HBRC Journal

ISSN: (Print) 1687-4048 (Online) Journal homepage: https://www.tandfonline.com/loi/thbr20

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To cite this article: Mohamed Sayed Bassiony Ahmed Abd El-Karim, Omar Aly Mosa El Nawawy & Ahmed Mohamed Abdel-Alim (2017) Identification and assessment of risk factors affecting construction projects, HBRC Journal, 13:2, 202-216, DOI: 10.1016/j.hbrcj.2015.05.001

To link to this article: https://doi.org/10.1016/j.hbrcj.2015.05.001

HBRC Journal (2017) 13, 202–216

Housing and Building National Research Center

HBRC Journal

http://ees.elsevier.com/hbrcj

FULL LENGTH ARTICLE

Identification and assessment of risk factors affecting construction projects

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Received 27 November 2014; revised 1 March 2015; accepted 11 May 2015

KEYWORDS

Risk assessment;
Cost overrun;
Schedule overrun;
Likelihood;
Probability;
Scale

Abstract Cost saving and time performance are usually essential to all parties who are involved in a construction project, that is owner, contractor, subcontractor. The main causes of disputes in construction projects involve delay and failure to complete the work in the specified cost and time frame. The delivery time of a project is a key factor to the owner in terms of cost as much as it is for the contractor.

Unexpected increase in cost and delays in construction projects are caused by owner, contractor, environments, etc. in which several types of risk factors may occur concurrently. The effect of cost overrun and schedule overrun do not only influence the construction industry but the overall economy as well. Even though construction project increasing in cost and schedule has received extensive attention of researchers, but because of continuous changes and development in the field, the study considered of added value to the construction industry in Egypt, in addition to risk strategy and plan analysis. In order to meet the deadline of a project and due to the complex nature of construction projects, cost and scheduling should be flexible enough to accommodate changes without negatively affecting the overall project cost and duration. As such, the objectives of the presented research in this paper are to identify, study, and assess the effect of the factors that affect cost and time contingency. Data are collected from sixteen construction companies in Egypt. The collected

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Peer review under responsibility of Housing and Building National Research Center.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.hbrcj.2015.05.001

data, output charts and analyses spreadsheets will be used for the development of computerized model built by the authors with identification abbreviation *RIAM*.

Introduction

Risk management has become an essential requirement for construction projects. Risk management process includes Hazard identification, Risk assessment and Risk control. Risk is assessed by Qualitative Methods and Quantitative Methods. Risk management is the systematic process of identifying, analyzing, and responding to project risk, and it includes *maximizing* the probability and consequences of positive attributes and *minimizing* the probability and consequences of attributes adverse to project objectives.

Project risk is an uncertain event or condition that, if occurs, has a *positive* or *negative* effect on a project's objectives. Components of risk are an event that may or may not happen, the probability of the occurrence of that event and the impact of the occurrence of that event.

There are many sources of uncertainty in construction projects, which include the performance of construction parties, resources availability, environmental conditions, involvement of other parties, contractual relations, etc. As a result of these sources, construction projects may face problems that cause delay(s) in the project completion time [1].

The key success indicators of construction management system(s) include completing the project with cost and time, within the planned budget and duration, and within the required quality, safety, and environmental limits. These goals are interrelated where each of them is affecting and affected by the others. An accurate cost estimating and scheduling should be sought in order to meet the overall budget and time deadline of a project.

Time contingency is used to guarantee the completion time of either an activity or a project [2]. Due to the unique nature of construction projects, cost overrun and schedule overrun uncertainty are essential for true budget and scheduling, which should be flexible enough to accommodate changes without negatively affecting the overall cost and duration. It is also essential to allocate a contingency value to both cost and time [3].

Yet, there are situations where there could be delays in activities, whether they are within the critical path or not, which result in a delay in the overall project duration. These delays will consequently have a negative impact on the quality, budget, and might be safety of a project. Therefore, estimating cost and time contingencies are seen as a prime factor in achieving a successful construction project. Although several industrial sectors developed and used software for estimating time and cost contingencies in order to minimize delays and avoid being over budget, yet limited efforts are reported in the literature in the area of predicting time contingency in construction projects. The overall objectives of the presented research in this paper are as follows: (1) to identify and study the factors that affect cost overrun and schedule overrun; (2) to develop a probability distribution charts for likelihood, cost impact and schedule impact; and (3) to quantify the Risk assessment impact on cost and schedule.

Rank	Descriptor	Description	Probability
Very high	Almost Certain	Even chance	> 50%
High	Likely	One in every 4 projects	> 25%
Moderate	Possible	One in every 10 projects	>10%
Low	Unlikely	One in every 20 projects	>5%
Very low	Rare	Less than 1 in every 20 projects	< 5%

Fig. 1 Probability matrix.

Rank	Schedule	Cost	Safety	Quality
Very high	>3 months	>$10 million	Fatality	>10 %
High	2-3 months	$ 5-10 million	Severe injury	5-10 %
Moderate	1-2 months	$ 2-5 million	Medical treatment	3-5 %
Low	2-4 weeks	$1-2 million	First Aid	1-3 %
Very low	< 2 weeks	< $1 million	No injury	<1 %

Fig. 2 Impact matrix.

Fig. 3 Strategies for negative risks.

Table 1 Factors affecting cost and schedule overruns.

Criteria	Sub-criterion	Attributes/risk factor	Risk Probability					Cost Risk Impact					Schedule Risk Impact				
			Very Low 1	Low 2	Moderate 3	High 4	Very High 5	Very Low 1	Low 2	Moderate 3	High 4	Very High 5	Very Low 1	Low 2	Moderate 3	High 4	Very High 5
Site conditions	Environmental	Earthquake															
		Precipitation /flood															
		Unpredicted Weather conditions															
		Pollution															
	Sub-surface	Unexpected Surface conditions															
		Archeological survey done															
		Geo-technical investigation															
	Site location	Construction area (rural/urban)															
		Access conditions															
		On-site congestion															
		Delay in permits and licenses															
		Security requirements															
		Safety regulation															
		Differing site conditions															
Resources	Labor	Labor skills level															
		Labor availability															
		Drop in Labor productivity															
		Labor accidents															
		Human resource planning															
		Working hours restrictions															
	Equipment	Equipment quality															
		Equipment breakdown															
		Equipment maintenance															
		Equipment malfunctions															
	Material	Material delivery															
		Material storage															
		Material theft & damage															
		Material procurement															
		Non-conforming material															
		Material monopoly															
		Nominated vendors															
Project parties	Owner	Owner type															
		management strategy															
		organization structure															
		Work/labour permits															
		on-site access															
	Engineering and Design	Team experience															
		Project goal															
		Complexity of design															
		Ad-hoc consultants															
		Design error															
	Contractor	Contractor pre-qualified															
		New technology															
		Defective work															
		Rework															
		no of subcontractors															
		Contractor Reputation															
		Nominated sub-contractors															
		no. of current projects															
	Project management	Management experience															
		Owner quality assurance															
		Scope definition															
		quality control process															
		Type of contract															
		availability of variations															
Project features	Financial	Type of Funds															
		Fluctuation in prices															
		Invoices delay															
		Change in currency rate															
		Owner financial capacity															
		Progress payment															
		rate of interest															
		tax rate															
		foreign currency															
		project size															
	Political	Bribery and Corruption															
		Wars and revolutions															
		Changes in laws and regulations															
	Schedule	Fast track schedule															
		Project duration															

Strategies for *Negative* Risks or Threats are Avoid, Transfer, Mitigate or Accept. On the other hand Strategies for *Positive* Risks or Opportunities are Exploit, Enhance or Accept.

Background

Delays have an adverse impact on project success in terms of time, cost, quality and safety [1].

Time-delays and cost overruns are among the most common phenomena in the construction industry [4]. Therefore, planners and schedulers have used time contingency to guarantee the completion time of either an activity or a project [2]. The easiest and safest way to build a time contingency is to extend the project end date to a point where there is a comfortable amount of positive float, which may not be cost effective or acceptable to the client. However, it might not also be acceptable to proceed in a project with a zero float plan [5].

