Estimating Cost Contingency for Highway Construction Projects Using Analytic Hierarchy Processes

Ahmed S. EL-Touny[1], Ahmed H. Ibrahim[2], Mohamed I. Amer[3]

[1] M.Sc. Student, Construction Engineering Dept., Faculty of Engineering, Zagazig University, Zagazig, Egypt

[2]Assistant Professor, Construction Engineering Dept., Faculty of Engineering, Zagazig University, Zagazig, Egypt

[3]Associate Professor, Construction Engineering Dept., Faculty of Engineering, Zagazig University, Zagazig, Egypt

Abstract

Winning a bid at a price that yields a profit, is one of the contractor's major goals from bidding. One of the significant components of markup is the risk allowance (contingencies). Therefore, contractors should be wise to consider the likelihood that a particular risk will occur, identify the potential financial impact, and determine the suitable contingency allowance if the risk was to be mitigated through contingencies. Based on previous research, usually most of the contractors set a percentage of cost as contingencies. This approach of setting the contingency percentage intuitively could either lead to losing the bid or leaving money on the table. Therefore, the objective of the presented research in this paper is to identify financial impacts of the risk factors during the bidding stages that affect cost contingency and to develop a fast and reliable model that can be used in estimating the expected cost contingency of highway construction projects. A survey was conducted on ninety construction companies and experts in Egypt. The data obtained from the survey was then processed using Analytic Hierarchy Processes (AHP) technique on the most important fourteen factors out of 175 ones that effect on cost contingency. The developed model was tested using historical completed projects and results show that the predicted cost contingency matches with (96.31%) the average estimated contingency for real case projects. The developed cost contingency model showed robust results.

Keywords: *Bid, Risk, Uncertainty, Risk assessment, Contingency, Analytic Hierarchy Processes (AHP).*

1. Introduction

Risk assessment can be used to determine the probability of occurrence and the likely impact of adverse events during a project, the estimated impact can be added to the project base estimate as a contingency. There are three basic types of general contingencies of projects: tolerance in the specification; float in the schedule; and money in the budget [1]. Project cost contingency is an estimate of costs associated with identified uncertainties and risks, the sum of which is added to the base estimate to complete the project cost estimate. Usually the contingency is set by the estimator and the top management, according to the company policy. Several researchers have proposed a number of sliding scale, methods and models for dealing with risks and uncertainties. Generally, these sliding scale and models were characterized by their complexity, limited and high mathematical treatment and thus difficulty for application. As a result, usually most of the contractors neglect these methods and based on their intuition, they set a percentage of cost as contingencies. This approach of setting the contingency percentage intuitively could either lead to losing the bid or leaving money on the table. Therefore, the objective of the presented research in this paper is to identify financial impacts of the risk factors during the bidding stages that affect cost contingency and to develop a fast and reliable model that can be used in estimating the expected cost contingency. The developed model designed for of highway construction projects, especially roadway projects during a tender preparation using Analytic Hierarchy Processes (AHP) technique.

2. Research Methodology

The research methodology was performed using deterministic approach. Using the AHP technique, the weight of each factor was obtained and cost contingency can be determined. The developed deterministic AHP model validated and a sensitivity analysis were conducted to determine the effect of these factors on cost contingency. Research methodology presented in Fig. (1).

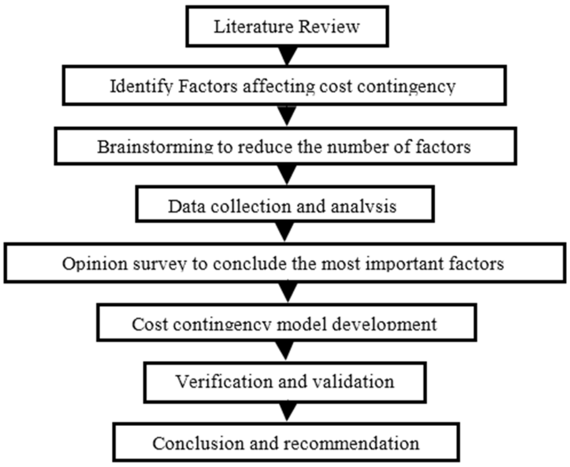

Fig. 1 Research Methodology [2].

3. Literature Review

3.1. Contingency

Contingency has been defined as: "An amount of money or time (or other resources) added to the base estimated amount to (1) achieves a specific confidence level, or (2) allow for changes that experience shows will likely be required" [3]. It should not be used to cover up deficiencies in the estimated cost of projects" [4]. Cost contingency has been broadly defined as "The amount of funds, budget or time needed above the estimate to reduce the risk of overruns of project objectives to a level acceptable to the organization" [5].

Contingency in a construction project from the owner's point of view to is "the budget that is set aside to cope with uncertainties during construction" and in general the owner anticipates that the contingency would not be needed during a project [6], or" the source of funding for unexpected events and described three classifications: designer contingency, contractor contingency and owner contingency". Designer contingency is included in the preliminary budget by the estimator for potential cost increases during the pre-construction phase of project development. Contractor contingency is included in the construction budget to cover unforeseen conditions that may occur during the construction phase. Owner contingency on the other hand is included in the owner's project budget as an additional hedge against project uncertainties which can lead to cost growth, and owner contingency is controlled by the owner [7].
Two major categories of contingency can be identified for construction projects [8]:

(i) Design Contingency: is for changes during the design process for such factors as the incomplete scope definition and the inaccuracy of estimating methods and data.

