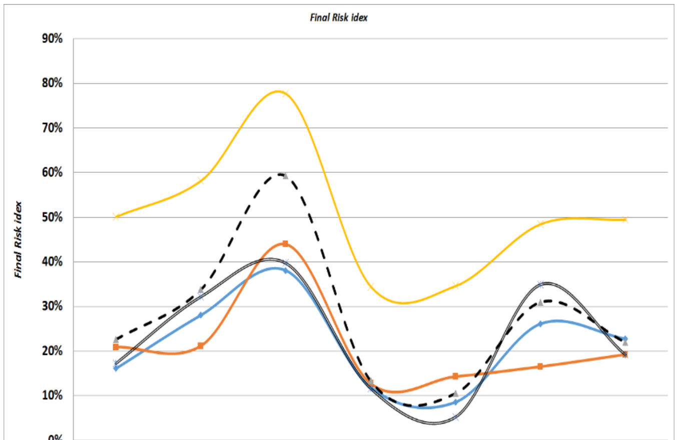
Table (4) : Company and project risk indexes each project conjunction with each approach.(appendix A)

	Proj 1: Nuayyim Field ASL Pipelines/Suadi				Proj 2 : Habshan Saiem plant and Pipelines /Emarates				Proj 3 : Nasria Pipeline /16 "/ 200km/Oil Pipeline Company(OPC) /IRAQ				Proj 4 : Sareer Plant / Entisar field Pipeline 195 km (Libya)			
	Proj 1 : NASL (Suadi)				Proj 2 : HSP (Emarates)				Proj 3 : NAS (IRAQ)				Proj 4: SAR (Libya)			
	Dias	P2=100	P2_Only	Fzy/ Sgm	Dias	P2=100	P2_Only	Fzy/ Sgm	Dias	P2=100	P2_Only	Fzy/ Sgm	Dias	P2=100	P2_Only	Fzy/ Sgm
Comp	0.42	0.47	0.70	0.40	0.43	0.58	0.75	0.570	0.44	0.59	0.78	0.61	0.36	0.39	0.64	0.36
Proj	0.49	0.48	0.72	0.44	0.49	0.58	0.78	0.565	0.52	0.62	0.80	0.65	0.35	0.34	0.53	0.32
Risk index	20.9%	22.6%	50.1%	17.3%	21.1%	33.8%	58.2%	32.2%	22.8%	36.5%	62.0%	39.8%	12.7%	13.4%	34.5%	11.7%

	Proj 5: Desouq Fields				Proj 6: BP WEST Nile delta Gas				Proj 7: New Cold Crystallization			
	Proj 5: DFDP (Egypt)				Proj 6: (WND)Egypt				Proj 7: (Potash) Jordan			
	Dias	P2=100	P2_Only	Fzy/ Sgm	Dias	P2=100	P2_Only	Fzy/ Sgm	Dias	P2=100	P2_Only	Fzy/ Sgm
Comp	0.31	0.28	0.55	0.19	0.53	0.69	0.81	0.71	0.36	0.36	0.62	0.31
Proj	0.46	0.37	0.64	0.27	0.31	0.45	0.60	0.495	0.53	0.61	0.80	0.63
Risk index	14.3%	10.5%	34.6%	5.2%	28.1%	35.6%	60.9%	35.5%	19.2%	22.0%	49.5%	19.2%

The figure shows that in P2 Only and P2=100 approaches, most of detailed evaluations were higher than Diaz approach evaluations. This was the result of the assumption that performance level point P1 was kept equal zero in these two approaches, so that any factors performance less than P1 and bigger than zero had a worth score value and shall be included in the evaluation of the total value of the project (eq. 1) while in Diaz approach; the factors performance level point P1 was considered in the evaluations so that all the factors performance levels located behind P1 had zero worth score resulted in zero worth value and it shall be excluded from the equation1.

The figure also shows that 'P2 only approach had bigger values than P2 =100 approach, this was mentioned in P2 Only approach. The performance level points P2 provided by respondents were considered as extreme points of risk performance and worth 100 points even if it was not at the extreme end of the performance scale and all the attributes performance levels located after this point shall have the same worth score. While in P2 = 100 approach the attributes performance point P2 was always kept at the end of the performance scale.



	Proj 1 : NASL (Suadi)	Proj 2 : HSP (Emarates)	Proj 3 : NAS (IRAQ)	Proj 4: SAR (Libya)	Proj 5: DFDP (Egypt)	Proj 6: (WND) Egypt	Proj 7: (Potash) Jordan
Holistic 0	16.09%	28.04%	38.07%	11.93%	8.58%	26.10%	22.75%
Diaz	20.92%	21.14%	43.96%	12.73%	14.28%	16.5%	19.2%
P2=100	22.62%	33.76%	59.24%	13.35%	10.52%	31.0%	22.0%
P2_Only	50.12%	58.18%	77.67%	34.49%	34.62%	48.5%	49.5%
Fuzzy	17.27%	32.21%	39.75%	11.67%	5.24%	34.9%	19.2%

Figure (11) : Overall Project risk index for detailed approach for each project.