There is no standard definition of contingency in which it could imply different meanings to estimators, contractors, and owners' organizations [6]. Contingency is probably the most misunderstood, misinterpreted, and misapplied word in project execution [7]. It is an amount of money or time (or other resources) added to the base estimated amount to achieve a specific confidence level or allow for changes where experience shows obligation [8]. It can also be defined as the budget that is set aside to cope with uncertainties during construction [3] or the amount of money/time needed above the estimate to reduce the risk of overruns of project objectives to an acceptable level within the organization [9]. Treasury [10] identified two major categories of contingency for construction projects:

1. *Design Contingency* – it addresses the changes during the design process for factors such as incomplete scope definition and inaccuracy of estimating methods as well as data [11].
2. *Construction Contingency* – it addresses the changes during a construction process. Under a traditional procurement arrangement, the contract typically contains a variation clause(s) to allow for changes and provide a mechanism for determining and valuing variations.

There are many definitions for contingency in the literature; most of them focused on cost contingency. Contingency has

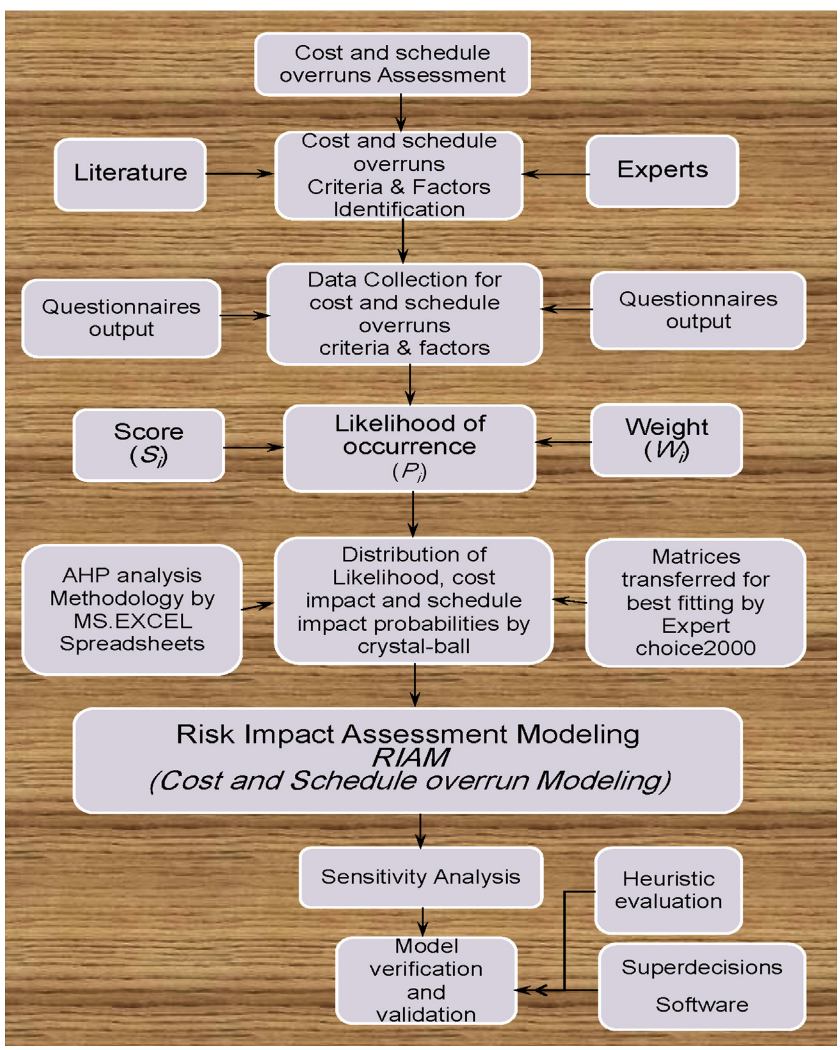

Fig. 4 Research methodology flow chart.

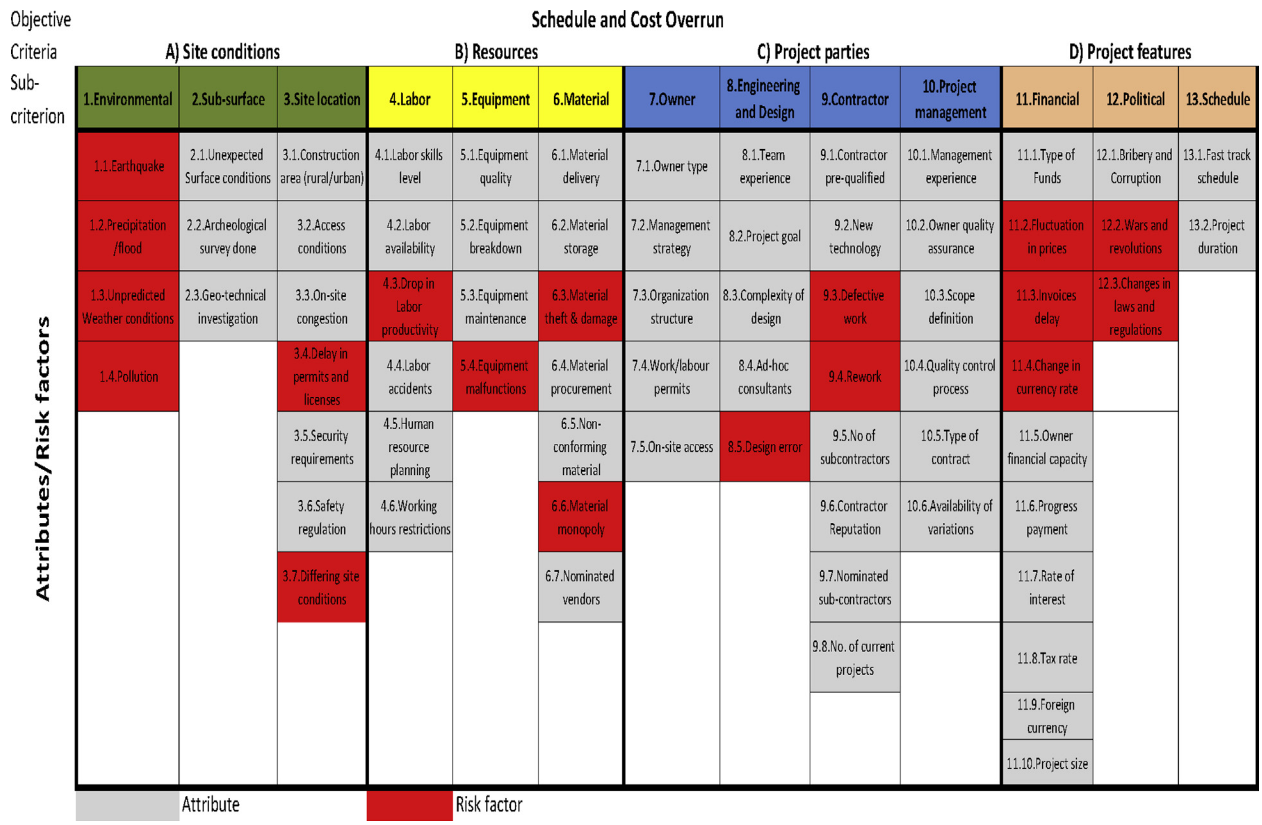

Fig. 5 Summary of attributes.

different meanings to different people. Despite its importance, estimating time contingency was not thoroughly addressed in the literature. Prior to reviewing the estimating methods for project contingency, there are different attributes that affect contingency. Iyer and Jha [12] identified 55 factors affecting the performance of project schedule. They observed seven factors that have the most significant impact on schedule outcome and divide them into two main categories (see Figs. 1–3).

The first category included factors that encompassed the capability to improve performance level, such as owner's competence as well as commitment and conflict among project members. The second included factors that tended to retain the schedule at its existing level, such as coordination among project members, lack of knowledge and skills for the project managers, hostile socioeconomic environment, and uncertainty in selecting project members/team. In addition, Touran [3] indicated that the effect of change orders increased the original cost and schedule since they modified the original contract. Boskers and AbouRizk [13] presented a methodology that incorporated network analysis and duration uncertainty in project time analysis. They studied the effect of various factors on time contingency using a linear equation.