(ii) Construction Contingency: is for changes during the construction process. Under a traditional procurement arrangement, the project sponsor procures professionals to produce the design before competitively selecting the construction contractor. A contract is signed between the project sponsor and the contractor, which typically contains a variation clause to allow for changes and provide a mechanism for determining and valuing variations. Construction contingency exists to cater for these variations allowable under the contract between the sponsor and contractor.

3.2. Methods of determining Project Contingency Cost

Determination of an appropriate Contingency Cost requires an understanding of how estimators make budget contingency. The Contingency Cost, usually expressed as a percentage markup on the base estimate, is used in an attempt to allow for the unexpected conditions [9]. There are 12 methods of determining Contingency Cost for construction works as presented in Table (1) [10]:

Table 1: Contingency - Estimating methods [10]

No.	Contingency Estimating methods
1	Traditional percentage
2	Method of Moments
3	Monte Carlo Simulation
4	Factor Rating
5	Individual risks – expected value
6	Range Estimating
7	Regression Analysis
8	Artificial Neural Networks
9	Fuzzy Sets
10	Influence Diagrams
11	Theory of Constraints
12	Analytical Hierarchy Process

3.3. Risk Analysis and Contingency Estimation in Construction Industry:

The detailed quantitative assessment of risk is usually known as risk analysis. In general, this process involves associating certain objective and meaningful levels of probability of risks and then quantifying the impact of such risks in terms of time, cost and quality. Several research works have been developed, within the vicinity of the construction industry, to address the problem of risk analysis. These research works are based on the common risk analysis techniques:

- Merrow and Schroeder (1991) highlighted the important link between predicting cost growth and project cost contingency by stating that cost growth can be viewed as inadequate contingency within cost estimates [11].
- Moselhi (1997) pointed out that it is possible to highlight the most common elements and essential characteristics of contingency [12].
- (AACEI 1998) presented that "Contingency amounts may be determined either through statistical analysis of past project costs, or by applying experience gained on similar projects. It was noted that contingency usually does not include changes in the scope or schedule or unforeseeable major events such as strikes or earthquakes" [13].
- Baccarini (2006) in his review of the concept of contingency highlighted several methods for estimating project cost contingency [10].
- Gunhan and Arditi (2007) proposed a four step method for budgeting owner contingency and tested it in a case study [7].
- Molenaar et al. (2008) suggests that risk-based cost estimates support identification of critical cost containment issues which inform the design team about risks throughout the phases of project development [14].
- Alfred E. Thal Jr. et al. (2010) develop a model to predict the amount or required contingency funds for air force construction projects [15].

4. Data Collection (Phase I)

Identifying factors that affect projects cost contingency can help to accurately assess the required cost contingency, which should be added to the project cost estimate. These factors were identified based on the previous literature review and interview with the Egyptian construction market experts through three stages. In the first stage, 175 factors were collected from the literature review. Fig. (2) Shows the hierarchy of the main categories of 175 factors affecting cost contingency from literature. The second stage a brainstorming session was conducted to reduce the number of these factors and get the most important factors that have an impact on cost contingency. A brainstorming meeting was held to get the most important factors that identified from literature review and have an impact on cost contingency. A brainstorming meeting attended by professionals, experts in highway construction projects, practicing contractors, cost estimators, civil engineers, project managers, consultant and owner. The result was 55 factors out 175. Fig. (3) Shows the hierarchy of the main categories of (55) factors affecting cost contingency from after a brainstorming. In the third stage, a questionnaire was used to identify the most significant factors. For data collection, two questionnaires were developed. The first questionnaire was developed to get the most significant factors. The questionnaire included two parts. Part one included the respondent person general information. In part two, table was prepared to be used for measuring the probabilities and impacts of these factors on Cost Contingency.

The questionnaire respondents have provided numerical scoring expressing their opinions based on their experience in the highway construction projects in Egypt. The respondents have inserted two scores in front of each factor. The first represented the frequency (probability) of occurrence of each factor. The second is the expected impact of each factor on projects cost contingency. In order to facilitate the answers for the reviewers, a scale consisting of numbers from 1-10 for probability and impact is used in which 1 means extremely ineffective and 10 means extremely effective.
Such analysis includes many important steps that can be summarized at the follows steps:
First, calculate the total score of frequency and total score of impact. Second, calculate frequency and impact indexes, then calculate importance index for the previously identified fifty five factors, finally the result identified the most important 14 factors that affect cost contingency. These factors were divided into three major categories: project, management, and external conditions. Fig. (4) shows the hierarchy of the most important factors affecting cost contingency in highway construction projects while Table (2) shows the most important (14) factors affecting cost contingency and their frequencies and impacts in highway construction projects in Egypt which calculated from the following four Equations:

Total score of frequency = ∑frequency of each factor = $\sum_{i=1}^{n} Fi$ …………………………………………..…… Eq. (1)

Total score of impact = ∑impact of each factor= $\sum_{i=1}^{n} Ii$ …………….…………………………….. ……….Eq. (2)

Frequency index (Fi) = $\sum_{i=1}^{n} Fi/(N*10)$ ……… Eq. (3)

Impact index (Ii) = $\sum_{i=1}^{n} Ii/(N*10)$ ……….…… Eq. (4)

Where:

N = total number of respondents to each factor, **(N=90).**

10 represented the upper scale of the measurement.

