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Predicting Cost Contingency Using Analytical Hierarchy Process and Multi Attribute Utility Theory

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Abstract: An endeavor to predict the optimum contingency value that balances between maintaining business competitiveness and achieving project objectives is definitely an essential contributor to the survival of contractors. The chief objective of this research, therefore, is to develop a mathematical prediction model of the optimum cost contingency value for building projects in Saudi Arabia. The analytical hierarchy process (AHP) technique was used to define the most significant risk factors inherent in public work projects. The multi attribute utility theory (MAUT) technique was used to measure contractors' risk attitudes and to establish the utility functions through MATLAB. The required data to build the model for the AHP and MAUT were collected from 17 contractors mostly through intensive face-to-face interviews and email-response to a developed structured questionnaire. The integrated contingency model reflects the basic dimensions of risk and considers the various risk attitudes of contractors. The model has been implemented in prototype software using object-oriented programming. Two completed local building construction projects were used to validate and demonstrate the use of the developed model in recommending the optimum cost contingency value for building projects in Saudi Arabia. The developed model was proven reliable in estimating the contingency with an accuracy skewed 9% to the high side.

Keywords: Risk management, AHP, contingency, MAUT, model.

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1. Introduction

The accuracy of construction cost estimates is crucial for contractors. Inappropriate cost estimates may lead to underestimation or overestimation, delay in completing projects and abandonment of projects which affect the contractor's business. The cost estimate consists of two components: the baseline estimate and contingency, which both formulate the contractor's budget for the execution of the project. The baseline estimate is prepared by estimating the direct, indirect, job overhead, and office overhead based on the quantities taken off from the project drawings. The contingency is added to the baseline cost to cater for events that will occur during the construction phase but with unknown magnitudes. Therefore, contingency is a fund added to the baseline cost estimate to compensate for the cost estimate inaccuracies caused by uncertainties in the project definition. Patrascu (1988) stated that contingency is probably the most misunderstood, misinterpreted and misapplied word in project execution. Cost contingency has been broadly defined as "Time or money allocated in the schedule or cost baseline for known risks with active response strategies" (PMI, 2017). The Association for the Advancement of Cost Engineering (AACE, 2019) defines a contingency as "an amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs."

The contingency value is estimated either by deterministic or probabilistic methods. The deterministic method is a conventional approach mostly employed for estimating cost contingency based on predetermined percentage or expert judgment. The deterministic method usually expresses cost contingency in terms of a certain percentage of the aggregate baseline cost or subcomponents of the baseline cost based on experience, intuition or historical data (Mak et al., 1998). While this method is expedient and easy to understand, the project risk profile is not taken into consideration. The method is deemed to be arbitrary and undefendable (Thompson and Perry, 1992), unscientific (Chen and Hartman, 2000), and implies a degree of certainty that is not justified (Mak et al., 1998). Multiple studies have demonstrated that subjective judgments and arbitrary decisions on the amount of cost contingency are inefficient and imprecise (Akinradewo and Awodele, 2016). Despite the weaknesses of this approach, it is the most famous and used method in practice (Baccarini, 2005; Asamoah et al., 2013).

In contrast, under the probabilistic method, project cost components are assigned probability distribution functions (PDF), thereby generating a PDF for the overall project cost through the summative process indicating a possible decrease or increase in the construction cost based on the changes to the cost components (Eldosouky et al., 2014). The first order magnitude, expected value, the probability tree, the regression, AHP, the fuzzy techniques, and the artificial neural network (ANN) (Bakhshi and Touran, 2014; Baccarini (no date)) are the known used techniques for estimating the contingency value. However, the Monte Carlo simulation (MCS), regression analysis, and ANN have gained prominence in recent times (Baccarini, 2005).

Risk and uncertainty are deeply inherent in the nature of the construction because of its viability to be influenced by numerous factors and the unique circumstances of each project. For decades, the strategy of cost contingency allocation has been the prevalent practice adopted to address risk and uncertainty in construction projects (Chen and Hartman, 2000). Estimating using risk analysis (ERA) is a procedure to give a realistically estimated cost for each identified project-related risk, which makes the relevant importance of each risk immediately apparent. ERA involves three main activities: (1) identifying significant risks, (2) assessing the probability and extent of those risks occurring, and (3) establishing appropriate considerations for the risks. Identifying risks and assessing probabilities is a collective responsibility that avoids the risk of incomplete commitment and inconsistent decisions. The AHP is a ubiquitous component of ERA. AHP is employed to identify the weights of the identified risk factors on a project.

Cost contingency allocation requires a delicate estimation where it should be implemented systematically within the risk management framework. While predicting the optimum cost contingency percentage that balances between maintaining business competitiveness and achieving project objectives is essential, the commonly available methods for estimating contingency do not consider the decision-makers' characteristics toward risk: risk-averse, risk-neutral, or risk-taker. The reported research aims to develop a model for contractors to accurately estimate the required cost contingency percentage by integrating defined risk factors and a contractor's characteristic toward risk. The risk factors are identified through the AHP and the contractor's characteristics through the MAUT techniques. The model is intended to estimate the required cost contingency for construction projects built adopting a design-bid-build project delivery system with a unit price contract.

Contingency cost allocation is believed to be a global issue, which contractors encounter in projects estimate. However, the researchers used information extracted from the Saudi construction industry simply because they have direct access to this industry, hoping that the research concepts and outcomes will be used globally. This paper has a practical value to contractors worldwide, as determining the contingency value would result in better project cost performance.

2. Literature Review

Contractors usually need to have an accurate cost estimate to provide a sufficient budget for contracted projects. However, risks and uncertainties associated with a project are impediments to reach an accurate cost estimate. Project estimates tend to be too optimistic as the forces of competition that determine how projects are acquired encourage contractors to underprice the project and thus make the project liable to budget overrun (Afetornu and Edum-Fotwe, 2005). Many projects overrun their estimated budgets. Numerous researchers have devoted their work to identifying project risk factors and cost escalation factors to overcome the cost overrun issue. Appendix A summarizes the identified factors responsible for cost overruns. A contingency budget is added to the project base cost to absorb these risk factors' cost impact.

The contingency is considered either a reserve, which is probably the most commonly understood component of project cost contingency, a reflection of risk and uncertainty in projects, or a representation of total financial commitment (Hammad, 2016). A range of estimating techniques exists for calculating project cost contingency. These methods are commonly classified into deterministic and probabilistic methods.

The deterministic method usually expresses cost contingency in terms of a certain percentage of the base cost. The percentage is either predetermined and applied on the total base cost or variable applied on total base cost or subcomponents depending on potential risks. The percentages are typically derived from intuition, past experience and historical data (Hammad, 2016). The deterministic methods are considered the simplest and most common methods to establish contingency budget (Bakhshi and Touran, 2014). This estimating method is arbitrary and unsatisfactory for large and complex projects (Islam et al., 2019). Usually, the deterministic method uses a percentage between 5 and 10% of the project cost for contingency (Akinradewo et al., 2019). This is always unjustified as the degree of certainty cannot be established. Therefore, the contractor is subjected to risk of overcompensation and mostly underpayment for uncertainties. Tang and Musa (2011) found that the average estimated cost contingency is 5.07%, and the actual cost overrun is 9.52%. A percentage addition results in a single-figure prediction of estimated cost, which implies a degree of certainty that is not justified (Bakhshi and Touran, 2014). According to Rey (2001), deterministic methods assume no randomness in predicting a dependent variable value implying that the model provides a certain unique value for the cost contingency.