There are many factors that impact time contingency in which it is not only important to identify these factors but assess their impact on the project duration as well. Most engineers, planners, and agencies relied on their experience to estimate cost and time contingencies [3,13–15]. The contractor's contingency was represented as a fixed percentage of the contract value [16] or as a percentage of total project cost or duration [3]. The completion date of a project was often missed due to uncertain events in which their impact was difficult to predict because of the uniqueness of construction projects.

Schedule contingency analysis is the process of identifying and evaluating contingency factors, present or anticipated, and determining both the probability and impact of identified contingency factors [17]. It is a preliminary step in establishing a schedule and time control strategy, which is intended to increase the probability of desired outcome while minimizing risk factors [12].

Factors affecting cost overrun and schedule overrun

Based on the literature and the opinion of practitioners/Expert through fifty nine questionnaires, several imperative factors that affect cost and time contingency are identified and studied. They are divided into four major criteria: (A) Site conditions, (B) Resources, (C) Project parties, and (D) Project features related factors. Table 1 shows the detail of these main criteria and their factors. Site conditions include environmental, Sub-surface and Site location. Resources include Labor, Equipment and Material. On the other hand, project parties cover Owner, Engineering & Design, Contractor and Project management. In addition Project features cover Financial, Political and schedule sub-criterions.

The detail attributes/risk factors related for each sub-criterion are shown in Table 1. It is quite clear that the identified criteria and factors effectively contribute to the uncertainty in construction project cost and scheduling, which in turn, impact the assessment of cost and schedule overruns.

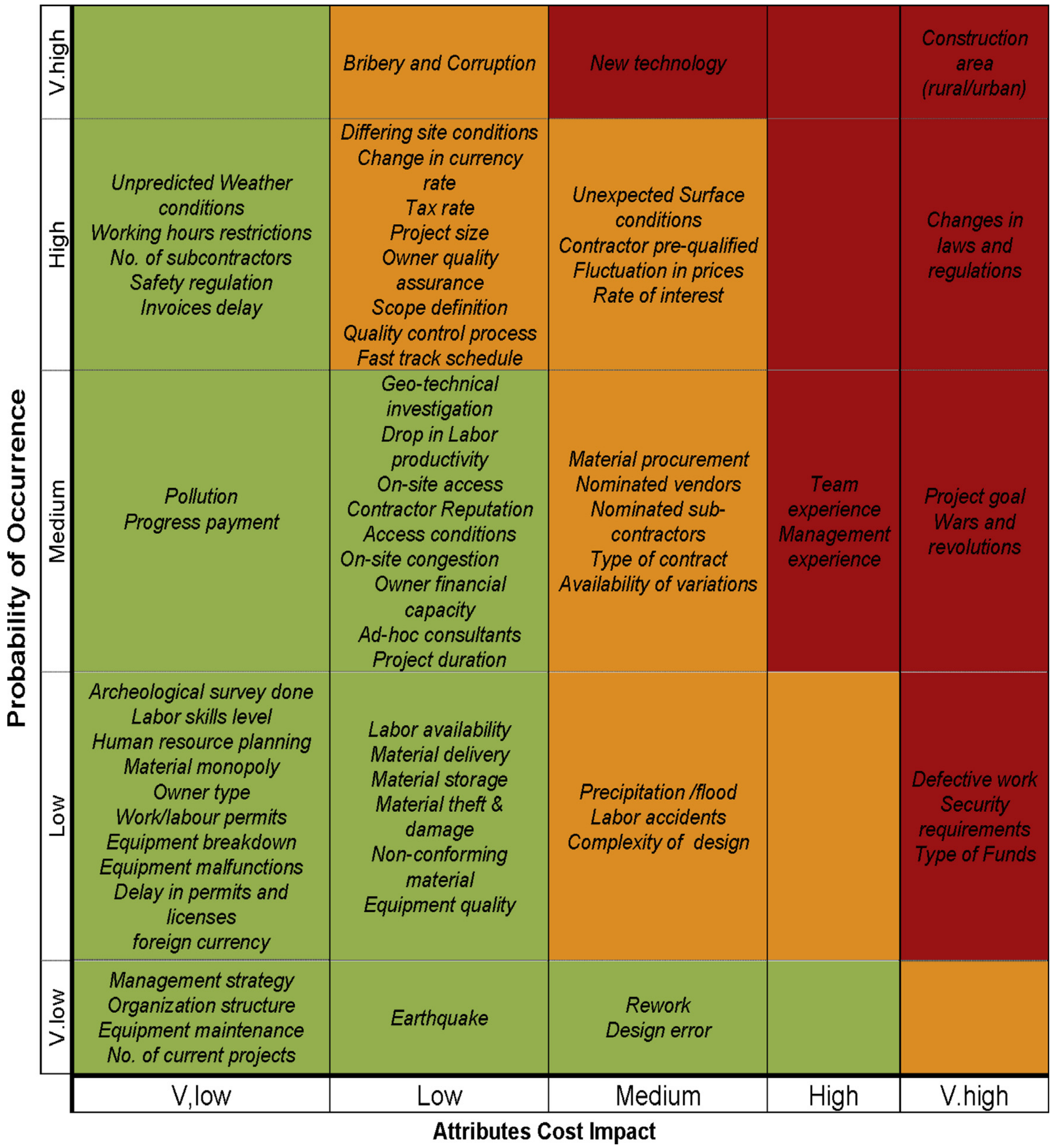

Fig. 6 Heat map concerning attributes *COST* impact.

In the present research, these factors are considered in predicting project budget and time contingencies.

Research methodology

Fig. 4 shows the detailed steps utilized to perform the various activities of the present research. Factors that affect cost and schedule overruns are identified and discussed using literature review and experts opinion. A questionnaire survey is conducted to collect the impact of each factor. The research methodology is performed using probability distribution developed by crystal ball software. The collected data through questionnaires will be used to illustrate the min., mean, max. and stander division values (see Fig. 5).

The output charts developed by crystal ball software will be divided into three stages: the first one illustrates the probability distribution per each attribute likelihood [P_i], the second stage will concern the cost impact probability distribution either for attributes which will be defined as [weight W_i], or concerning the sub-criterion itself, which will be defined as [Score S_i], furthermore the third stage will reflect the schedule impact probability distribution either for attributes/risk factor or for the sub-criterions themselves as described previously. These data will be used by AHP based simulation modeling which will be described in detail in another paper.

As illustrated in Fig. 4 below, the upper steps will be done in this paper, and on the other hand the lower part of the flow chart includes AHP analysis will be illustrated in detail in