So as for the attributes of performance point P were bigger than the P2 point estimated by respondents. Their worth scores were less than 100 point thus resulting, of course, in worth values less than those of P2 only approach.

The figure also included the holistic evaluation curve, in order to compare the differences between the six approaches results and the holistic evaluations.

Figure 11 shows that P2=100 approach curve and fuzzy approach were the closest to each other moreover they are the closest to the holistic curve which means that they are the best approaches seeking the holistic approach.

The Fuzzy approach model is more accurate than other models and the reasons for that are:

(1). It deploys fuzzy program for evaluating the minimum and maximum risk performance to estimate the expected risk performance instead of using questionnaire as per previous method.
(2). Also, the new model applies nonlinear function in assessing the risk factors effectiveness instead of linear functions as in previous approaches.
(3). Fuzzy approach is the closest one to the holistic approach as shown in figure 11.

Figures 12, 13 present the results of risk factors on both company and projects levels based on model of fuzzy approach and data collected from excel sheets. As for the risk indices they were provided in table 4. As seen on Figures 12, 13 the Current market volume and competitors, previous experience in host country, have the highest risk value in project no (1) in Saudi Arabia. On the other hand, the highest risk values on project level were for the following factors: lack of skilled workers, unavailable subcontractor or poor performance and Strict Quality Requirements. In relevance to company level the Change of regulation/laws, dependence on or significance of major power, volume of future market and competitors, size of current market and competitors and geographical distance have the highest risk value in project no (2) in Emirates, in addition to these; lack of skilled workers and delay in materials supplying delivery have the highest risk value on project level.

The following factors had the highest risk values on company level in project No. 3 in Iraq: tension/conflicts/terrorism, dependence on or significance of major power and previous experience in host country. On the other hand, and as for the project level; subcontractor unavailability or poor performance and defective design errors and rework have the highest risk values.

In project No. 4 in Libya, previous experience in host country and Current market size and competitors have the highest risk values on company level, while Cost overrun, unsuitable design, weather and natural causes of delay have the highest risk values on project level. The highest risk values on company level in project 5 in Egypt were for; payment risk and Instability of economic conditions and on the project level the highest risk values were of; delay in materials supplying and delay in design and regulative approvals. The highest risk values on company level in Project 6 (WND) in Egypt were for; the Change of regulation or laws, Instability of economical conditions and Currency exchange rate, besides on the project level the highest risk values were of; delay in materials supplying, Availability of special Equipment and Strict Safety and Health Requirements.

In project No. 7 in Jordan, Interaction of management with local contracts, Future market volume and competitors and Geographical Distance Obstacles have the highest risk values on company level, while Weather and natural Causes of delay, Availability of special Equipment and lack of skilled workers have the highest risk values on project level.

The above analysis indicates that the following factors: previous experience in host country attribute, volume of current market and competitors, change of regulation/laws, dependence or significance of major power, payment risk and instability are considered high risk in the six existing profile projects. Meaning that; decision makers should concentrate well on such factors in order to decrease their risk before proceeding with similar projects. Also the above analysis shows that the factor of availability of resources is of high risk in the most of the existing profile projects. Therefore, the decision makers should concentrate well on such attributes to decrease their risk before proceeding with the project by insuring settling the following items in the feasibility study phase; the project required local resources availability, as well as, availability of required imported resources with their paper works (type, cost, import licenses, taxes, delivery time, etc.,). Moreover, figures (12,13) show that it is worth noting that some factors have low risk value and in another project have high risk relevant to each project conditions.