The inherent weaknesses in the deterministic methods have driven researchers and practitioners to exert tremendous efforts and several attempts to develop more formularized models to assist contractors in assessing risks and predicting cost contingency accurately in construction projects. Probabilistic models are distinguished from deterministic models in the existence of randomness in predicting a dependent variable value. Probabilistic models become quite essential when dealing with situations involving variation in nature, besides an outcome variable that is preferably presented by a probability distribution instead of representing it by a point estimate for the dependent variable (Mak and Picken, 2000). AHP, MCS, and regressions analysis methods, expected value, range estimate, ERA, fuzzy set theory, and ANN estimate contingency based on the probability theory. AHP is an analytical tool that addresses multi-criteria decision-making (MCDM) problems and allows decision-makers to set priorities through a series of pairwise comparisons. Thomas Saaty introduced AHP in 1980. According to Darko et al. (2018), AHP was effective in the area of risk management. AHP and MAUT have been popular MCDM methods that have attracted considerable attention throughout numerous industries, including construction, over the past two decades. Both methods have been being employed either simultaneously or separately in multiple studies for decision-making problems in construction. Mohamed et al. (2009) had utilized AHP to develop a model that predicts the required time contingency for construction projects. Doloi (2008) had also employed AHP to identify the current issues surrounding labor productivity in construction projects in Melbourne. The results proved that the chief influences on construction labor productivity are planning and programming, which contradicts the prevailing assumption that financial rewards are the only drivers for labor productivity. Mohamed et al. (2009) had utilized AHP to develop a model that predicts time contingency in construction projects. Similarly, El-Touny et al. (2014) used AHP for prediction purposes but estimated the amount of cost contingency required for highway construction projects in Egypt.

MAUT, on the other hand, has been in use for many applications in construction. In a study conducted in 2010 by Chen et al., MAUT was used to decide on the economic feasibility of employing prefabrication and how it should be applied in concrete buildings. Likewise, Antoniou et al. (2016) have exploited the use of MAUT to assist on the appropriate procurement system for highway projects in Greece, considering multiple criteria including project characteristics, needs of the awarding authority and market conditions. Furthermore, the literature has revealed hybrid usage of AHP and MAUT for estimation, prediction, assessing, and selection purposes in construction. Alshamrani et al. (2018) developed a model utilizing AHP and MAUT that can help select the lighting systems in residential buildings considering four selection criteria: life-cycle cost, illumination, environmental performance, and life-span.

MAUT was also incorporated with the AHP in two studies to estimate bids markup in construction projects (Dozzi et al., 1996; Marzouk and Moselhi, 2003). Those studies inspired this research but with more emphasis on cost contingency prediction and risk management. The two studies considered 21 criteria that affect the bidding decision. The main issue in this approach is the blurriness in the mechanism of determining the certainty equivalent of the various attributes. For instance, the decision-maker would face difficulties determining the certainty equivalent for attributes such as project location. The two studies restricted the model in only a few vague attributes such as "estimate uncertainty" and "other risk." Although all contingency models aim to reduce the subjectivity in evaluating risks and predicting contingency funds, risk attributes in the model were assigned to a linguistic scale with no accountability for the actual financial impacts of risks.

Above all, the literature revealed a lack of studies on cost contingency prediction models in Saudi Arabia, especially for building contracting firms. Therefore, this paper presents a cost contingency prediction model for unit price contracts under the design-bid-build project delivery system. The model is distinguished from the above by its capability to reflect the basic dimensions of risk and its systemic procedures within the risk management framework.

3. Research Methodology

The model's development consists of four major phases: Literature review, AHP module development, MAUT module development, and contingency model development. The literature review set the basis for the study direction and the study tools for collecting the data. The required data to develop the AHP and MAUT models were collected from top management and cost estimators of Grade 1 and 2 contractors through a structured questionnaire consisting of three sections. The first section sought general information about participants (i.e., experience, job position, education, etc.) and organizations. The second section consisted of questions seeking information on the contingency risk factors and their importance against each other in developed pairwise comparisons. The last section contained questions seeking information on the maximum and the minimum monetary loss as a percentage of the total contract value that a particular risk factor is expected to cause along with their associated probabilities. A pilot interview was conducted with three experts to evaluate the clarity of the developed questionnaire, improve and modify any deficiencies, and measure the time required to complete an interview. The pilot interview indicated no significant modifications to the questionnaire content. However, the experts expressed the importance of notifying participants of the assumptions being considered in the research, such as the type of project delivery system and contracting method. The required data were mostly collected through face-to-face interviews where the researchers were writing the participants' answers directly in the developed questionnaire.

According to Darko et al. (2018), there is no standardized method or common rule to calculate the sample size in the AHP technique. Nevertheless, there has been a unanimity that AHP could lead to robust results even with small sample size. In this research, the population size was obtained from the statistical reports issued in 2017 by the Ministry of Municipal and Rural Affairs in Saudi Arabia. The population size was 48 classified Grade 1 and 2 building contractors in the Eastern Province, Saudi Arabia. The required sample size was calculated using Kish's (1995) formulas as shown in Eq. (1) and (2). In this research, the maximum allowed percentage of error was set to 10%, and the planning values of the sample population were considered 0.5 to maximize the sample size. Subsequently, the calculated and, hence, the required sample size was found to be 17 contractors.

$$n_\circ = \frac{p \times q}{E^2} \tag{1}$$

$$n = \frac{n_\circ}{1 + \frac{n_\circ}{N}} \tag{2}$$

4. Results Analysis

The 48 contractors were contacted in person in the last quarter of 2019 to participate in the study by filling in the developed questionnaire in an interview setting. However, only 28 experts agreed to participate. However, due to time constraints, 14 experts preferred to complete the survey on their own. The researcher provided such participants with a brief explanation of the whole survey and how to complete it. Out of these 14 experts, 3 experts submitted properly completed questionnaires, 4 experts submitted completed questionnaires, however, with major errors and thus eliminated, and 7 experts did not respond at all despite the researcher's continuous reminders through emails and telephone calls.

Moreover, complete 14 face-to-face interviews were conducted with the remaining of the contacted experts. The interview length ranged between 60 and 90 minutes. Therefore, a total of 17 experts participated in the study, which is considered acceptable. AHP technique can be performed with small sample size and still yield sound results. Multiple studies have applied AHP with a sample size ranging from 4 to 9 (Dalal et al., 2010). Besides, as per Kish's equation, 17 participants are believed to represent the population.