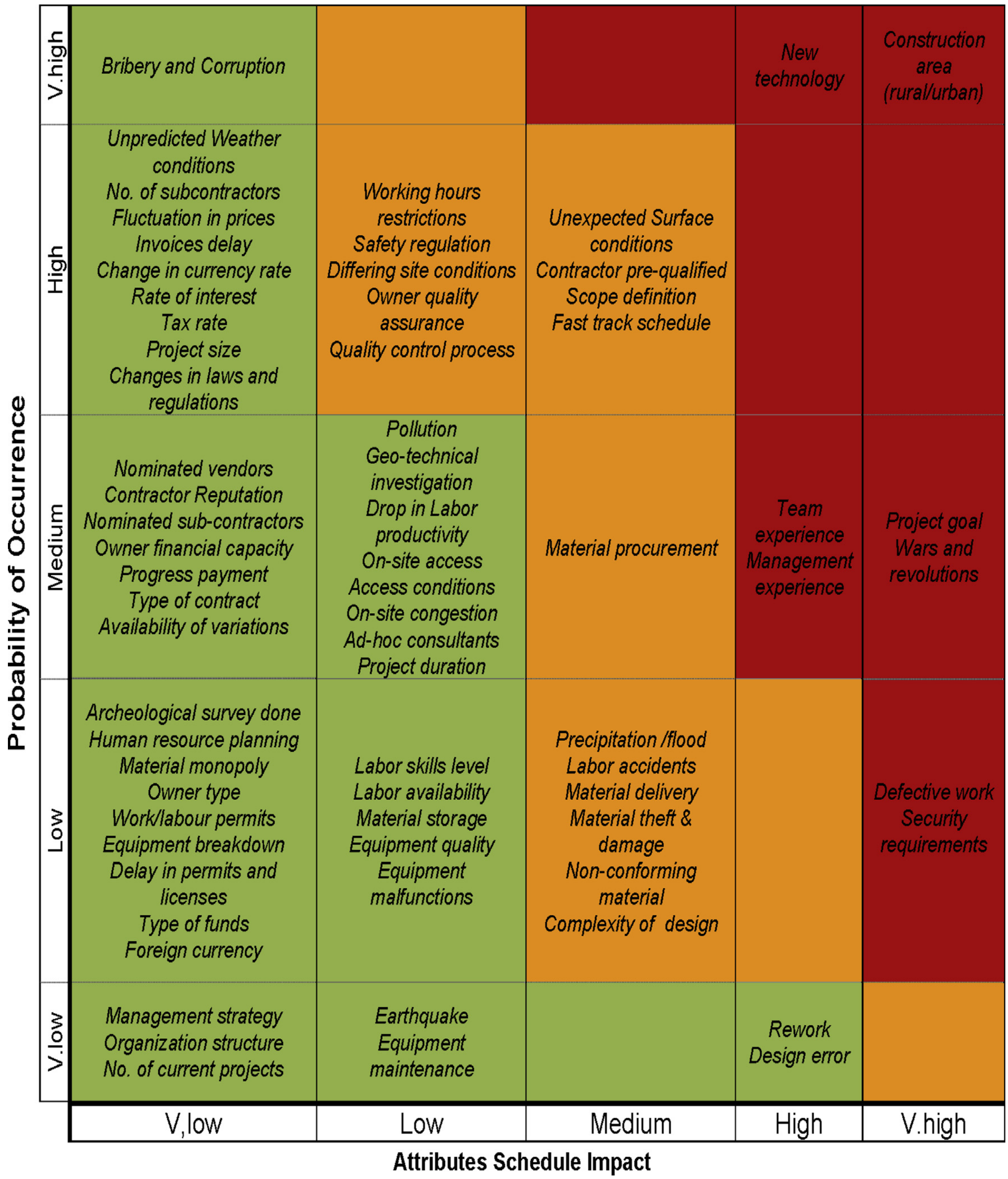

Fig. 7 Heat map concerning attributes *SCHEDULE* impact.

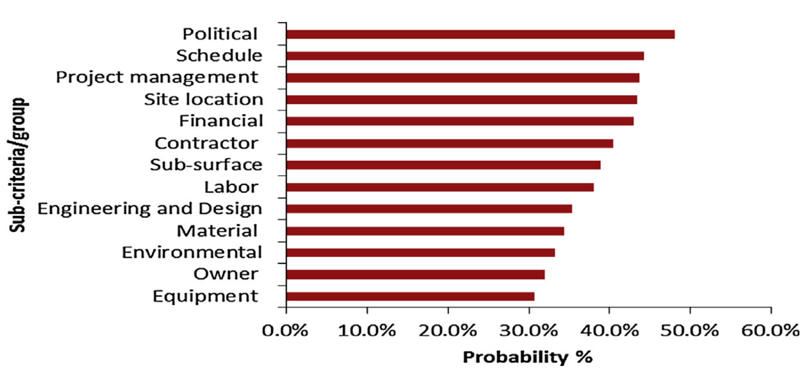

Fig. 8 Attributes probability of occurrence tornado chart (for sub-criterions).

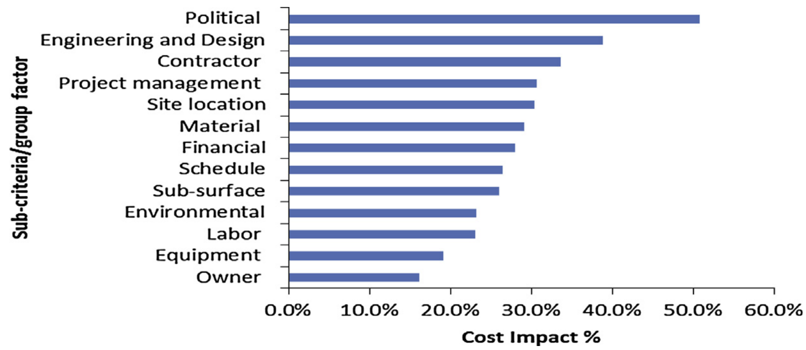

Fig. 9 Tornado chart for sub-criterions cost impact.

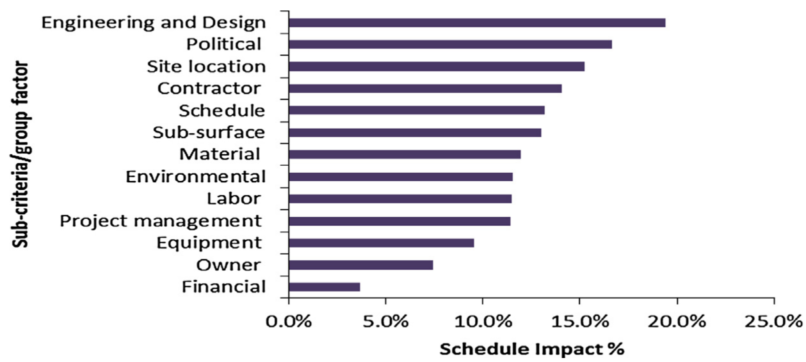

Fig. 10 Tornado chart for sub-criterions schedule impact.

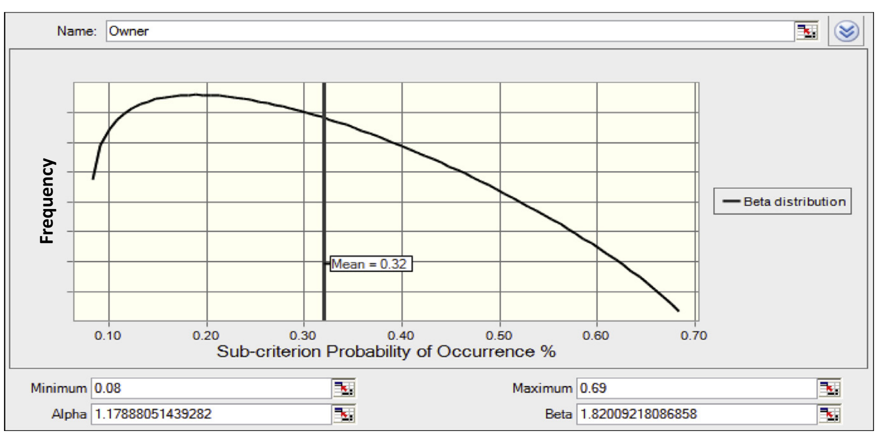

Fig. 11 Probability of occurrence for *OWNER* sub-criterion.

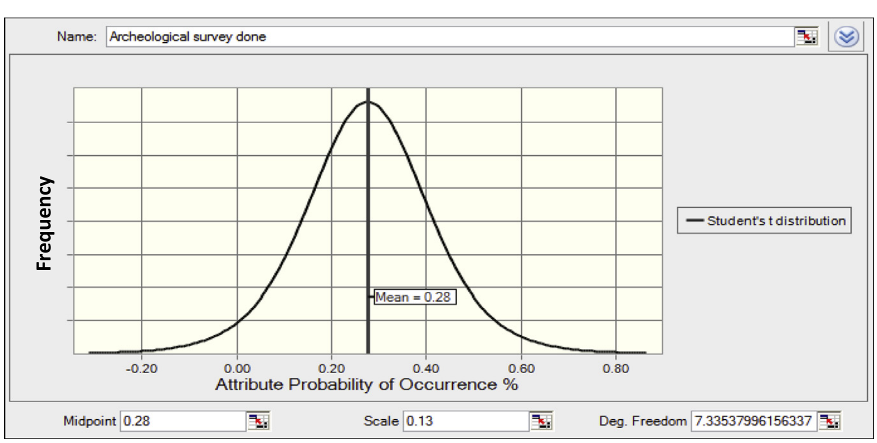

Fig. 12 Probability of occurrence for *ARCHEOLOGICAL SURVEY DONE* attribute.