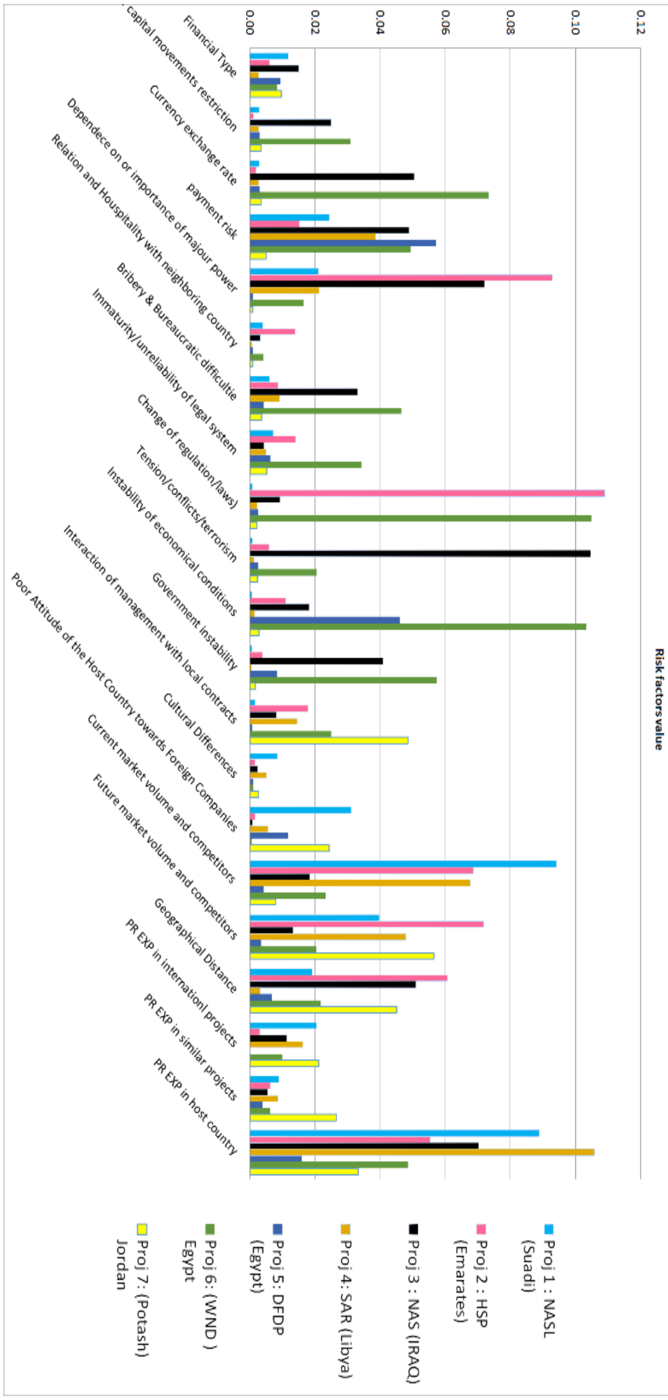


Figure (12) : Risk attributes values on company level for each project (Model based on fuzzy approach).

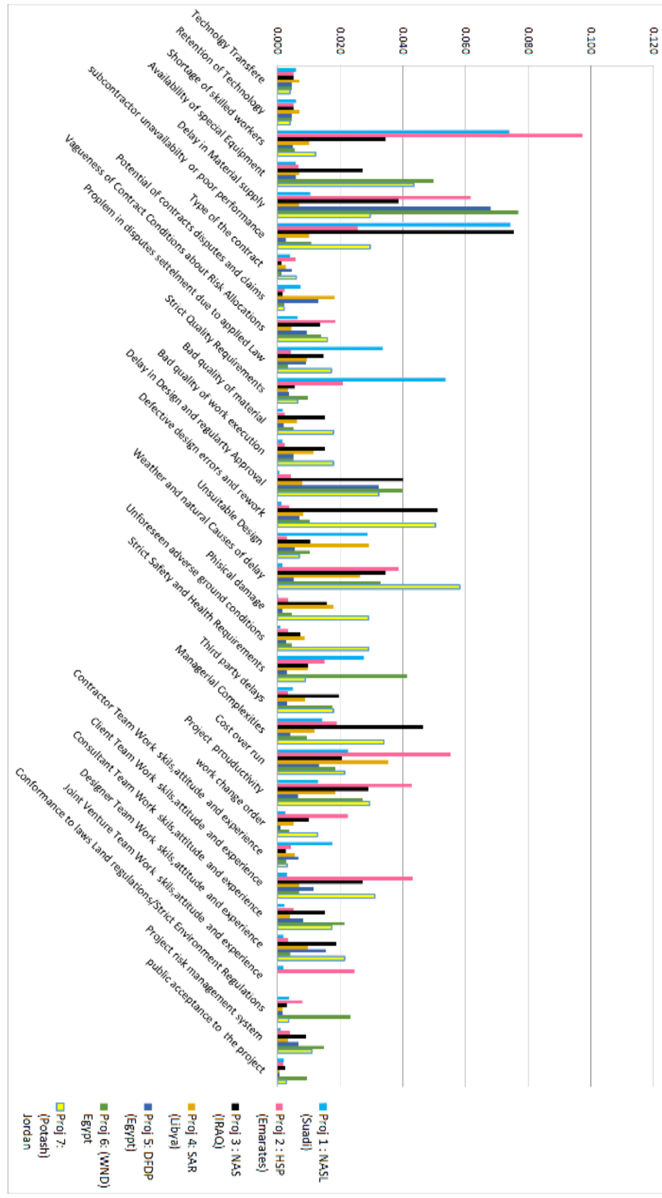


Figure (13) : Risk factors values on project level for each project (Model based on fuzzy approach).

XIII. MODEL VALIDATION

The objective of the model validation process is to introduce statistical methods to validate the risk evaluation model results. Therefore, the validated results are used in estimating the overall risk contingency using MATLAB software based in FUZZY logic approach.

Dias and Ionone, 1996 mentioned that the use of external criteria to objectively assess the validity of the evaluation models is a difficult matter due to subjective nature of the multi- attribute decision models. Thus, past research relied on indirect approaches, such as convergent validation, predictive validation, and axiomatic validation methods**.**

13.1 Holistic Assessment.

Holistic assessment (also called 'integrated assessment') focuses on the evaluating the whole work activities rather than specific elements. Holistic assessment is a direct evaluation made by the professional decision makers.

13.2Convergent Validation.

Convergent validation consists of comparing the results obtained by a fuzzy model with the holistic one; that is a direct evaluation undertaken by the decision makers (average, average plus standard deviation, and average minus standard deviation values. Figure (14) show the developed fuzzy model results, in addition to the holistic evaluation for company and project level risks. It is worth noting that the developed fuzzy model results are in the range of average plus standard deviation, and average minus standard deviation values.