4.1. Characteristics of the Participants

The results indicated that the participants are civil engineers (70% of the participants), electrical, industrial and building engineers. The majority (53%) have more than 10 years of experience in bid pricing and tendering. The participants held managerial and non-managerial responsibilities in their organizations but were directly associated with contingency value determination. The participants affirmed that they have the necessary experience and the authority to decide on a bid price and contingency value for a project. Five experts worked directly under cost estimation departments either as cost control engineers, cost estimators or quantity surveyors. Two experts held top-level managerial roles, with one serving as a general manager and the other as a commercial manager. Five experts held middle-level managerial roles, such as quality control manager, project manager and construction manager. The rest worked either at the site, such as site and project engineers or departments such as procurement engineers and senior technical engineers.

4.2. AHP Module Development

Identifying potential risk sources is a key step in the risk management process (Rehacek, 2017). As a matter of fact, failure to explore all sources of risk could become a predicament as corrective actions would be needed, which are, in most cases, costly than planned ones. Given that the determination of cost contingency is a decision-making problem, risk factors can be considered as attributes or criteria impacting cost contingency. The extensive literature review identified potential risk factors that influence the decision on the amount of cost contingency. Risk factors were adopted to best conform with the research scope. International risk factors were excluded since this research is devoted to predicting the amount of cost contingency assigned by local contractors in domestic construction projects in Saudi Arabia. The initial review of related literature resulted in identifying 25 risk factors. Undoubtedly, the contingency cost is not supposed to cover all sources of risk. In agreement with Smith and Bohn (1999), a contingency cost shall cover all risk sources except those covered by other risk treatment strategies such as risk transfer and insurance. Hence, it is noticeable that the amount of cost contingency vastly depends on several factors, including the project delivery system and the procurement method used. For this research, the design-bid-build project delivery system and unit price contract were assumed to be the interest under the unified contract for public works (UCPW). Thus, further investigations were needed to determine risk factors that shall be handled with a contingency treatment strategy. For this purpose, the UCPW in Saudi Arabia was closely examined to extrapolate risk factors whose responsibility falls on the contractor and determine the most common practiced risk treatment strategy for each identified risk factor in a unit price contract with the design-bid-build delivery system. Eighteen risk factors that influence the amount of cost contingency were identified, grouped and structured in a hierarchy format. Risk factors were classified according to their primary source under one of the following groups: bidding, construction, environmental, legal, and economic. The developed hierarchal structure, including all levels, is shown in Fig. 1. Pairwise comparisons were performed for all groups and risk factors at all hierarchal levels. The pairwise comparisons were created in an (n) square matrices, where n is the number of groups or risk factors being considered. The numerical nine-point scale, suggested by Saaty (1980), was employed to assess risk factors, with 1 indicating equal importance and nine extreme importance.

The discrepancy of the pairwise comparisons' evaluations made by decision-makers was measured using the consistency ratio (CR). An inconsistent judgment indicates that unreliable or contradicting information has been committed. The consistency ratio of a pairwise comparison matrix should exactly equal 0 for a perfect consistent decision-maker. In accordance with Saaty (1980), it was suggested that only evaluations or responses having a consistency ratio lower than 0.1 are considered reliable. In this research, the strategy followed to handle responses was to eliminate evaluations with a consistency ratio of more than 0.2, revaluating responses having a consistency ratio between 0.1 and 0.2 and definitely to accept evaluations having a consistency ratio of less than 0.1. Following this strategy resulted in 15 consistent evaluations out of the 17 collected responses. As previously mentioned, the 17 responses resulted from the complete 14 one-on-one interviews, plus the 3 received completed surveys. The computation process was accomplished via the AHP-OS package, an online tool that supports the eigenvector and the eigenvalue calculations, developed by Goepel (2018). It should be noted that the summation of each of the categories' weights and the local weights of risk factors must be equal to 1. The global weights of risk factors falling under a certain category must also add up to the category's weight.

4.2.1. Risk factors impacting the allocation of cost contingency

The outcome of the pairwise comparisons was used to demonstrate the importance of risk factors on three different levels. The first level prioritization weighted the main categories in the hierarchy: bidding, construction, economic, environment and legal. This prioritization provided an overall indication of which category contractors should put more effort and emphasis on.