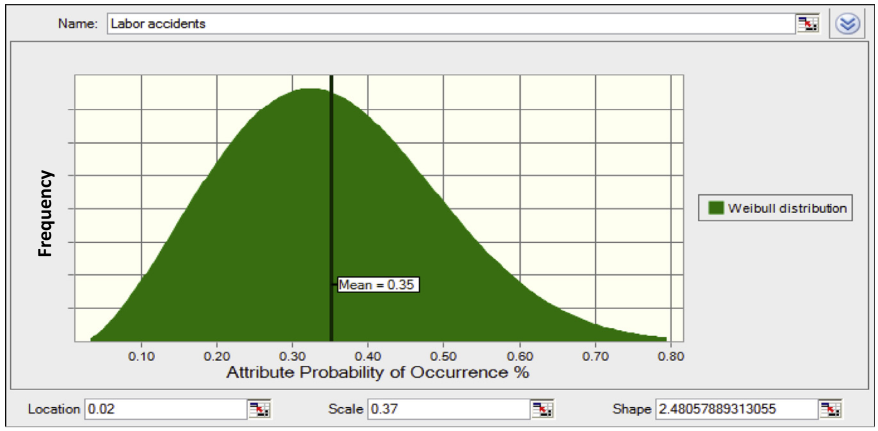

Fig. 13 Probability of occurrence for *LABOR ACCIDENTS* attribute.

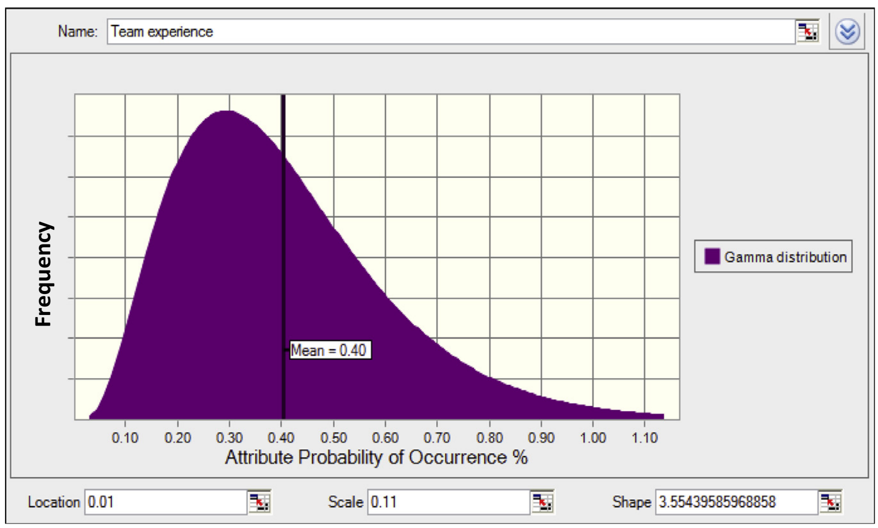

Fig. 14 Probability of occurrence for *TEAM EXPERIENCE* attribute.

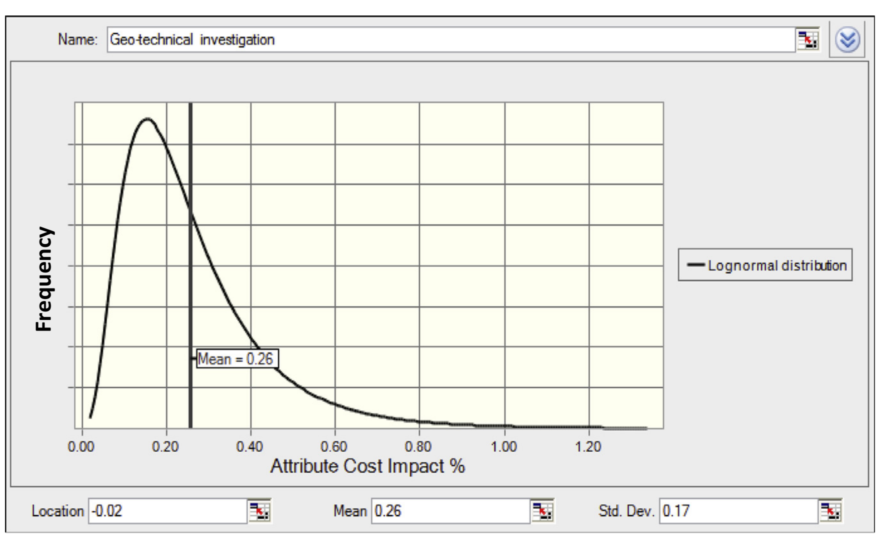

Fig. 15 Cost impact probability distribution for *GEO-TECHNICAL INVESTIGATION* attribute.

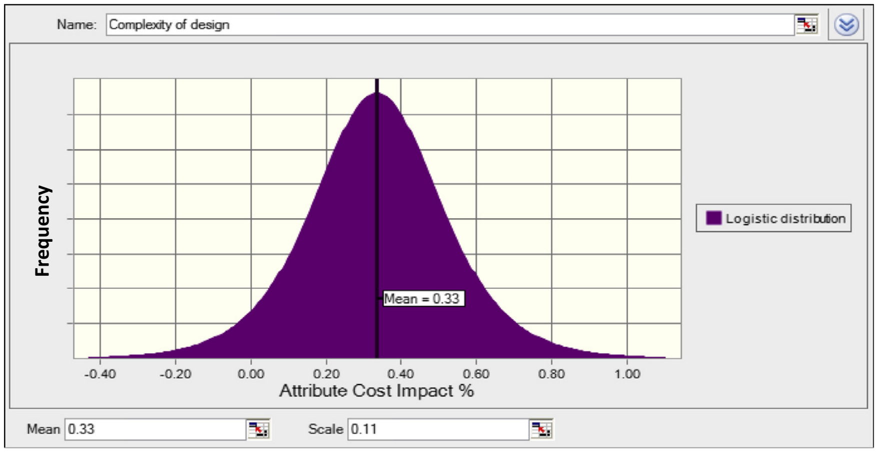

Fig. 16 Cost impact probability distribution for *COMPLEXITY OF DESIGN* attribute.

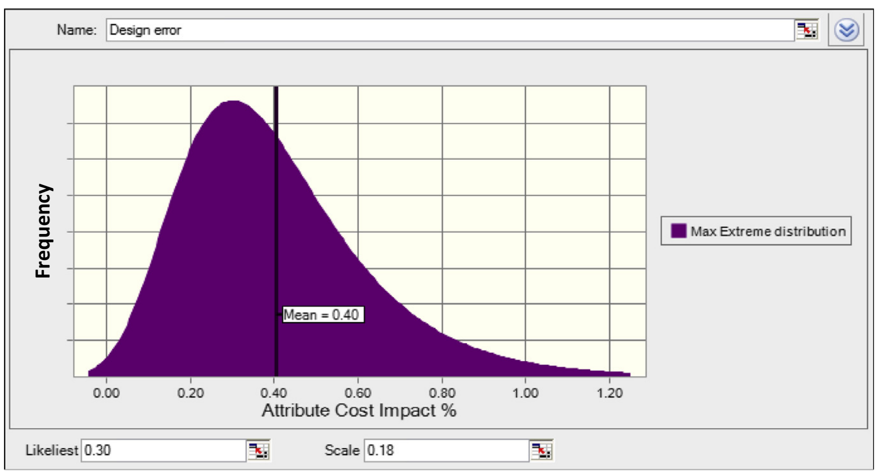

Fig. 17 Cost impact probability distribution for *DESIGN ERROR* attribute.

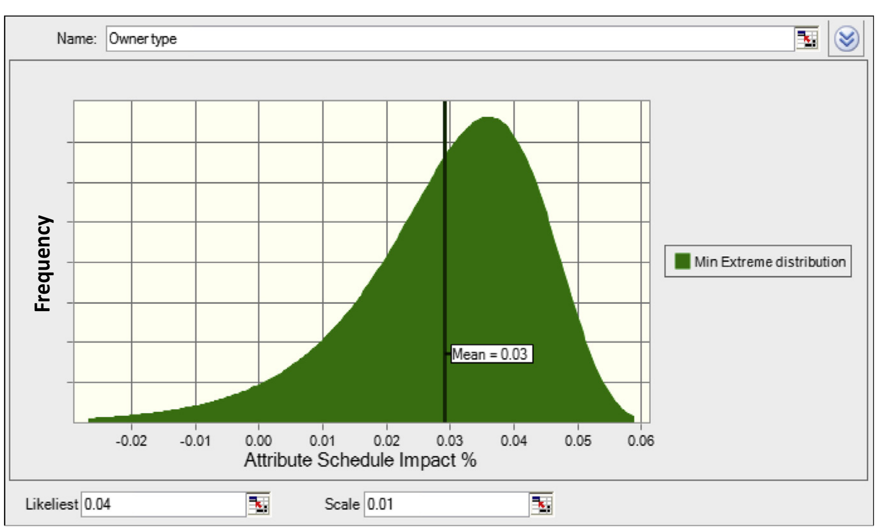

Fig. 18 Schedule impact probability distribution for *OWNER TYPE* attribute.