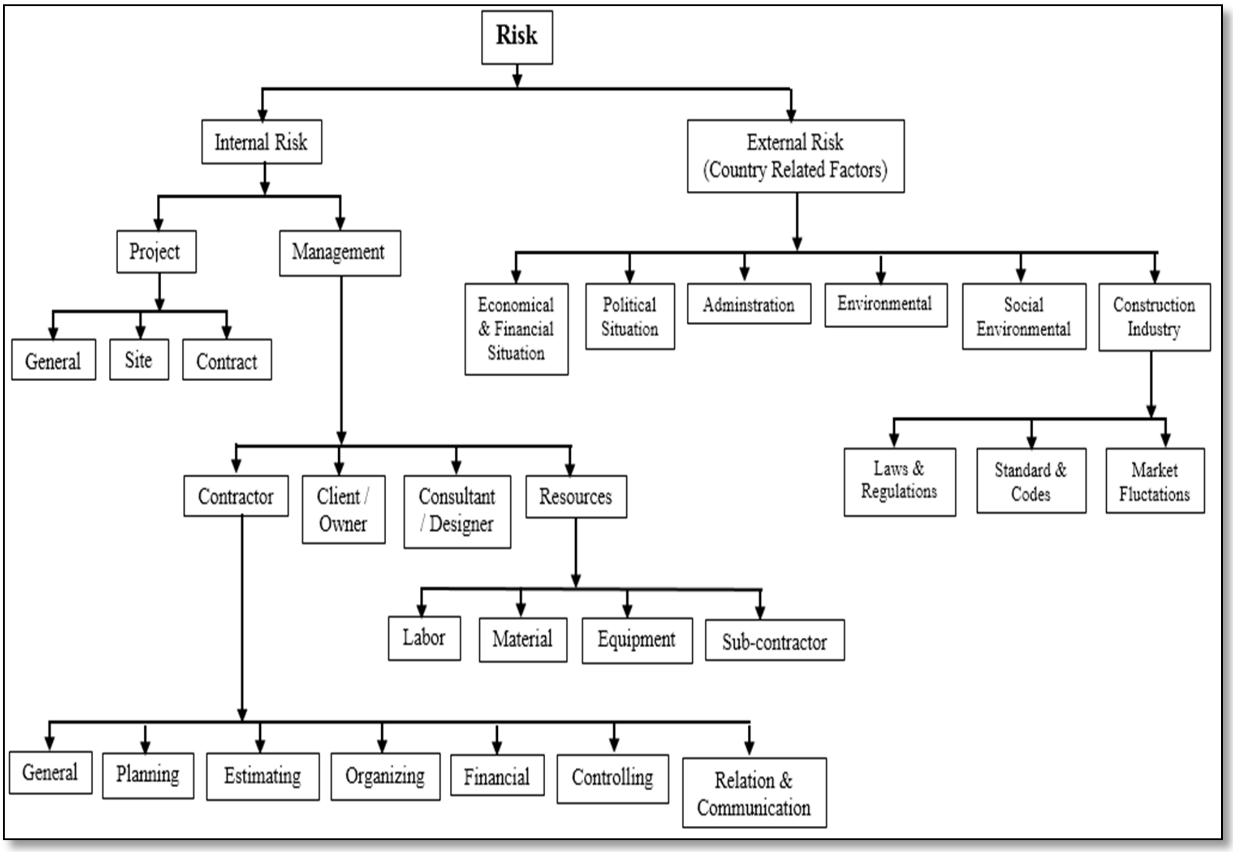

Fig. 2 Hierarchy of the main categories of (175) factors affecting cost contingency from literature [2].