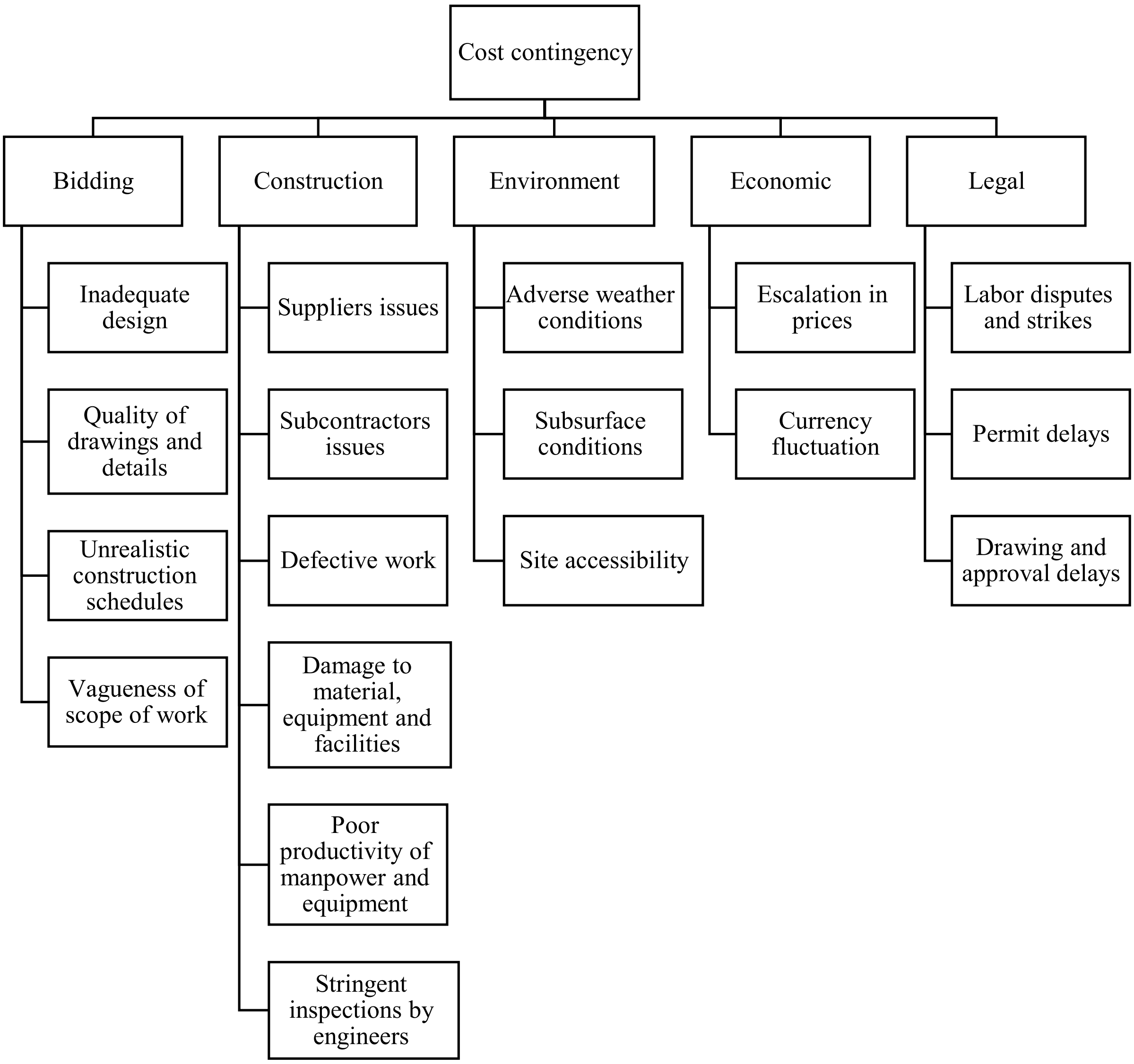

Fig. 1. AHP hierarchy structure

The categories were ranked according to the average weight of consistent responses-the highest average weight corresponding to rank 1, and so on, as shown in Table 1. The second or local-level prioritization provided weights for risk factors in each main category of the hierarchical structure. This process helped us understand which risk factors had the most significant impact on cost contingency compared to other risk factors in the same category. The final prioritization was performed globally to determine the most significant risk factors compared to all other risk factors in all categories. Table 2 demonstrates the ranking of risk factors at the local and global levels.

The analysis showed that bidding-related risks were the most influential, with a weighted score of 0.313. This category was comprised of risks such as unrealistic construction schedules and inadequate design. Experts stated that poor planning of various elements during the bidding process could affect the whole project, unlike risks in the other categories. The effect of such risks may not be realized until the advanced stages of the project. Corrective action for bidding-related risks is usually more costly and may require the implementation of radical changes. Construction-related risks ranked second, with a weighted score of 0.255. Despite that construction-related risks have an immediate impact and may not have a long-term effect on the project as bidding-related risks, those risks are more probable to occur than risks in the other categories.

Table 1. Ranking of categories

Category	Average Weight	Rank
Bidding	0.313	1
Construction	0.255	2
Environment	0.171	3
Legal	0.138	4
Economic	0.124	5

Prioritization at the local level highlighted the most significant risk factors within each category. This prioritization was helpful for focusing on specific risks related to issues expected to emerge from a particular category. The analysis showed that the most significant risk factor in the bidding process was unrealistic schedules, while the least significant risk factor was the quality of drawings and details. Contractors are sometimes vulnerable to being forced to work under schedule pressure, either to maintain a project on track or even from the beginning if they bid on a project with unrealistic or tight construction schedules to satisfy the client's requirements.

Table 2. Local and global ranking of risk factors

Category	Risk Factors	Local Weight	Local Rank	Global Weight (W_i)	Global Rank
Bidding	Unrealistic construction schedules	0.338	1	0.109	1
	Inadequate design	0.262	2	0.095	3
	Vagueness of scope of work	0.243	3	0.0573	8
	Quality of drawings and details	0.157	4	0.0517	11
Construction	Subcontractors issues	0.204	1	0.065	4
	Suppliers issues	0.185	2	0.0555	9
	Defective work	0.184	3	0.0646	5
	Poor productivity of manpower and equipment	0.174	4	0.0539	10
	Stringent inspections by engineers	0.137	5	0.0513	12
	Damage to material, equipment and facilities	0.116	6	0.0374	15
Environ-ment	Subsurface conditions	0.533	1	0.0585	6
	Adverse weather conditions	0.268	2	0.0253	17
	Site accessibility	0.199	3	0.0241	18
Eco-nomic	Escalation in prices	0.761	1	0.098	2
	Currency fluctuation	0.239	2	0.0255	16
Legal	Drawing and approval delays	0.360	1	0.0577	7
	Labor disputes and strikes	0.342	2	0.0409	13
	Permit delays	0.298	3	0.0392	14

One contractor stated that their firm had recently bid on a project knowing that the proposed duration was not achievable by any means. The firm tackled this issue by allocating a 10% contingency, the delay penalty stipulated in the UCPW. The risk of working in such an environment may yield not only a delayed penalty but adversely impact other project objectives such as quality and productivity. This inference is in agreement with the findings of Nepal et al. (2006), whose study analyzed the effects of tight construction schedules on project performance in Singapore. The adverse effects can be in the form of work defects, cutting corners and lost motivation. Through an empirical investigation of 38 construction projects, it was proved that losses in quality and productivity offset the desired results and advantages of compressed schedules by. Certainly, contracting firms realize that all of that would be at their own expense, especially without the owner's recognition of such factors. Therefore, an unrealistic construction schedule was perceived as the most serious risk in the bidding stage and even at the global level, among all risk factors, as demonstrated in Table 2.

The most significant risk in the construction phase was related to subcontractors, while the least risk was related to damage to equipment and materials. Subcontracting is an essential and indispensable practice in construction projects. Studies found that up to 80% of the work in building projects in Hong Kong is sublet to subcontractors (Chiang, 2009). In Saudi Arabia, it was found that 20% of the contract value of industrial projects is undertaken by subcontractors (Ganiyu, 2010). Subcontractor failure implies bargaining for the sublet work. Subcontractors, however, may fail in delivering quality work or in delivering work on time. Experts stated that subcontractors are challenging to control completely. The experts stated that subcontractors are challenging to control. When comparing the impact of subcontractors' issues with that of suppliers (which ranked second in the construction category), it was found that the relationship between general contractors and subcontractors tends to be much more multifaceted and complex than that of general contractors and suppliers. General contractors have the upper hand in imposing conditions and exerting pressure on suppliers because they can replace them with minimal impact. However, subcontractors are much more challenging to replace in the case of construction failure. This condition explains why contractors in the United States of America (USA) usually add 5% to 10% to the total bid price when working with contractors with whom they have never worked before (Shash, 1998). General contractors usually allocate a lower contingency percentage if the subcontractor is reputable.

Finally, the risk factors were ranked on a global level to show their relative significance. The analysis revealed that unrealistic construction schedules, escalations in prices, and inadequate designs had the greatest impacts on project costs in descending order. These results comport with those of Zou et al. (2007), which investigated the key risks in the Chinese construction market. The risks were prioritized according to the significance of their effect on project objectives. The significance index score was used as a function of the impact of consequence and the likelihood of occurrence. The top four risks in descending rank were variation orders, price escalation, design variation, and tight project schedule. However, the first-ranked risk has not been deemed a risk within the research scope. It is evident that risk factors with significant impact and a high probability of occurrence to be ranked among the top. The construction industry in Saudi Arabia has been facing serious vicissitudes over the last few years. For instance, building materials and labor wages have been fluctuating dramatically due to a variety of reasons. Experts stated that the market has been facing a workforce shortage which caused a significant increase in labor cost by approximately 47% due to substantial governmental regulatory changes.