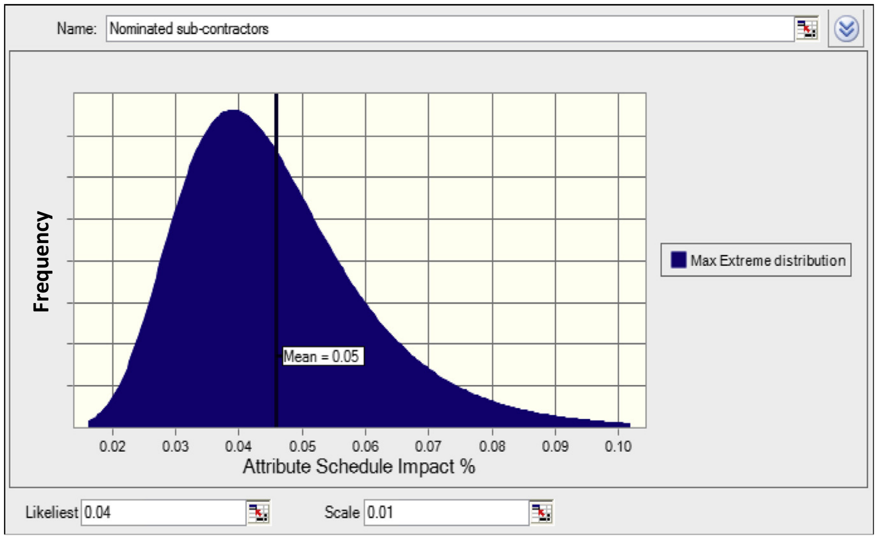

Fig. 19 Schedule impact probability distribution for *NOMINATED SUB-CONTRACTOR* attribute.

another paper which can be considered as a complementary part for the present paper.

Development of data and charts

Introduction

Cost and schedule overruns analysis are defined in this research as the process of – identifying and evaluating contingency factors, present or anticipated, and determining the cost and schedule overruns indexes. In order to assess these indexes, some steps are utilized to perform the intended analysis. These steps are discussed further in the following sections.

The questionnaires have been developed to evaluate the probability of attributes in addition to attributes cost impact and schedule impact, and these questionnaires cover a lot of attributes/risk factors from the literature to allocate various categories as per environmental and financial effects which had covered by 65 factors and increased up to 70 factors by practitioners' advice. These added factors are equipment malfunctions, ad hoc consultants, availability of variations, owner financial capacity and tax rate.

The data have been mentioned in Excel spreadsheets to determine the min., max., mean values in addition to standard deviation, and the evaluated *weights* have been transformed into percentages using (PMBOK® Guide) chapter-11 scales. The probability distribution of likelihood of occurrence, cost impact and schedule impact has been developed using Oracle

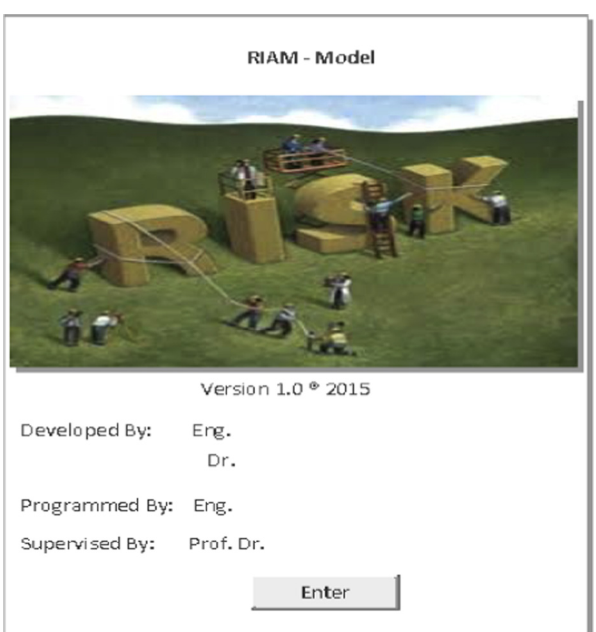

Fig. 20 Model information screen.

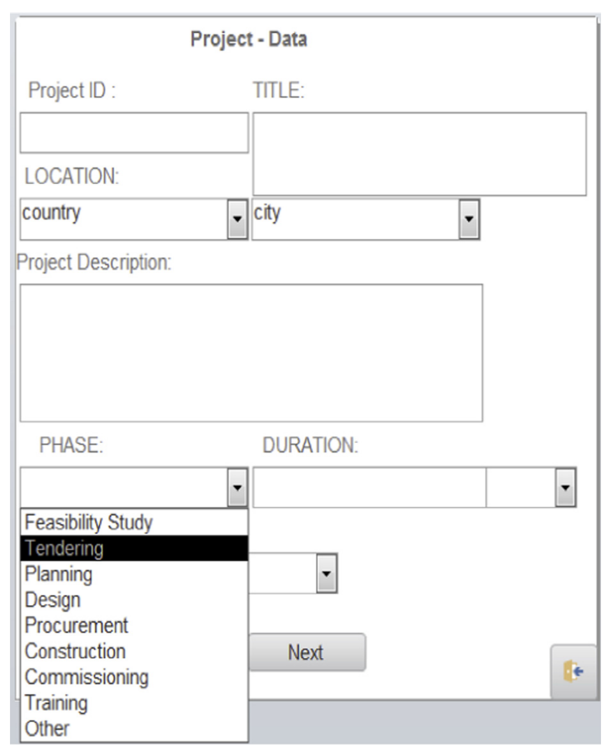

Fig. 21 Project information screen.