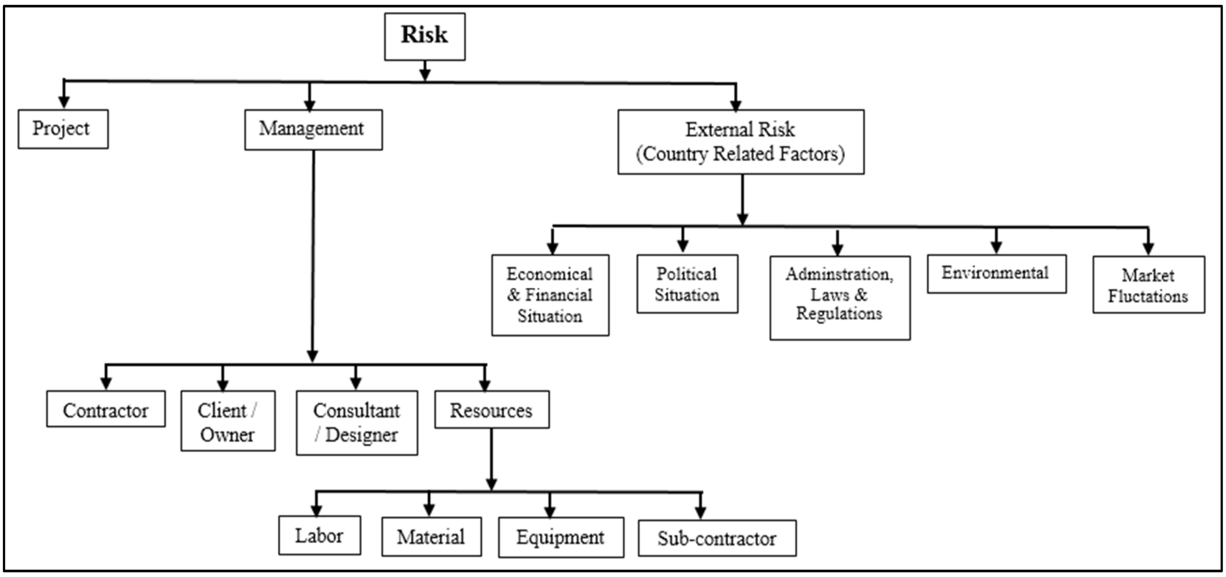

Fig. 3 Hierarchy of the main categories of (55) factors affecting cost contingency after a brainstorming [2].

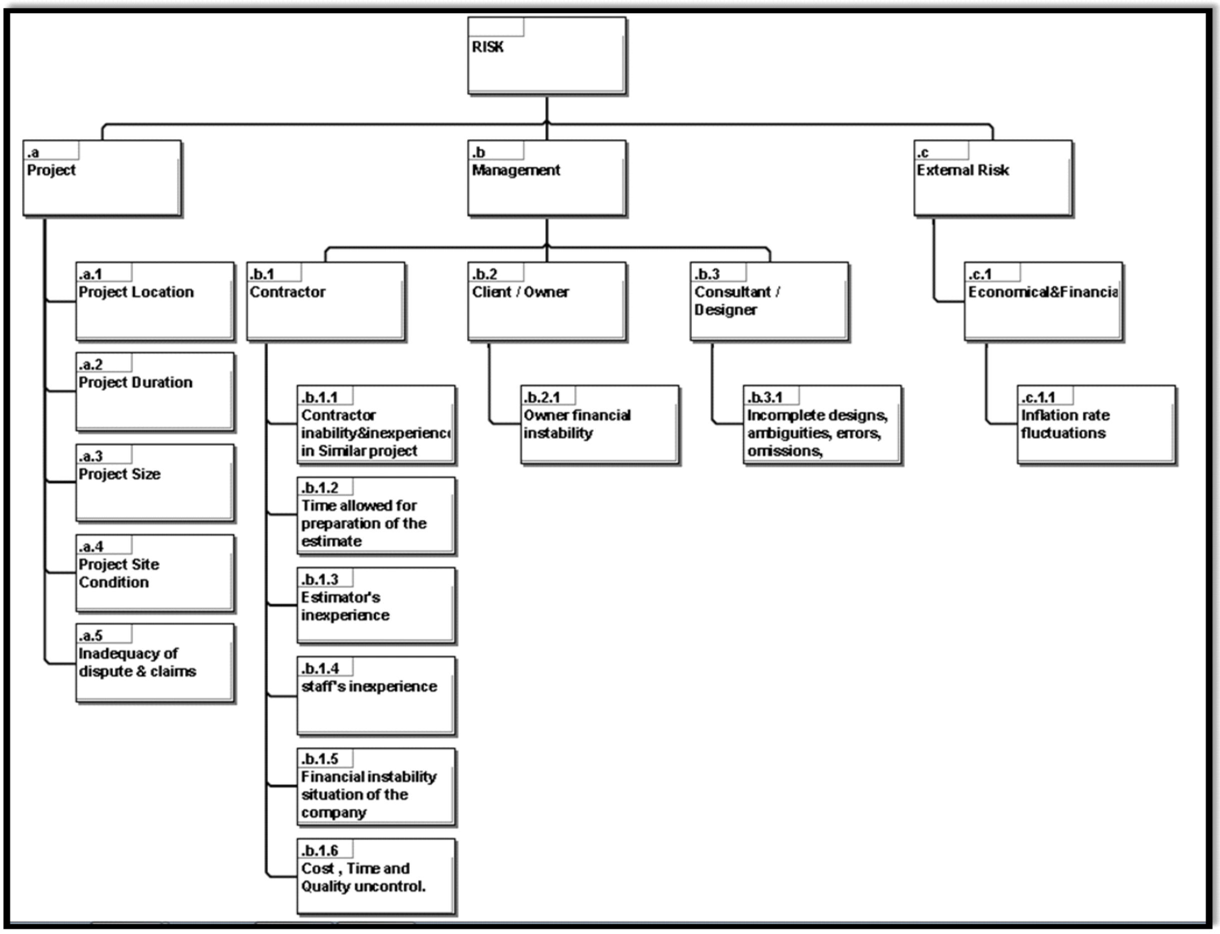

Fig. 4 Hierarchy of the most important factors affecting cost contingency in highway construction projects [2].

Table 2: The most important factors affecting cost contingency and their frequencies and impacts in highway construction projects in Egypt [2].