Furthermore, raw building materials have experienced an increase in price, such as concrete price, for instance, increased by about 29% per meter cube. The precedence of some risk factors such as approval and drawing delays over poor productivity or supplier issues can be wonderingly brought up for discussion. However, experts stated that suppliers' issues or poor productivity risk factors could be more controllable than approval and drawing delays, implying that risks being under the direct control of contractors reduces the impact of the consequence of risks. Thus, contractors attribute greater significance to risk factors over which they have little control.

4.3. MAUT Module Development

Understanding contractors' risk attitudes are crucial in the cost contingency assignments' decision-making process to construction projects under uncertain situations. In particular, contingency assignment is heavily dependent, in the first place, on decision-makers' beliefs and attitudes. In contrast, each decision-maker might react differently to a risky situation even if it has analogous circumstances (Akintoye and MacLeod, 1997). The concept of MAUT has been introduced to tackle decision-making problems involving several factors (so-called attributes) that are of a decision-maker's interest or influence the decision to be taken. What makes making decisions a complicated issue is the multitude of attributes and the natural conflict among attributes. Commonly, different people have different preferences, especially when uncertain conditions exist. For this reason, utility functions were introduced to quantify decision-makers' preferences in terms of satisfaction over various available options of a specific factor. According to the expected utility theory, the option with the highest utility value should be considered. However, the utility function is just the degree of satisfaction against a certain attribute with any preferred units. Logically, the most preferred option gives the decision-maker the highest level of satisfaction. In contrast, the least preferred option should give the decision-maker the lowest level of satisfaction or utility. Furthermore, utility values and people's preferences may vary according to their attitudes towards risk. There are three defined risk attitudes: risk-aversion, risk-neutrality and risk-seeking. The utility functions of the various risk attitudes are represented by a concave function, straight line function and convex function, respectively. Risk-aversion is the willingness to give up an amount of money to have something for certain. At this point, a new term called certainty equivalent (CE) shall be introduced. CE is the amount of payoff that is acceptable for decision-makers to be indifferent between two options. For a risk-averse decision-maker, CE is lower than the expected gain from an uncertain situation, which means that two different values will have the same degree of satisfaction for a decision-maker. Risk-neutrality is the state of being indifferent between taking and avoiding risk. Risk-seeking is the state of preferring an uncertain situation with the hope of potential gain rather than accepting something lower than the potential gain for certain. In this case, the CE, which a risk-seeking decision-maker would accept for not entering an uncertain situation, would be higher than the expected gain. Wang and Yuan (2011) pointed out several factors that could substantially influence contractors' attitudes toward risk, other than personal beliefs and perceptions, in construction projects in China. It is more logical to determine the utility function shape based on variables whose relationships are identifiable and measurable rather than basing it on subjective factors. Market status is one factor that can be explained by the concept of demand and supply and determined by the level of competition linked to bids. To illustrate that, an interview study with 12 contractors in the USA conducted by Smith and Bohn (1999) revealed that contractors do not consider risk management when they are thirsty for work and where competition is high. On the contrary, research has found that contractors raise bid prices by approximately 3% of the total value of a project to reimburse their lack of enthusiasm for work and risk (Neufville and King, 1991). The second factor is the company's financial standing, which refers to the "Company's Economic Strength" mentioned in the research conducted by Wang and Yuan (2011). Moreover, Slovic et al. (1984) has demonstrated the relationship between decision-makers' risk attitudes and companies' financial strength. It has been found that contractors' propensity to take risks increases along with the increases in companies' financial strength.

The objective of the MAUT reported here was to develop a utility function for each identified risk factor and develop the contingency utility functions. Unlike the AHP technique, where only consistent evaluations were considered, the MAUT technique does not require any particular testing because most of the responses were collected in interview settings. Thus, all properly completed questionnaires were considered valid. Therefore, a total of 17 responses were collected and analyzed to achieve the MAUT objectives.

4.3.1. Utility functions development

Utility functions are used to transform various attribute values into dimensionless utility scores to combine all dimensioned attributes with a unified unit. The literature revealed different approaches in developing utility functions and measuring decision-makers' risk behaviors (Dozzi et al., 1996; Filip, 2002). However, this research followed the approach reported in Marzouk and Moselhi's study (2003).

The identified risk factors' utility functions were developed based on three coordinate points driven from the MAUT survey. The participants provided five parameters: the maximum and the minimum loss percentages, the probability of losing the maximum and the minimum loss percentages, and the certainty equivalent. The first two points define the limits from which each risk factor can assume values. The financial impact represents the independent variable on the x-axis, while the y-axis denotes the utility value. The independent variable takes on values between the defined limits, while the dependent variable takes on values from 0 to 1. As stated earlier, the most desirable scenario corresponds to the highest satisfaction with a utility score of 1, and the least desirable scenario corresponds to the lowest satisfaction with a utility score of 0. Thus, the maximum financial impact corresponds to the lowest utility value on the y-axis, which is zero, because it is the least desirable scenario. In contrast, the minimum financial impact corresponds to the highest utility value, which is one, because it is the most preferred scenario. The third point is the certainty equivalent and its utility score. The certainty equivalent is defined, in this context, as the value that the decision-maker is willing to pay to ensure holding no liability if a particular risk factor occurred. It should be noted that the certainty equivalent is a value between the defined limits of any considered risk factor. The decision-maker would deficiently pay a value lower than the maximum financial loss because the level of impact and the likelihood of the expected maximum impact is uncertain. The specified certainty equivalent utility value is equal to the summation of the utility value of the maximum financial impact multiplied by the probability of its occurrence and the utility value of the minimum financial impact multiplied by the probability of its occurrence, as shown in Eq. (3). Upon identifying and establishing the three coordinate points, decision-makers' risk attitudes were determined by comparing the certainty equivalent with the expected value to determine the equation to be used. The participants provided the certainty equivalent. The expected value is the summation of the multiplication of the maximum percentage loss value by its associated probability and the minimum percentage loss value by its associated probability. Determining the risk attitude towards each risk factor allowed determining the shape of the utility function to form three equations with three unknowns to obtain the coefficients' values (a, b and c). The comparison between the certainty equivalent and the expected value determines the risk attitude and thereby the shape of the utility function such that (1) the certainty equivalent should be greater than the expected value for a risk-averse decision-maker; (2) the certainty equivalent should be less than the expected value for a risk-seeking decision-maker; and (3) the certainty equivalent should exactly equal the expected value for a risk-neutral decision-maker. The utility functions of the three risk behaviors, including risk-aversion, risk-seeking and risk-neutrality, are defined in Eq. (4), (5), and (6), respectively. MATLAB software was employed to solve the established system of equations.