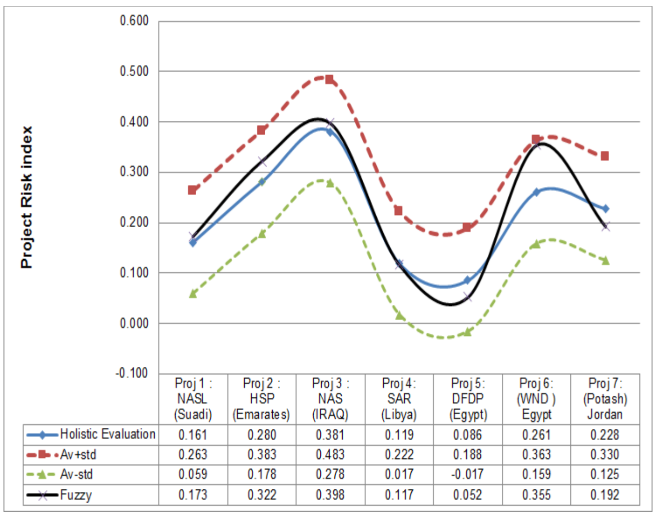


Figure (14) : Convergent validation of developed fuzzy model results for project risk.

13.3 Correlation Coefficient, R (Pearson Product Moment Correlation):

Correlation is a technique for examining the relationship between two quantitative, continuous variables. The quantity r, called the linear correlation coefficient, measures the strength and the direction of a linear relationship between two variables. The linear correlation coefficient is sometimes referred to as the Pearson product moment correlation coefficient

$$r =/ \frac{n(\Sigma xy)-(\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2-(\Sigma x)^2]\ [n\Sigma y^2-(\Sigma y)^2]}} \qquad \text{Eq. (4)} \qquad [13].$$

The correlation estimation was performed by calculating the Pearson's product- moment correlation coefficients between the holistic approach and the four detailed approaches for each project profile for company and project levels results; to verify the validity of fuzzy model and in order to determine which approach was the closest to the holistic one. The results shown in table (5) indicate that the Pearson correlation coefficients in the four approaches proved that fuzzy approach was the one that almost matched the holistic approach.

Table (5) : Correlation Coefficient for each model results in addition to the holistic evaluation.

Pearson Coefficient	Risk assessment model	Holistic	Diaz	P2=100	P2 Only	FUZZY
	Company level	100%	91.6 %	98.2%	99%	98.8 %
	project level	100%	59.5 %	94%	84.8 %	94.4 %

13.4 Test factor.

Test factor validation a step applied to test the designated model and verify its strength in predicting construction project's risk. The results from the model and the holistic evaluation were compared the test factor in model as follows:

Test Factor (TF) = RMR/RHE Equation (5), [31].

Table 4 shows the test factor results of the holistic and detailed models evaluations in terms of the risks on the company and project levels. They show that fuzzy approach is the closest to the holistic which means that it is the closest approach to match the Holistic. The previous test factor reveals that the accuracy and robustness of FUZZY model on company level have been tested using holistic evaluation, which proves its strength in risk assessment (99%) in company level and 101 % in project level as shown in table 6.

Table (6) : Test Factor for detailed approach.

Test factor	Risk assessment model	Holistic approach	Diaz approach	P2=100 approach	P2 Only approach	FUZZY approach
	Company level	100%	96%	109%	165%	99%
	project level	100%	99%	105%	152%	101%

13.5 Coefficient of determination r^2.

The coefficient of determination is a measurement of the regression line representation of the data. In cases at which the regression line should pass through every point on the scatter plot, it then shall be able to explain all the variation. The farther the line is away from the points, the less able to explain it shall be. The coefficient of determination, r^2 gives the proportion of the variance (fluctuation) of one variable that is predictable from the other variable. It is a measure that allows us to determine how certain the predictions made from a certain model/graph are. It is useful because it gives the proportion of the variance (fluctuation) of one variable that is predicted from the other variable.

The correlation was made between holistic and detailed evaluations for the four approaches in terms of the company Risk model results. Figures (15,16) show the correlations between risks attributes of holistic and detailed evaluations of the project profile for the four alternative approaches and their regression lines showing that the trend line of fuzzy approach is the closest one to the 45-dcgree line and the detailed evaluations values in this approach are the closest ones to the holistic evaluation values (correlations for Diaz, P2=100, P2 Only, and fuzzy approaches are 0.839, 0.964, 0.980, 0.976 respectively) for Company Risk model results. (Correlations for Diaz, P2=100, P2 Only, and fuzzy approaches are 0.355, 0.883, 0.718, 0.890 respectively) for project risk model results.