No.	Factors	Frequency (Fi)	Impact (Ii)
A	**Project Related Factors**		
a.1	Project Location (Project in an area of high sensitivity for paleontology, in the coastal zone, on a scenic highway, near a wild and scenic river, in a flood plain or a regulatory floodway)	0.2604	0.2525
a.2	Project duration (Project completion period)	0.2591	0.2499
a.3	Project Size	0.2277	0.2106
a.4	Project Site Condition (Arrival and access, Weather conditions, Security (e.g., theft), Geotechnical or ground water issues, congestion, approximate to critical zones (Near from governmental Buildings i.e. embassies, ministries, etc.))	0.2813	0.2878
a.5	Inadequacy of dispute settlement procedures and Construction claims	0.2080	0.2290
B	**Management Related Factors**		
b.1	**Contractor**		
b.11	Contractor Previous disability, un-Prequalification and un-experience in Similar project.	0.2486	0.2577
b.12	Time allowed for preparation of the estimate is pressed	0.2198	0.2237
b.13	Estimator's inexperience	0.2224	0.2708
b.14	Staff's inexperience	0.1779	0.2551
b.15	Unstable Financial situation of the company	0.2120	0.2512
b.16	Cost, time, scope, safety and quality uncontrolled	0.2146	0.2394
b.2	**Client (Owner)**		
b.21	Owner financial instability (delays payment of certificates and claims)	0.2420	0.2577
b.3	**Consultant (Designer)**		
b.31	Incomplete designs, ambiguities, errors, omissions, inadequate or inconsistent detailing, etc.	0.1779	0.2721
C	**External Risk (Country Related Factors)**		
c.1	**Economical and Financial**		
c.11	Inflation rate fluctuations (Resources prices fluctuation)	0.2146	0.2159

5. Development of cost contingency model

Analytic hierarchy process (AHP) has been applied in multi-criteria decision making, planning and resource allocation, conflict resolution, and prediction problems [16]. Therefore, the AHP is used in the presented research to assess the weights of various factors that affect cost contingency through pairwise comparison matrices. The proposed cost contingency model developed using the following steps:

Step-1: Establish objectives: Objectives are defined as to estimate cost contingency.

Step-2: Identify all relevant criteria: The model starts with identifying all relevant criteria (factors affecting cost contingency). Based on the research methodology and after determining the most important factors shown in Table (2), data for testing the proposed cost contingency model were collected. These data were gathered from experts in highway construction projects in Egypt using a questionnaire. Physical and telephone interviews with senior managers of several construction management teams were conducted. The studied construction projects were located in Egypt. The surveyed companies had an experience history ranged from 3 to 40 years. They are working in highway construction projects. The budget values of these projects ranged from 50 LE to 800 LE Million Egyptian pound and the duration ranged from 6 months to 5 years.

Step-3: Construct all criteria into a hierarchy structure: These criteria are then structured into a hierarchy descending from an overall objective to various criteria and sub-criteria in successive levels as shown in Fig. (2).

Step-4: Collect experts' opinion: The priority weights of structured criteria are then determined through pairwise comparison to reflect the judgments and relative preferences of different decision makers using a questionnaire. Comparison Matrix between Factors is formed as a dimensional square matrix. The comparison matrix defined by Saaty employs 1-9 scales as showed in Table (3). The diagonal elements of the matrix are all equal to one because they represent the comparison of a criterion against itself. The lower triangle values are the reciprocal of the upper triangular values (i.e. aij = 1/aji). All numbers in the matrix are positive. The priority weights may vary from one person to another. When there are several levels of criteria and sub-criteria, the weight vectors of higher-level criteria are first computed. The weight of the corresponding higher-level criterion is then used to weight the criteria at the lower level in the hierarchy (composite weight).

Table 3: Saaty's scale for pairwise comparison [17].

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	A reasonable assumption
1.1–1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

Step-5: Compute priority weights and ratings of criteria: The procedure is repeated by moving downward along the hierarchy, computing the weight of each criterion at a particular level and using these to determine composite weights for succeeding levels.

Step -6: Developing Cost Contingency (Cc) Model: After determining the weights of each factor in the hierarchy, the cost contingency (Cc) is developed using the model shown in the following Equation (5) [18]:

$$Cc = \sum_{i=1}^{n} W_i * F_i * I_i \qquad \text{… … … … … … Eq. (5)}$$

Where, **Wi** represents the relative weight of factor i; relative to the weight of its category shown in Table(4); **Fi** represents the frequency (probability) of the occurrence average of factor I; and **Ii** represents the impact of each factor in a specific project shown in Table (2);

6. Data Collection (Phase II)

The second questionnaire was developed to collect project data for (AHP) technique. The questionnaire included two parts. Part one included the respondent person general information. In part two, a comparison between criteria and sub-criteria developed to obtain the ratio among parameters of cost contingency (**Wi**) which calculated from Equation (6):

Priority Vector = Priority Weight = Total Weight from respondents / N ……………………………..……Eq. (6)

Where: N= No. of Respondents; (N=90) and summary of priorities of criteria and sub-criteria of the (90) Interviews' data shown in Table (4).