$$u(x) = P(x_n) \times u(x_n) + P(x_m) \times u(x_m) \quad (3)$$

$$u(x) = ae^{bx} + c \quad (4)$$

$$u(x) = a \times ln(x + b) + c \quad (5)$$

$$u(x) = ax \quad (6)$$

where:

u(x): the utility of any considered point

P(x): The probability of occurrence of any point

4.3.2. Contingency utility function development

The contingency utility functions were developed based on three coordinate points provided by participants, the actual largest and smallest contingency percentages. The actual contingency percentages would represent a precise actual reflection of the local market when predicting a project contingency percentage. The largest contingency percentage reflects the worst-case scenario and thereby corresponds to a utility value of 0, while the smallest contingency percentage which corresponds to a utility score of 1. The third point was manipulated between the largest and smallest percentages with a corresponding 0.5 utility score to observe the three risk behaviors' effect on a contingency percentage. When assuming a risk neutrality attitude, the third point is equal to the expected value, computed as the average of the largest and smallest contingency percentages. On the other hand, contractors might assume a risk-seeking behavior when the competition is high and thirsty for work. In this case, the third point should be less than the expected value and was computed as the average of the expected value and the smallest contingency percentage. Furthermore, contractors might assume a risk-aversion behavior when expecting a high level of uncertainty, operating at full capacity, or lacking competition. In this case, the third point was assumed higher than the expected value and was computed as the average of the expected value and the largest contingency percentage. The consideration of risk attitudes here provides contractors with the opportunity to decide on which strategy to adopt when estimating project cost contingency depending on the nature of the project and project-specific conditions. The obtained largest and smallest contingency percentages form a range in which the final project cost contingency percentage will fall. Regarding the development of the contingency utility function, as the largest contingency percentage corresponds to a utility score of 0 and the smallest corresponds to a utility score of 1, the inversion of the scale here would cause the function to be more complicated and problematic to solve. Therefore and for simplicity, the range 1.7-11 was normalized to a scale 0-100 such that 1.7 and 11 were substituted by 100 and 0, respectively. Moreover, the values in between preserved their relative distances as in the former range and can be figured out using Eq. (7). Oppositely, Eq. (8) can be used to convert values from the range 0 to 100 to the range of 1.7 to 11. Table 3 presents the identified coordinate points and their corresponding converted values on the new scale. It should be noted that because of the inversion of the scale, the predefined logarithmic equation was used to represent the risk-aversion behavior, while the predefined exponential equation was used to represent the risk-seeking behavior.

Table 3. Scale conversion

X-coordinate Points	1.7	4	6.35	8.7	11
Corresponding Values on the New Scale	100	75	50	25	0

Compared with previous studies, the parameter values used to develop the utility functions of risk factors could be further verified and logically demonstrated. For instance, the maximum financial impact of unrealistic construction schedules risk factor could reach up to 13% of the contract value, as provided by the experts. This percentage was composed of two parts, 10% representing the maximum delay penalty stipulated in the UCPW to which a contractor can be subject, and 3% the other incurred costs represented as overhead and additional resources required. However, unrealistic construction schedule risk can be a result of constructive acceleration as well. Constructive acceleration occurs when a contractor is legally entitled to an extension of time, but the contractor is still held to the original schedule due to the owner's refusal (Nelson, 2013). Mills et al. (2009) examined the impact of defective work in a study conducted on Australian residential projects. That study found that the cost of rectification was 4% of the total contract value, and the probability of occurrence was 12.5%. The results obtained in the present study (approximately 7%) can be considered rational compared to the 4% in the study mentioned above, which did not consider the effect of defects on the project schedule. Finally, the results of the MAUT analysis somehow confirm those obtained from the AHP. The escalation in prices was perceived as a serious risk (it was ranked second); the experts also exhibited risk-aversion to price escalation, implying that contractors are unwilling to take on this particular risk factor. However, if the maximum financial impact of the escalation in prices was broken down, it would yield a very close value to that obtained by experts.

$$x_0 = \frac{(y_2 - y_0)}{(y_2 - y_1)} \times (x_2 - x_1) \tag{7}$$

$$y_0 = y_2 - \frac{x_0(y_2 - y_1)}{(x_2 - x_1)} \tag{8}$$

where:

x_0 and y_0: the value of any considered point to be converted

x_1 and y_2: the lower and upper limits of the new scale

y_1 and y_2: the lower and upper limits of the original scale

4.4. Model Implementation

The proposed model was coded using Java programming language through NetBeans IDE (Integrated Development Environment) to provide a user-friendly interface capable of carrying out complex calculations quickly. The decision on selecting the development tool was made based on certain criteria that assure the best implementation to serve the desired objective of the model.

The proposed system requires mainly two levels of input: (1) evaluation of the identified risk factors; and (2) selecting the desired risk attitude depending on the nature and objective of the project. The inputs are entered through a set of designed dialogue boxes, and the model produces the optimum cost contingency percentage.

The proposed model commences once the user first evaluates the provided risk factors according to the engineer's vision and expectation of the impact of risk factors and probability of occurrence in any specific project being considered. The evaluation is based on the Impact-Probability matrix presented in Lavanya and Malarvizhi's (2008) paper at the PMI Global Congress. The paper discussed the process of risk management followed at Nokia and Siemens projects. The use of the impact-probability matrix enables a more systematic approach that takes the basic dimensions of risk into account and is shown in Table 4. The impact of risk is divided into three levels: high, medium and low, and each level is assigned to a quantitative rating as 100, 50 and 10, respectively. For example, when evaluating the "subcontractors' issues" risk factor, the user shall select a low level of impact if all subcontractors are very familiar with the work and the general contractor has previously worked with them. Similarly, the probability of occurrence of risks is divided into four levels: high, medium-high, medium-low and low. Each level represents a range of probabilities. The high level represents a probability of risk occurrence of 80% up to 100%; The medium-high represents a probability of risk occurrence of 60% up to 79%. The medium-low represents a probability of risk occurrence of 30% up to 59%. The low level represents a probability of risk occurrence of 0% up to 29%. The outcome of the Impact-Probability matrix is a level of exposure associated with a quantitative score that combines the impact level's rating and the probability of occurrence. The exposure score was computed by multiplying the impact level's rating by the upper limit of the probability of occurrence as shown in the matrix. Since the utility functions of risk factors were developed based on the maximum and minimum financial impacts, the evaluation can only assume a value between the defined maximum and minimum financial impacts. Therefore, the obtained exposure score was transferred into a scale whose limits were obtained from the MAUT survey, which is defined by the maximum and the minimum financial impacts of each risk factor. The exposure score was used as a percentage to determine the value of the evaluation (x_i). By way of illustration, if the exposure score was determined to be 30, the evaluation of the "subcontractors' issues" risk factor would equal 6.47. The score was computed using Eq. (9) as a percentage of the range of the obtained maximum and minimum financial impacts.

$$Evaluation\ (x_i) = min + exposure\ score \times (max - min) \tag{9}$$

4.4.1 Utility value

The model further proceeds by computing the utility value of the evaluation value provided by the user. At this point, utility functions become essential to determine the utility values of the user's input. The utility value is computed by substituting the evaluation value of any risk factor being considered in the corresponding developed utility function.