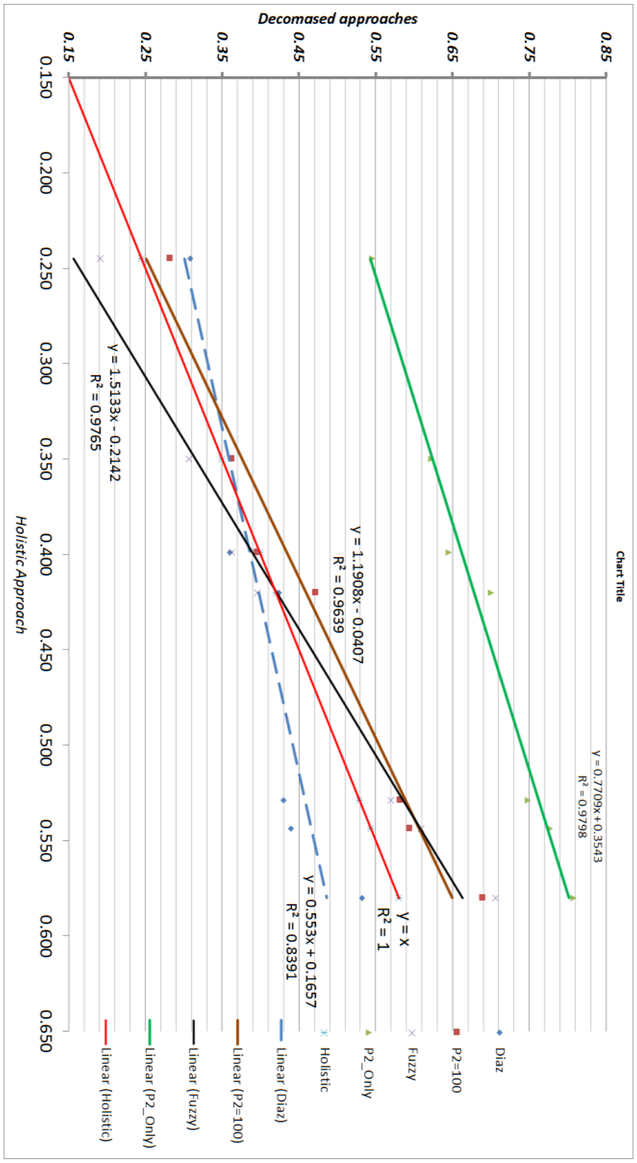


Figure (15) : The correlations between risks attributes holistic and detailed evaluations of the project profile for the four alternative approaches (company level risk).

XIV. SUGGESTED FINAL RISK VALUE (SUGGESTED PROJECT RISK CONTINGENCY VALUE)

Cost overhead could be estimated through aggregating and defuzzification of company's and project's final risk ratings through such rules and these rules might differ according to the risk attitude of experts and corporate policies, as such policies are company specified and each company has its own risk knowledge, thus leading to different fuzzy rules, as well as, different risk attitudes. (Cooper et al. 2007) [33] Managed to comply the philosophy of aggregated rules close to risk priorities for water pipelines.

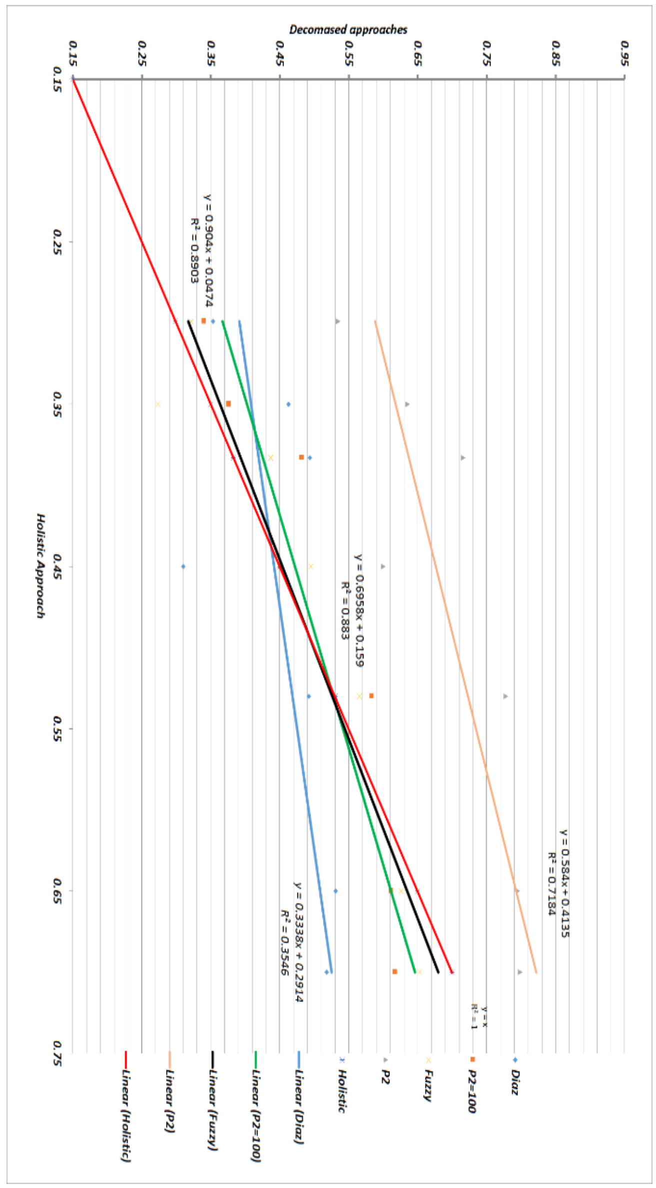


Figure (16) : The correlations between risks attributes holistic and detailed evaluations of the project profile for the four alternative approaches (project level risk).

figure 17 show FUZZY risk contingency model [1]. Figure 18 shows Membership functions for company and project risk indices' input obtained from excel program concerning fuzzy approach and Figure 19 shows Membership functions for final risk output.