Table 4: Summary of priorities of criteria and sub-criteria of the (90) Interviews' data [2]

	Categories:	**Total Weight**	**Priority Vector**
a)	**Project**	21.697	0.2411
b)	**Management**	43.072	0.4786
c)	**External Risk (Country)**	25.231	0.2803
a)	Project		
a.1)	Project Location	36.395	0.4044
a.2)	Project Duration	7.104	0.0789
a.3)	Project Size	6.736	0.0748
a.4)	Project Site Condition	29.531	0.3281
a.5)	Inadequacy of dispute & claims	10.234	0.1137
b)	Management		
b.1)	Contractor	19.877	0.2209
b.2)	Client / Owner	62.817	0.6980
b.3)	Consultant / Designer	7.306	0.0812
b.1)	Contractor		
b.11)	Contractor inability & inexperience in Similar project	7.514	0.0835
b.12)	Time allowed for preparation of the estimate	14.064	0.1563
b.13)	Estimator's inexperience	7.758	0.0862
b.14)	staff's inexperience	7.269	0.0808
b.15)	Financial instability situation of the company	7.775	0.0864
b.16)	Cost, time, scope , safety and quality uncontrolled	45.619	0.5069

The analysis shows that the weight of all categories. Where, Figure (5) shows relative weights of the main risk categories where (management related factors) represented 48% followed by (Country related factors) represented 28% and finally (Project related factors) represented 24%.

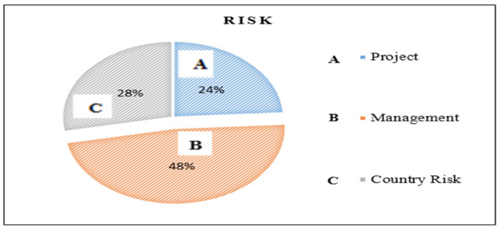

Fig. 5 Average relative weight of main criteria [2]

Figure (6) shows Relative weights of the sub-category Project Related Factors where (Project Location) represented 40%, (Project Site Condition) represented 33%, (Inadequacy of dispute & claims) represented 11%, (Project Duration) represented 8% and finally (Project Size) represented 8%.

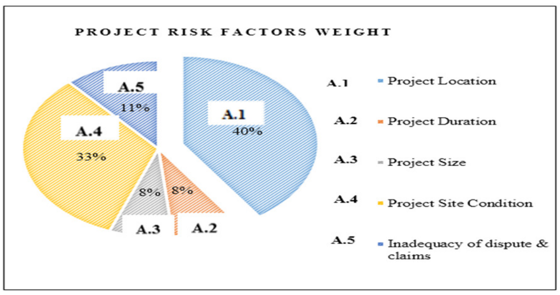

Fig. 6 Average relative weight of sub-criteria Project factors [2]

Figure (7) shows Relative weights of the sub-category Management Related Factors where (Client related factors) represented 70%, (Contractor related factors) represented 22%, and finally (Consultant related factors) represented 8%.

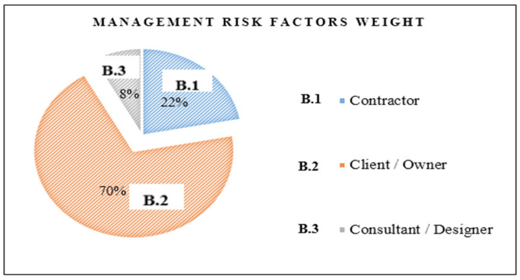

Fig. 7 Average relative weight of sub-criteria management factors [2]

Figure (8) shows Relative weights of the sub-category Contractor Related Factors where (Cost, time, scope, safety and quality uncontrolled) represented 51%, (Time allowed for preparation of the estimate) represented 16%, (Financial instability situation of the company) represented 9%, (Estimator's inexperience) represented 8 %, (Contractor inability & inexperience in Similar project) represented 8%, and finally (staff's inexperience) represented 8%.

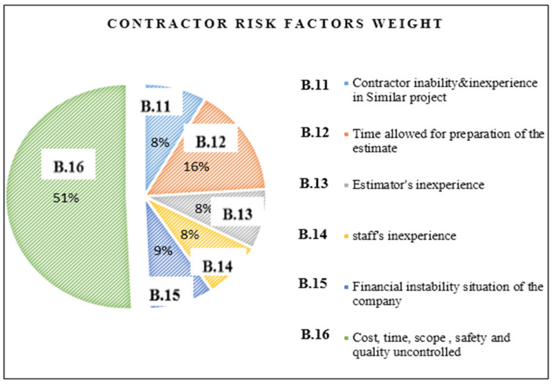

Fig. 8 Average relative weight of sub-criteria Contractor factors [2]

Table (5) shows the weights and relative weights of categories and factors, respectively. In addition, it shows the cost contingency calculation based upon average values of probabilities and impacts. It also shows that cost contingency represents 5.75% of project cost. Therefore, the cost estimator has to consider an almost 5.75 % increase in project cost due to the effect of the contingency factors. This value based on the occurrence of all factors; however, the case might be different if only a few of them are expected to occur. In this case, the contingency value might be lower.

Table 5: Summary of priorities of criteria and sub-criteria of the Interviews' data and the Cost Contingency Calculation [2].