4.4.2 Project expected utility

Unlike the method suggested by Lifson and Shaifer (1982) and Dozzi et al. (1996), each risk factor's expected utility is obtained by integrating the computed utility values with AHP importance scores.

The combination of the expected utility values of all risk factors forms an expected utility value for any project being considered (EU_p). The project expected utility can be seen as an overall project evaluation. The expected value of any risk factor (EU_{ai}) and the project expected utility (EU_p) was computed using Eq. (10) and Eq. (11), respectively (Keeney and Raiffa, 1993).

$$EU_{a_i} = W_i \times u(x_i) \tag{10}$$

$$EU_p = \sum_{i=1}^{n} W_i \times u(x_i) \tag{11}$$

Where W_i is the global weight of risk factor i and $u(x_i)$ is the utility value of point x for risk factor i.

Table 4. Constructability implementation decision based on project complexity measurement

Risk Management Matrix		Likelihood			
		High $80\% \leqslant x \leqslant 100\%$	Medium high $60\% \leqslant x < 80\%$	Medium Low $30\% \leqslant x < 60\%$	Low $0\% < x < 30\%$
Impact	High (Rating: 100)	Very high (Score: 100)	Very high (Score: 80)	High (Score: 60)	Moderate (Score: 30)
	Medium (Rating: 50)	High (Score: 50)	Moderate (Score: 40)	Moderate (Score: 30)	Low (Score: 15)
	Low (Rating: 10)	Low (Score: 10)	Low (Score: 8)	Low (Score: 6)	Low (Score: 3)

Table 5. Summary of the developed contingency utility functions and results

Risk Attitude	Risk-Aversion	Risk-Neutrality	Risk-Seeking
Utility Function Shape	Logarithmic	Linear	Exponential
Certainty Equivalent	8.7 ≡ 25	6.35 ≡ 50	4 ≡ 75
Constant (a)	0.4551	0.01	0.0957
Constant (b)	12.5	0	0.0244
Constant (c)	-1.1495	0	-0.0957
Cost Contingency Percentage – Case Study 1	21.03 ≡ 9.04%	44.9 ≡ 6.82%	71.27 ≡ 4.37%
Cost Contingency Percentage - Case Study 2	37.65 ≡ 7.5%	63.22 ≡ 5.12%	83.15 ≡ 3.27%

4.4.3. Cost contingency value

The computed project expected utility is substituted in one of the developed contingency utility functions depending on the user's selected desired risk behavior to obtain the cost contingency percentage. In other words, the contingency utility function associated with the selected desired risk attitude by the user is set equal to the project expected utility to obtain the normalized score. The normalized score is then converted back to a cost contingency percentage.

4.5. Model Validation

The model was applied on two completed local building construction projects in the Eastern Province of Saudi Arabia by Grade 1 general contractors. The fundamental notion was that the risk factors be evaluated according to the engineer's vision while considering their expectation of the impact of the risk factors and probability of occurrence. Users were asked to evaluate risk factors based only on the information they had at the beginning of the project, despite the finished project. The first case study was a construction project of a psychiatric children's hospital. The project was located in Dhahran, Eastern Province. The project duration was 24 months with a contract value of SR 70,000,000. A decision-maker from the construction contractor that built this project was requested to evaluate all the risk factors in the contingency model as if he allocates the contingency value for such a project during the cost estimation stage. Different cost contingency percentages were predicted using the model, corresponding to each risk attitude. The model predicted a value of 4.37% contingency when the user selects a risk-seeking behavior. The actual expenditures from the project contingency account were 4%, which is 9.25% below the model estimated contingency. The selection of risk seeking behavior implies that the competition is high and that the contractor wants to maintain his competitive advantage. This observation explains why the risk-seeking behavior results in the lowest cost contingency. It can be noticed that the least predicted cost contingency still guarantees the contractor with the desired profit margin as it does not cut off any of the contractor's profit margin. In other words, the incurred cost resulted from risk factors, which is 4%, was totally covered by the predicted cost contingency, which is 4.37%, with a surplus of only 0.37%. Furthermore, if the contractor has little interest in the project due to any reason such as work overextension or when dealing with stakeholders with whom the contractor has a previous bad experience, it became logical that the cost contingency is on the high side. It can also be noted that the cost contingency is high when the user decides to adopt a risk-aversion attitude. This attitude can be seen as a very logical result due to some potential reasons such as lack of competition, which encourages contractors to reduce their willingness to take the risk and, therefore, increase the price.

The second case study was a construction project for an administration building consisting of four stories and extended across an area of 4,000 m^2. The project was located in Dhahran, Eastern Province. The project's duration was 48 months and had a contract value of SR 86,000,000. Table 5 shows the constants of the contingency utility function for the three risk behaviors for both case studies. The model predicted a value of 3.27% contingency when the user selects a risk-seeking behavior and 7.5% when considering a risk-aversion strategy. The actual expenditures from the project contingency account were

3%, which is 9% below the model estimated contingency-referring to the definition of the optimum contingency cost, which is the value that simultaneously ensures winning the bid and maximizes profits. Thus, the decision on the desired risk attitude is left to the user to be determined based on the status of the project being considered in terms of competition, working capacity of the contracting firm, past experience with the owner etc. In this case, if the user selected a risk-aversion attitude, the model would have predicted a contingency value of 7.5%. Finally, considering a risk-seeking strategy would provide contractors with the least possible contingency value to cover expected risks.

5. Conclusion

It was possible to develop a reliable and valid computer-based model based on AHP and MAUT taking into account risk factors and different risk attitudes to accurately predicts the optimum contingency value for building projects within the framework of risk management under a unit price/lump sum contract within the design-bid-build delivery system. The proposed model predicts the required contingency value that keeps contracting firms safe from any cuts in profit. The model is a powerful tool to systematically predict the cost of risk with an estimated accuracy of 9%. It is believed that this would enhance the current management and estimation practices as it was found that contractors rely on expert judgment to determine the contingency value. The proposed model is believed to contribute significantly to the overall industry as it augments project expected outcomes and ensures more efficient utilization of governmental and private resources.

Nevertheless, the allocation of cost contingency percentages does not relieve contracting firms from managing risks properly by reducing the probability of occurrence and impact of consequence. A further important aspect is that risk factors included in this study were those whose responsibilities fall on the contractor as per the UCPW. On the technical side, the accuracy of the model can be further enhanced in two main ways. The first one is using actual empirical data to define the maximum and minimum financial impacts rather than obtaining them from experts. The second way should be through establishing the utility functions by more advanced mathematical approaches.