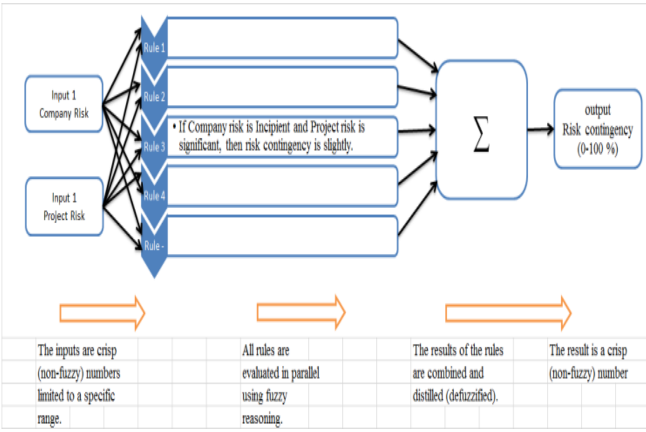


Figure (17) : Risk contingency model

The significance of evaluating risk lies in determining the maximum point in the output membership function representing the percentage that should be added to the project's budget in cases of extremely high risks on both company and project levels. Such points are company specified and every cooperate has a unique knowledge on the basis of its conditions. Such percentage varies according to the project and the point of view of its decision makers and estimators. Figure 19 represent out membership function of final cost shows that as for the current projects under study, the experts, estimators and decision makers decided that in case of extremely high project risk and the company risk is very high as well, then the percentage of risk shall be proportional to total budget and not less than 100% of the total budget (Extreme point in X axis). For project (2) HSP in (Emirates), company risk is 0.57 and project risk 0.56 (based on fuzzy approach), the final risk cost is the output of the fuzzy risk evaluation procedure, that is found to be 0.396 from the total budget as shown in (figure 21). Table (8) shows Fuzzy risk contingency for each project based upon the program.

Table (7) : Decision matrix showing aggregation rules merging company risk with project risk to give the overall project risk value.

		Project Risk				
		Low	Incipient	Significant	Outstanding	Optimal
Company Risk	Optimal	Low	Slightly	substantially	High	Extremely High
	Outstanding	Low	Slightly	moderately	substantially	High
	Significant	Low	Low	Slightly	moderately	substantially
	Incipient	Very Low	Low	Low	Slightly	Slightly
	Low	Very Low	Very Low	Low	Low	Low

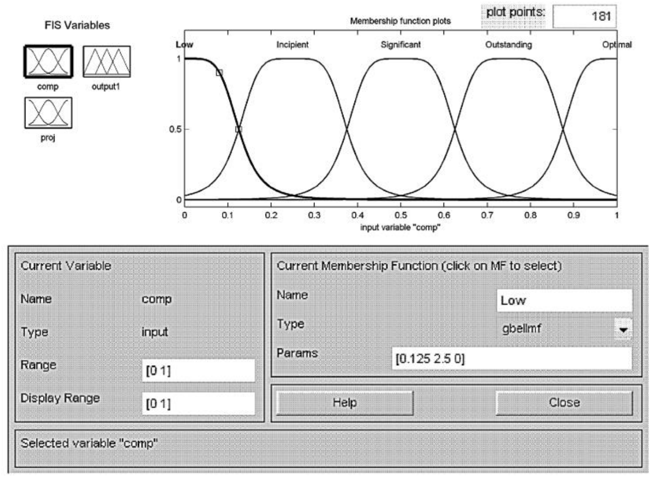


Figure (18) : Screen shot of Membership functions for company and project risk.

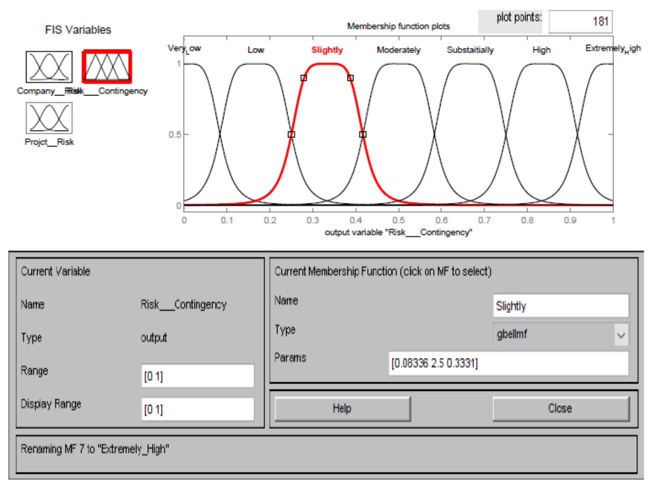


Figure (19) : Screen shot of output Membership functions for final risk.