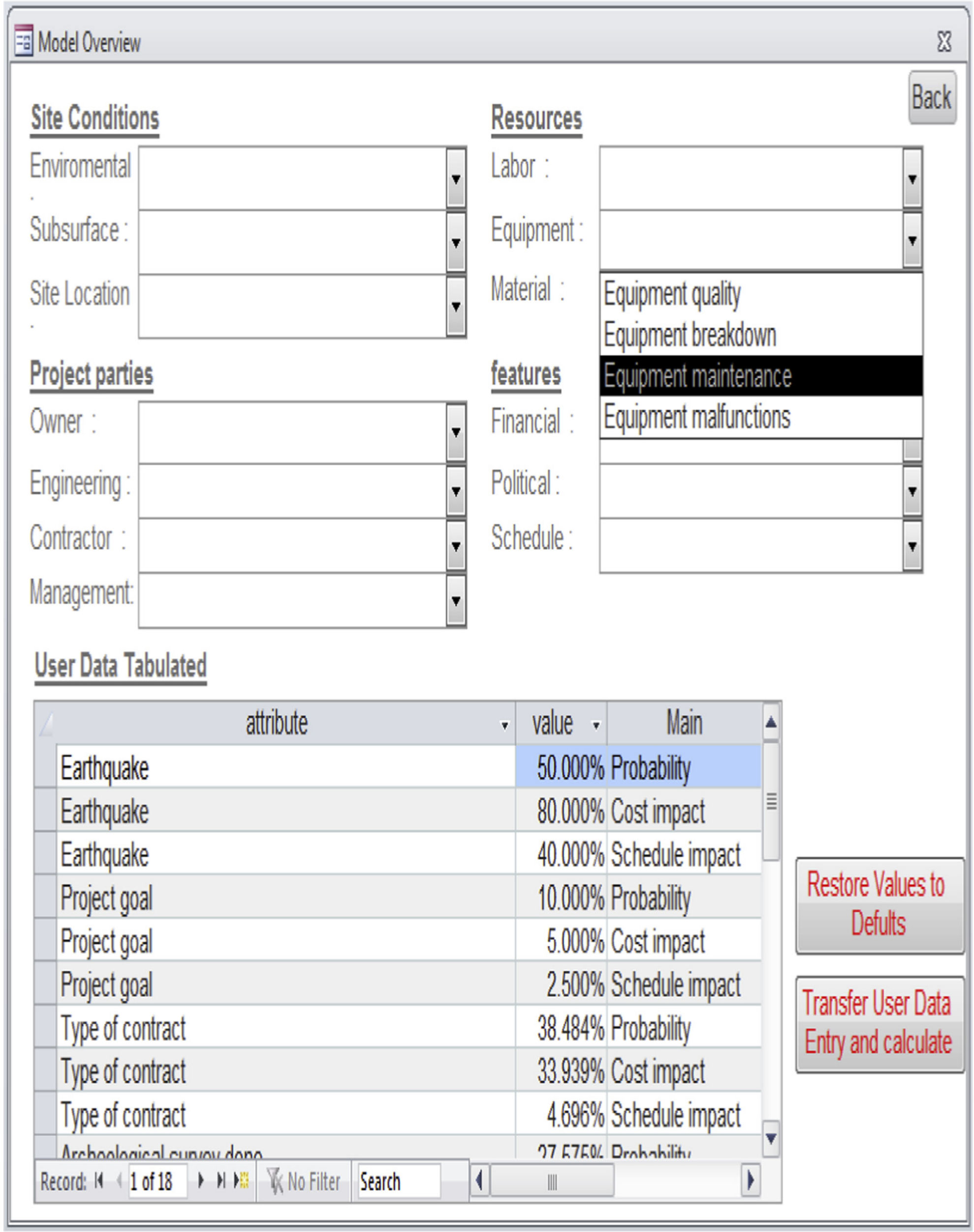

Fig. 22 Model main screen.

crystal ball Release 11.1.2.3 software, and these charts will be used in the graphical mode mentioned in the developed model as discussed later, on the other hand the user can use the numerical mode simply.

The spreadsheets will be used to present the heat maps and tornado charts as mentioned in the paper.

Data acquisition and probability distribution

The questionnaires have been prepared in Arabic language and English language to be simply filled; the sheets have been distributed in three evaluated portions, the first one concerning the attribute probability of occurrence, the second portion assigned for attribute cost impact and the third portion assigned for attribute schedule impact. The evaluation category is spread into five levels, very low = 1, low = 2, moderate = 3, high = 4 and very high = 5, Table 1 illustrates these details.

Oracle® Crystal Ball Release 11.1.2.3 software will be used for representing the probability distribution for all attributes as same as the probability distribution of sub-criterions themselves, referred to (PMBOK® Guide) – Fifth Edition chapter-11 and some distributions are frequently used as per Beta, triangular and lognormal distribution.

Some figures concerning tornado charts and probability distribution have been illustrated as samples, due to limited space and all charts and figures cannot be illustrated.

The sample charts mentioned in Figs. 11–19 will be used as a part of model structure named RIAM which has been built by the same authors and described in another paper titled

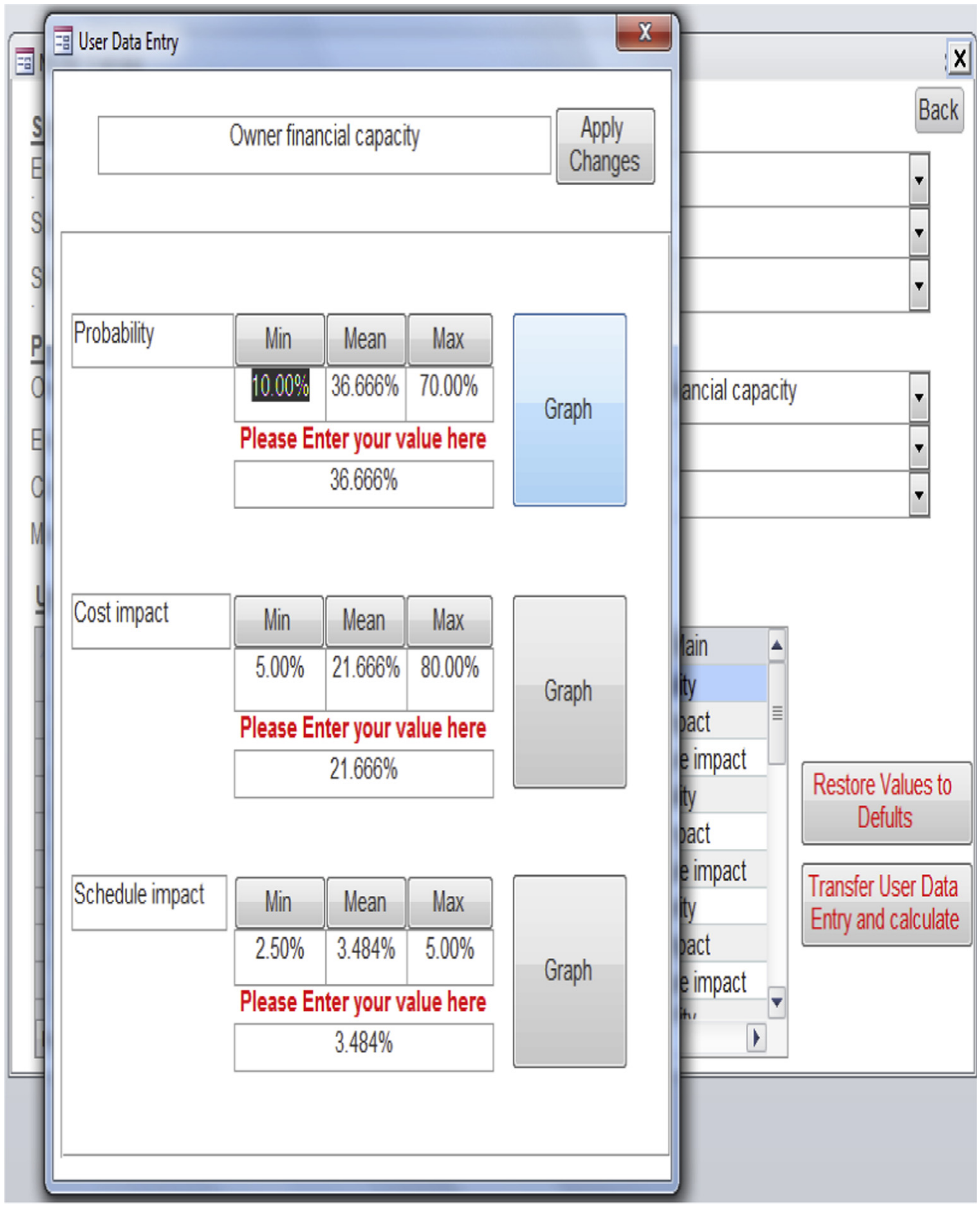

Fig. 23 User data entry.

"Decision Support System for Risk Assessment in Construction Projects Using AHP-Simulation Based Technique".

Data collection

Data are collected through one mean questionnaire and structured interviews to collect information on case study projects. A survey is conducted in the form of a questionnaire to collect each project risk factors and its probability of occurrence in addition to its cost and schedule overruns from the construction firms work in Egypt. The questionnaire is designed using the significant factors identified by the literature and experts as shown in Table 1. The questionnaire includes three parts. Part one includes the respondent personal general information, that is years of experience, total value of completed works, type of company partnership, type of the projects, project duration. Otherwise part two, includes the identified attributes probability of occurrence, cost impact and schedule overrun. Part three includes any additional attributes have been added by practitioner. In order to facilitate the answers of reviewers, a scale from 1 to 5 is used, using a scale range as mentioned in article 5.1 above. Furthermore the intensity of filled color is graded to attract practitioner sense of weight and simplify the choice.

Physical and telephone interviews are conducted with senior managers of sixteen companies, which are located in Egypt, or located outside Egypt but have some projects inside. The surveyed companies have experience and history ranges from 15 to 60 years in the construction industry.