Criteria	Weight	Sub-Criteria (1)	Weight	Sub-Criteria (2)	Weight	Relative Weight (Wi)	Frequency (Fi)	Impact (Ii)	Cost Contingency (Cc)
Project	**0.2411**	Project Location	**0.4044**			0.0975	0.2604	0.2525	0.0064
		Project Duration	**0.0789**			0.0190	0.2591	0.2499	0.0012
		Project Size	**0.0748**			0.0180	0.2277	0.2106	0.0009
		Project Site Condition	**0.3281**			0.0791	0.2813	0.2878	0.0064
		Inadequacy of dispute settlement procedures and Construction claims	**0.1137**			0.0274	0.2080	0.2290	0.0013
Management	**0.4786**	Contractor	**0.2209**	Contractor inability , Previous inexperience and Prequalification in Similar project	**0.0835**	0.0088	0.2486	0.2577	0.0006
				Time allowed for preparation of the estimate	**0.1563**	0.0165	0.2198	0.2237	0.0008
				Estimator's inexperience	**0.0862**	0.0091	0.2224	0.2708	0.0005
				Staff's inexperience	**0.0808**	0.0085	0.1779	0.2551	0.0004
				Financial instability situation of the company	**0.0864**	0.0091	0.2120	0.2512	0.0005
				Cost, time, scope , safety and quality uncontrolled	**0.5069**	0.0536	0.2146	0.2394	0.0028
		Client / Owner	**0.6980**	Owner financial instability (delays payment of certificates and claims)	**1.0000**	0.3340	0.2420	0.2577	0.0208
		Consultant / Designer	**0.0812**	Incomplete designs, ambiguities, errors, omissions, inadequate or inconsistent detailing, etc.	**1.0000**	0.0388	0.1779	0.2721	0.0019
External	**0.2803**	Economical and Financial	**1.0000**	Inflation rate fluctuations (Resources prices fluctuation)	**1.0000**	0.2803	0.2146	0.2159	0.0130
Cost Contingency (Cc) =∑ Wi*Fi*Ii									**0.0575**

Figure (9) shows relative weights of the criteria & sub-criteria affecting cost contingency. Where, (Owner Financial instability) represented 36.26%, (Inflation rate fluctuation) represented 22.59%, (Project location) represented 11.15%, (Project site condition) represented 11.14 %, (Cost, time, scope, safety and quality uncontrolled) represented 4.79%, and finally (Other factors) represented 14.07%.