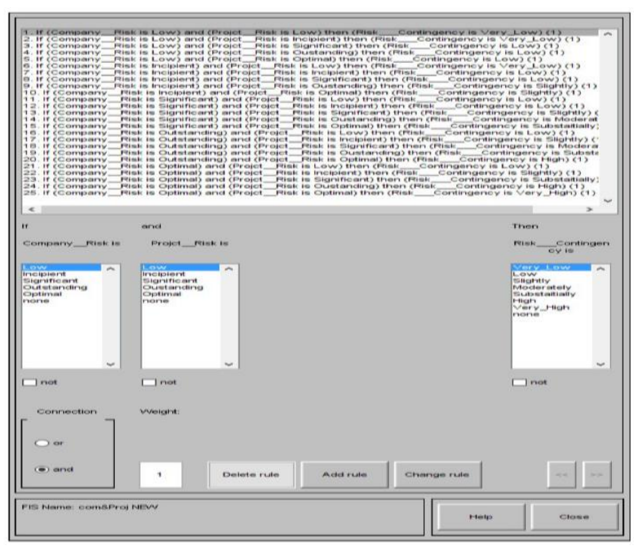


Figure (20) : Aggregation rules combining company risk with project risk producing overall project risk value.

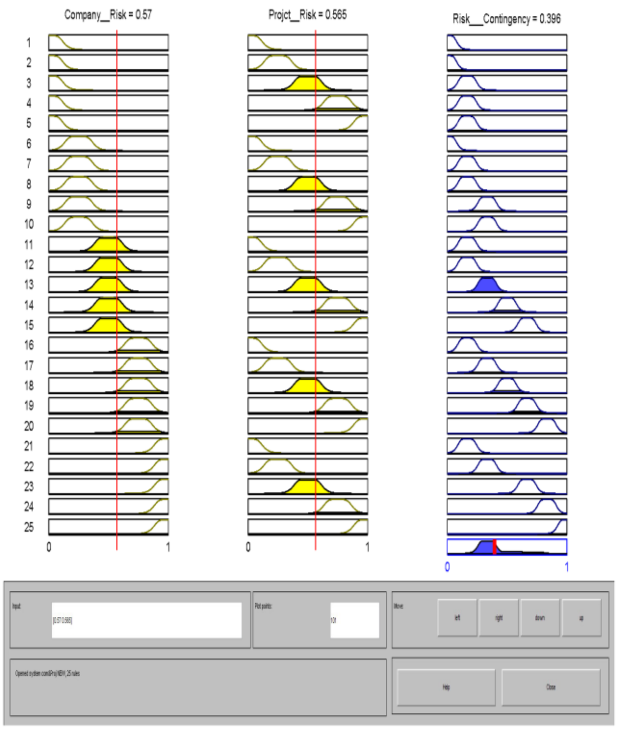


Figure (21) : Aggregation and defuzzification process showing aggregation rules combining company risk with project risk producing overall project risk value (Matlab program software.

XV. MODEL APPLICATION

Only the actual risk values of six projects were obtained through the available data from close out reports of these projects and the results thereof were compared with risk values according to FUZZY program that were discussed in the previous section and the results were shown in table 8.

Figure 22, table 8 show that project 5 in Egypt has low risk value percentage, as per FUZZY LOGIC program equal 17% with a high increase in actual value about 9 %. On the other hand, the proposed risk value percentage as per FUZZY LOGIC program soared with maximum risk value of 48.5 % in project 6 in Egypt, while the actual risk value percentage slowly increased with maximum increase of 6%.

On the other hand, the FUZZY LOGIC program proposed risk value up to 20.6 % in project 4 in Libya, while the actual value was 18 % represent the lowest actual value. A slight decrease in actual risk value about 6 % in project 7 in Jordan with 23 %.

On the other hand, the actual risk value percentage witnessed high increase in risk value in project 1 in Saudi Arabia with 38 % while the proposed risk value percentage were 29%. Moreover, table shows that the risk value percentage, as per FUZZY LOGIC program in project 2 in UAE was 39.6 %. This shows a slight decrease in the actual risk value percentage up to 34.33%.

Table (8) : Fuzzy risk contingency for each project on the basis of fuzzy program compared with actual results.

	Proj. 1 NASL (Saudi)	Proj. 2 HSP (Emirates)	Proj. 4 SAR (Libya)	Proj. 5 DFDP (Egypt)	Proj. 6 (WND) Egypt	Proj. 7 (Potash) Jordan	*Pearson*	R^2
Actual Risk value	38.00%	34.33%	18.00%	26.00%	54.90%	23.00%	1	1
Risk value according FUZZY program	29.00%	39.60%	20.60%	17.00%	48.50%	28.80%	85%	72%

Both table 8 and figure 22 indicate that the risk value results according to FUZZY program are close to those of the actual risk value with correlation coefficient (Pearson Product Moment correlation) of 0.85 and coefficient of determination of 0.72.