They work in variety of projects, such as pipelines, tanks, refineries, infrastructure and silos. The variety of companies type is taken into consideration as per national/international

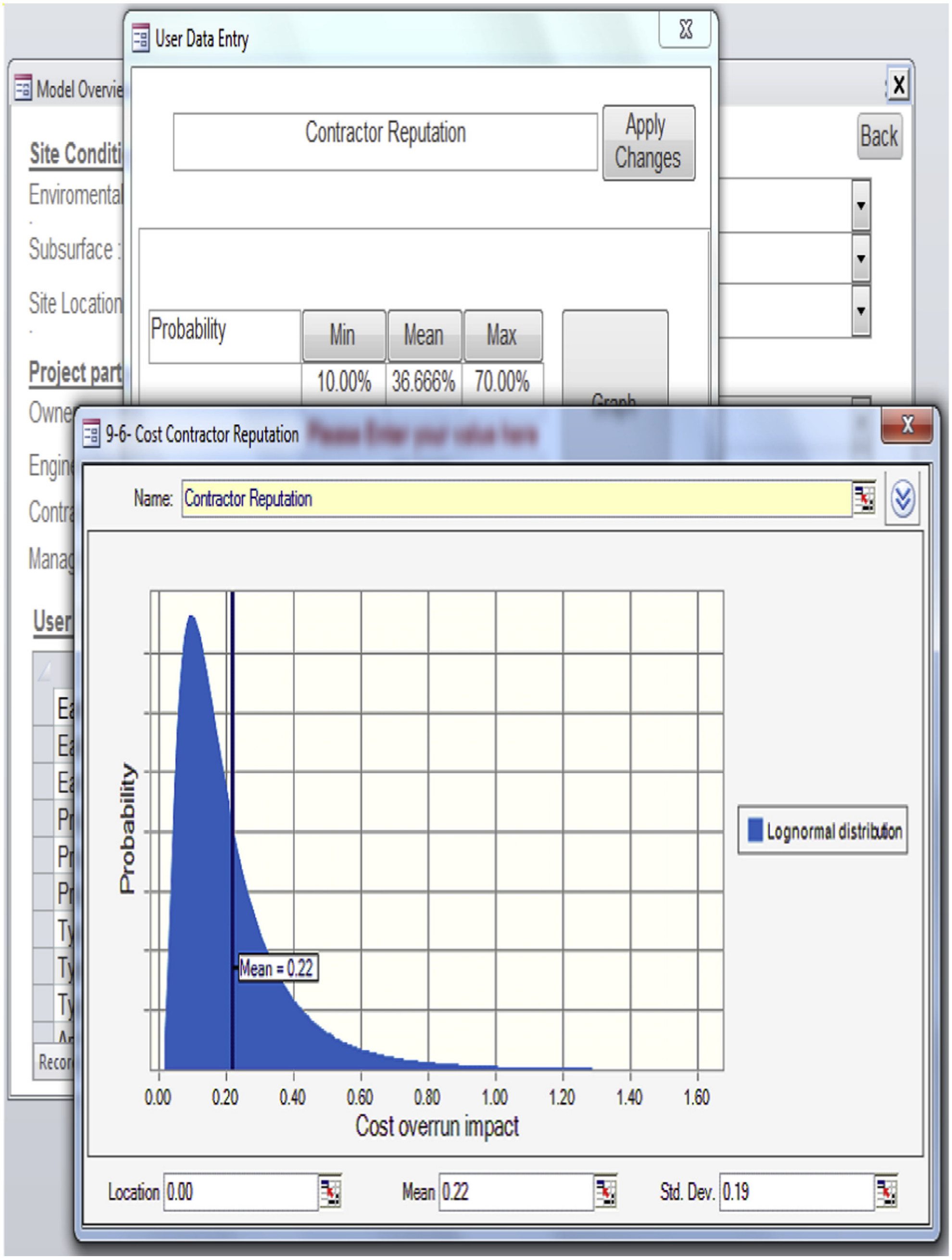

Fig. 24 The developed charts through graphical solution.

huge companies, construction firms, consultants and insurance group. Fifty nine feedbacks have been received, 6 have been rejected due to shortage data, the type of contact engineers are 5 consultants, 7 project managers, 9 construction managers, 8 planners, 11 cost estimators, 3 contract administrator, 1 insurance engineer and 9 site engineers. The budget values of projects that run by the interviewed managers range from $25 to $500 Million US dollars and the durations range from 6 months to 3 years.

The charts above present the normal distribution concerning the frequency of the risk factors percentage as collected from the questionnaires, the first group of charts will illustrate the frequency of attributes probability of occurrence percentage, in addition the second group of charts will illustrate the frequency of attributes cost impact percentage, and furthermore the third group of charts will illustrate the frequency of attributes schedule impact percentage.

The horizontal axes will refer to the percentage of such values as illustrated in the previous paragraph and will be divided into equal units. The vertical axes will intersect the mean value of the practitioners' assessment through the questionnaires.

The user can choose the type of chart distribution from the list as per Beta, Gamma, lognormal, uniform, triangle, Min Extreme, Max Extreme, Logistic, Weibull,...etc. In addition Crystal ball software can assist the user for best choice of chart distribution type by using option "Fit".

Brief of RIAM-model

The detail of this model will be discussed in another paper prepared by the same authors titled ‘‘Decision Support System for Risk Assessment in Construction Projects Using AHP-Simulation Based Technique’’.

A computerized system (RIAM) will be used for Risk assessment and risk strategy (plan) for project attributes as mentioned in Fig. 4 above. The system will be developed by Microsoft® Visual Basic™ programming language and Microsoft Access.

RIAM-model will be run through three softwares, Microsoft Excel and Crystal ball in addition to Expert Choice 2000.

This model is designed to be flexible and easy to use. It does not require previous knowledge of the above mentioned programs. Thus RIAM-model overcomes the deficiencies of previous risk analysis and quantification tools in being complicated, non-flexible, and time consuming. The system runs on Microsoft Windows XP and later (see Fig. 20).

As per Fig. 21 above, the user will insert brief of the project which will be assessed. The data can be allocated either by writing or using the attached arrows.

As illustrated in Fig. 22 above when the mentioned screen is opened, the user will choose each attribute by ticking the enclosed arrow, and sub-screen will be opened to choose the attribute probability, cost impact and schedule impact. The user can choose the minimum, mean or maximum values easily by either pressing the indicating button or writing the fraction in the related field. Taken into confederation that (a) if the user insert any number out of range, it will be rejected; (b) the default values are equal to mean values.

As referred in Fig. 23, the lower part of the previous screen will illustrate the user choices through table of data. In addition, the user can use the right buttons in order to restore the values to their mean values and furthermore to transfer data in order to start the analytical hierarchy process AHP for building the relationship matrices.

As previously mentioned, the user can allocate the fractions either numerically or through the graphical solution by illustrating the charts attached with each part of the form presented in Fig. 23.

The normal distribution of probability will be appeared as per Fig. 24 above, three buttons are appended with each attribute, one will illustrate the probability normal distribution of attribute likelihood and its button in the upper part, the second chart will consider the probability of cost impact related to its attribute, the button mentioned in the middle portion, and on the other hand the schedule impact probability distribution chart will be appeared through the lower button.

Conclusions

Estimating cost and scheduling contingencies are major factors in achieving a successful and realistic budget and schedule for construction projects. In the present research, a survey is sent to many construction companies to identify, qualify, study, assess, and quantify the factors that affect budget and time contingency.

From Figs. 6 and 7 as presented above, there are some attributes located in the red zone which reflect the great probability and impact effect of such factors, if the cost estimator takes the impact of those attributes as same as their values, the budget and schedule will increase accordingly, and the tenderer maybe unsuccessful. Therefore risk response and risk plan shall be studied and controlled to transfer or mitigate the impact of said factors to another party such as insurance company, sub-contractor or the client himself, which enhance the cost and schedule contingency demand. On the other hand the attributes located in the green zone have little probability and impact, and these factors maybe neglected or avoid.

From Figs. 8–10 political sub-criterion can be considered as the most probable and impacted factor, on the other hand owner sub-criterion can be considered the lowest probable and impacted factor.

Conflict of interests

The author states that there is no conflict of interests.

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