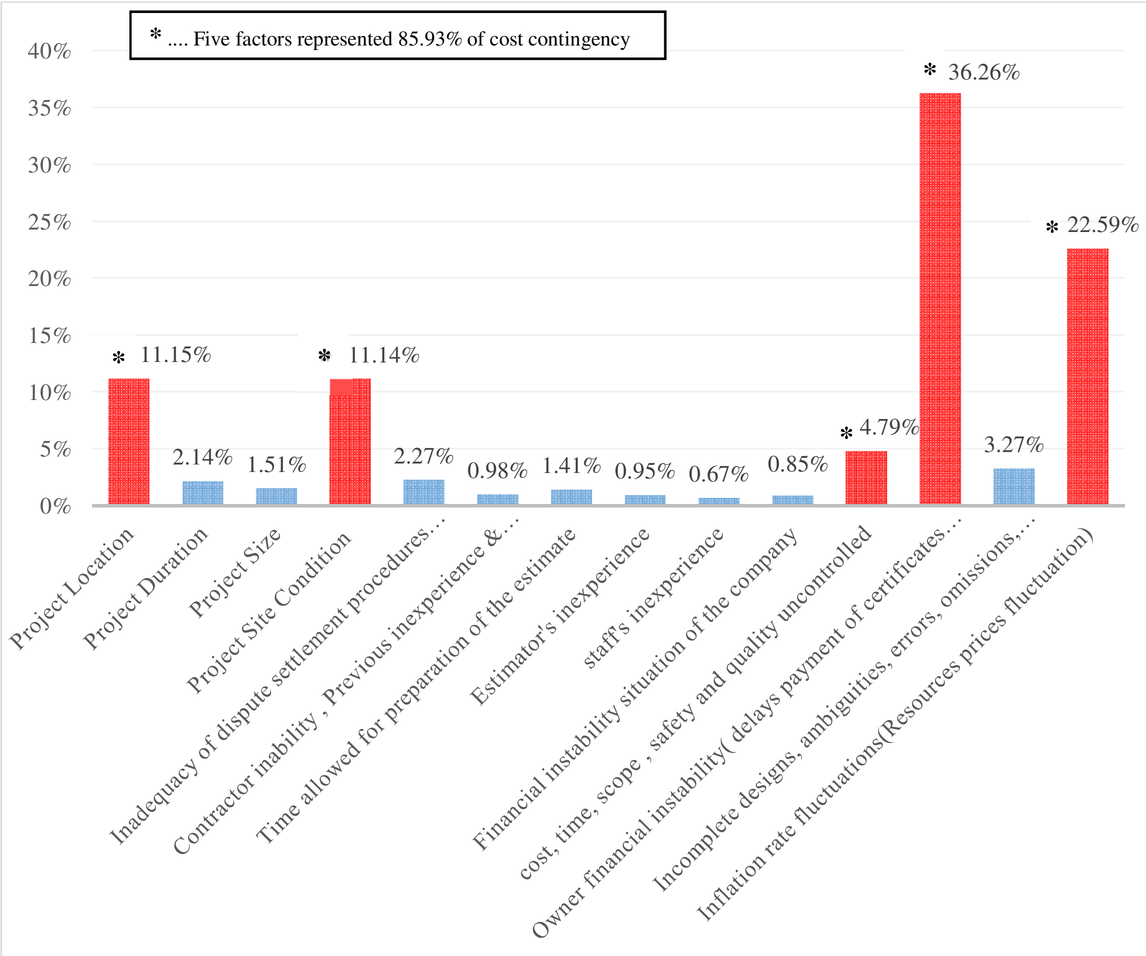

Fig. 9 Weight of all factors relative to cost contingency weight [2]

Sensitivity Analysis

Sensitivity analysis was performed to determine the most sensitive factors that affect cost contingency rate using @Risk software. After the analysis was done, the factors were put in order of their effect on cost contingency as shown in Fig. (10). It is clear from the chart that project site condition factor is the most sensitive factor followed by all other factors. Therefore, the developed model proved to be sensitive to all considered factors.

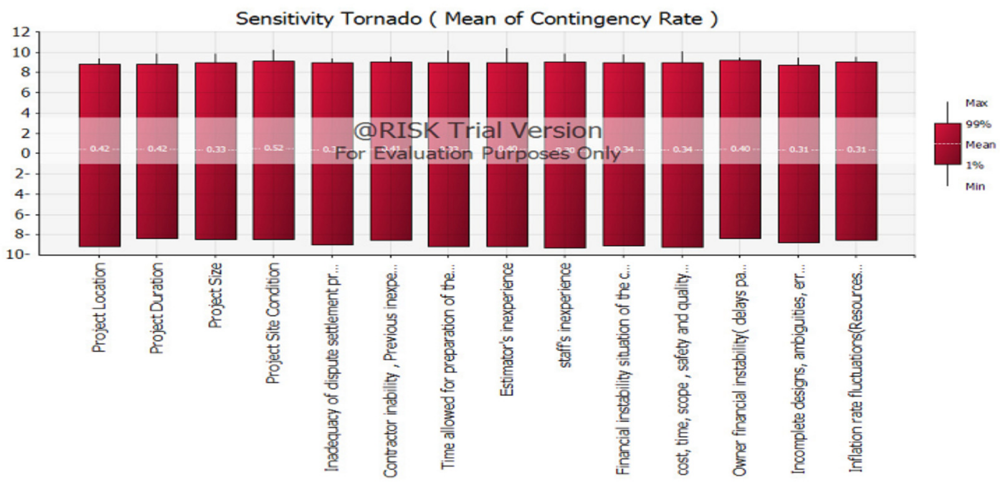

Fig. 10 Sensitivity Analysis of Cost Contingency Model [2].

7. Model Verification

The developed cost contingency model is verified against some projects. The data were collected from historical records and used to verify the model. Data available form five highway construction projects was used in the verification of the model. In order to check the accuracy of estimated average cost contingency (5.75%) that came from the model, data were collected from experts from their previous projects, which include estimated and actual cost. The additional unexpected cost of the projects was calculated by subtracting the estimated cost from actual cost, then, divided this additional cost over the estimated cost to obtain actual cost contingency as showed in Table (6). It is noticed that cost contingency ranged from 4.95% to 7.12% with an average cost contingency of the five projects is 5.97%, which is close to the value obtained from the developed model (5.75%).

Table 6: Additional Unexpected Cost and Contingency Analysis for five Highway Construction Projects [2].

	Project 1	Project 2	Project 3	Project 4	Project 5
Total estimated cost (a)	45,944,800	116,069,100	148,089,573	117,829,008	107,969,937
Actual cost (b)	48,570,105	123,319,560	155,414,433	126,215,460	114,261,505
Add cost c=(b-a)	2,625,305	7,250,460	7,324,860	8,386,452	6,291,568
Cost Contingency (c/a)%	5.71%	6.25%	4.95%	7.12%	5.83%
Average cost contingency	5.97%				

8. Summary and conclusions

The objectives of the research are to determine financial impacts of the risk factors during the bidding stages that affect cost contingency. Also, to develop a model that can be used in estimating the expected cost contingency of highway construction projects. In this research, a survey was conducted on construction companies to assess the factors that affect cost contingency. Factors that affect risk and have consequence on cost contingency were identified. The most important 14 factors out of 175 factors used in developing a simple model using Analytic Hierarchy Processes (AHP) for analyzing and estimate the cost of contingency for highway construction projects. The developed model was tested using historical completed projects. It is noticed that cost contingency ranged from 4.95% to 7.12% with an average cost contingency of the projects is 5.97%, which is close to the value obtained from the developed model (5.75%). The results show that the predicted cost contingency matches with (96.31%) the average estimated contingency for real case projects.

This mean that the developed model is robust in predicting the values of Cost Contingency. A sensitivity analysis was conducted on the model and showed that project site condition factor is the most sensitive factor followed by all other factors.

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