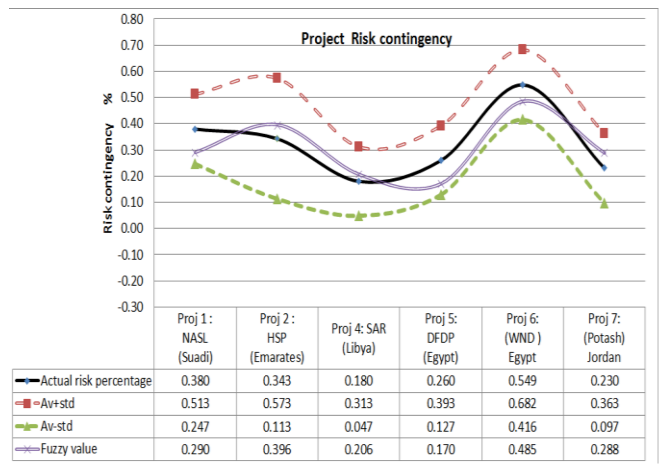


Figure (22) : Fuzzy risk contingency for each project on the basis of fuzzy program compared with actual risk results percentage.

XVI. CONCLUSION

The international markets witness high willing; among most of the construction companies to inter them; seeking maximization of profits and growth potentials. As for the high risk nature of international construction projects, it led to many cost overruns along the history of the industry. Hence contractors should apply a systematic approach to manage risks on the project. The current research suggests a risk index (R) with three functions, these are; estimating risk sources and uncertainty, prioritizing international construction projects and evaluating project risk contingency value.

A design of a calculation model for the R-index was developed by an applying analytic hierarchy process (AHP) with the purpose of estimating risk factors weights (likelihood) and the FUZZY LOGIC approached, in order to, evaluate risk factors impact (Risk Consequences) with aiding software tools such as EXCEL and MATLAB software. A promising risk quantification tool was provided through "FUZZY RISK ASSESSMENT" to quantify risk ratings; in case of vague risk impacts and are defined by subjective judgment and not objective data.

The present study tackled and discussed the model components in details. It also tested the applicability of the suggested methodology on actual cases. A selection of five actual case studies from five different countries was chosen to implement the developed models and test their results.

The model components were explained and discussed in detail throughout this paper. Applicability of the proposed methodology has been tested on real cases. Six case studies in different countries were selected to implement the designed models and test its results.

As shown from the risk factors results on company level using software aids (fuzzy Logic approach model), the Current market volume and competitors, previous experience in host country, have the highest risk value in project no (1) in Saudi Arabia. While lack of skilled workers, unavailable subcontractor or poor performance and Strict Quality Requirements were of the highest risk value on project level.

As for the company level in project No. 2 in Emirates, the change of regulations/ laws, dependence of major power, the size of future market and competitors, the size of current market and competitors and geographical distance were of the highest risk value and on the project level; the lack of skilled workers, delay in materials supplying and cost overrun had the highest risk value.

The following factors had the highest risk values on company level in project No. 3 in IRAQ: tension/conflicts/terrorism, dependence on or significance of major power and previous experience in host country. On the other hand, and as for the project level; subcontractor unavailability or poor performance and defective design errors and rework have the highest risk values.

As for the company level in project No. 4 in Libya, previous experience in host country and Current market size and competitors were of the highest risk value and on the project level; Cost overrun, unsuitable design, weather and natural causes of delay had the highest risk value.

On the other hand, the highest risk values on company level in project 5 in Egypt were for; payment risk and Instability of economic conditions and on the project level the highest risk values were of; delay in materials supplying and delay in design and regulative approvals and cost overrun.

The highest risk values on company level in Project 6 (WND) in Egypt were for; the Change of regulation or laws, Instability of economical conditions and Currency exchange rate, besides on the project level the highest risk values were of; delay in materials supplying, Availability of special Equipment and Strict Safety and Health Requirements.

In project No.7 in Jordan Interaction of management with local contracts, Future market volume and competitors and Geographical Distance Obstacles have the highest risk values on company level, while Weather and natural Causes of delay, Availability of special Equipment and lack of skilled workers have the highest risk values on project level.

The developed model could be useful in sorting projects on the basis of risk, thus aiding decision making on company's part in terms of the project in which they enter. The study examined and tested a developed R model and proved its strength in assessing risk (99%) on company level and also (101%) on project level as shown in Test Factor section (13.4). It can also be helpful in sorting the studied construction projects in the bids stage to take suitable preventive actions.

The ability to evaluate risk contingency values, was demonstrated by the developed model, through aggregating rules merging company risk index and project risk index by applying fuzzy logic approach and MATLAB software.

According to the results of the suggested models, project No. 6 in Egypt had the highest risk contingency percentage of 48.5%, while the lowest risk contingency percentage 17% where in project No. 5 in Egypt also. As for projects 1, 2, 4 and 7 in Saudi Arabia, UAE, Libya and Jordan, the risk contingency of 29%, 39%, 20% and 28% respectively. The actual results on the basis of the project's final reports were close to those of the suggested program.

The case studies findings showed that the suggested model can be applied in order to quantify risk ratings. The tool had the advantage of offering a guidance for the company in terms of the amount of risk premium which should be included in mark- up. The study, through this model, has proved that fuzzy logic approach that applies experts' knowledge managed to overcome the lack of data and uncertainty in predicting future events. It is expected that the model shall offer a very wide range of application in estimating whole life costs of public service.

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