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Appendix A: Risk Factors

Number	Risk Factors	Brief Description	References
1	Payments Delay	The contractor does not receive payments from the owner on the agreed dates which might results in schedule and cost issues.	Kangari (1995), Wiguna and Scott (2005), Enshassi et al. (2008), Polat and Bingol (2011), Goh and Abdul-Rahman (2013), Iqbal et al. (2015), Jarkas and Haupt (2015), Amoudi et al. (2015), and Jayasudha and Vidivelli (2016).
2	Unrealistic Construction Schedules	Project Schedules that are not achievable regardless of management or resources.	El-Sayegh (2008), Polat and Bingol (2011), Goh and Abdul-Rahman (2013), Jarkas and Haupt (2015), and Jayasudha and Vidivelli (2016).
3	Vagueness of Scope of Work	The statement of the project scope is not clear or vague, which might lead to misunderstandings. Scope of work should define the requirements including supply, installation, testing and commissioning.	Ghosh and Jintanapakanont (2004), Sonmez et al. (2007), Polat and Bingol (2011), Iqbal et al. (2015), and Amoudi et al. (2015).
4	Changes in Scope	Late changes in the proposed project scope which requires, in certain times, to rework multiple work items that may lead to eventually claims and disputes.	Wiguna and Scott (2005), El-Sayegh (2008), Iqbal et al. (2015), Jarkas and Haupt (2015), Amoudi et al. (2015), and Jayasudha and Vidivelli (2016).
5	Inadequate Design	Insufficient supplementary design documents of the project. It also implies the risk of improper coordination between various engineering drawings. Construction projects might require the design of temporary structures including shoring, underpinning and scaffolding.	Al-Bahar and Crandall (1990), Wiguna and Scott (2005), Enshassi et al. (2008), Polat and Bingol (2011), Iqbal et al. (2015), Amoudi et al. (2015), and Jayasudha and Vidivelli (2016).
6	Drawing and Approval Delays	Represents delays in obtaining approvals or feedback for requests for information, shop drawings, material approvals and so on.	Wiguna and Scott (2005), Sonmez et al. (2007), Iqbal et al. (2015), and Jarkas and Haupt (2015).
7	Quality of Drawings and Details	Insufficient information and detailing of drawings and specifications might lead to	Al-Bahar and Crandall (1990), Sonmez et al. (2007), and Jarkas and Haupt (2015).

		misunderstanding and raising inquires which in result will require time and cost.	
8	Defective Work	Refers to the cost of rework or repair caused by mistakes or nonconforming material.	Al-Bahar and Crandall (1990), Wiguna and Scott (2005), and Jarkas and Haupt (2015).
9	Poor Productivity of Manpower and Equipment	Poor productivity can affect project schedule and as a result may lead to cost overrun. Several factors could cause Poor productivity.	Sonmez et al. (2007), Jarkas and Haupt (2015), Amoudi et al. (2015), and Jayasudha and Vidivelli (2016).
10	Labor Injuries and Accidents	Undesired accident occurrence in the construction site due to several factors. Such as, crane falls or fire.	Al-Bahar and Crandall (1990), Jannadi, (2008), Iqbal et al. (2015), Jarkas and Haupt (2015), Amoudi et al. (2015), and Jayasudha and Vidivelli 2016).
11	Damage to Material, Equipment and Facilities	Any damage occurs to materials, equipment and facilities during installation, in storage, or in transit. For instance, risk is embodied in the downtime cost of equipment such as cranes, bar bending and cutting machines, concrete pumps and so on.	Al-Bahar and Crandall (1990) and Jayasudha and Vidivelli (2016).
12	Subcontractors Issues	Poor performance of subcontractors in terms of quality and time.	Al-Bahar and Crandall (1990), Ghosh and Jintanapakanont (2004), Polat and Bingol (2011), Iqbal et al. (2015), Jarkas and Haupt (2015), and Amoudi et al. (2015).
13	Suppliers Issues	Represents late delivery of material, nonconforming material and so on.	Al-Bahar and Crandall (1990), Ghosh and Jintanapakanont (2004), Polat and Bingol (2011), Iqbal et al. (2015), Jarkas and Haupt (2015), and Amoudi et al. (2015).
14	War and Civil Disorder	The state of instability in the nation which may pause, interrupt or hinder the current work progress.	Al-Bahar and Crandall (1990), Iqbal et al. (2015), and Amoudi et al. (2015).
15	Labor Disputes and Strikes	The unpredicted actions of labors during the project construction which may result in schedule changes.	Al-Bahar and Crandall (1990), Iqbal et al. (2015), and Jayasudha and Vidivelli (2016).
16	Changes in Laws and Regulations	Modification of governmental rules that have direct effect on construction items prices.	Al-Bahar and Crandall (1990), Sonmez et al. (2007), Iqbal et al. (2015), Jarkas and Haupt (2015), Amoudi et al. (2015), and Jayasudha and Vidivelli (2016).
17	Permit Delays	Delaying various construction permits such as work permits and lack of well-known systematic procedures can lead to schedule issues and as a result may affect project cost.	Iqbal et al. (2015), Jarkas and Haupt (2015), and Jayasudha and Vidivelli (2016).
18	Security and Theft	The loss of equipment, materials or any other items.	Al-Bahar and Crandall (1990), Iqbal et al. (2015), Amoudi et al. (2015), and Jayasudha and Vidivelli (2016).
19	Adverse Weather Conditions	Undesirable weather conditions that can hinder the progress of a certain work item/activity involved in the construction that have not been neither predicted nor accounted for in the cost.	Al-Bahar and Crandall (1990), Wiguna and Scott (2005), Sonmez et al. (2007), Polat and Bingol (2011), Goh and Abdul-Rahman (2013), Iqbal et al. (2015), Jarkas and Haupt (2015), Amoudi et al. (2015), and Jayasudha and Vidivelli (2016).
20	Subsurface Conditions	The unforeseen conditions that have not been discovered neither in site investigations nor in soil reports.	Al-Bahar and Crandall (1990), Wiguna and Scott (2005), Sonmez et al. (2007), Jannadi (2008), Jarkas and Haupt (2015), and Amoudi et al. (2015).
21	Natural Disaster	Acts of god that cannot be controlled such as; flood, earthquake, collapse and landslide design.	Al-Bahar and Crandall (1990), Sonmez et al. (2007), Iqbal et al. (2015), Amoudi et al. (2015), and Jayasudha and Vidivelli (2016).
22	Escalation in Prices	The increase or decrease associated with construction items such as material prices, equipment prices and so on due several causes such as inflation, embargoes or other economical phenomena.	Al-Bahar and Crandall (1990), Wiguna and Scott (2005), Sonmez et al. (2007), El-Sayegh (2008), Polat and Bingol (2011), Goh and Abdul-Rahman (2013), Iqbal et al. (2015), Jarkas and Haupt

			(2015), Amoudi et al. (2015), and Jayasudha and Vidivelli (2016).
23	Accuracy of Quantities Estimation	The degree to which calculated quantities in BOQs and drawings conforms to the actual quantities to be executed on site.	Iqbal et al. (2015), Amoudi et al. (2015) and, Jayasudha and Vidivelli (2016).
24	Site Accessibility	Several conditions such as traffic and permits could hinder employees, goods or equipment access to site. Placement of cranes and concrete pumps are well Illustrative examples.	Jarkas and Haupt (2015), Amoudi et al. (2015), and Jayasudha and Vidivelli (2016).
25	Stringent Inspections by Engineers	Refers to inspectors' strictness beyond requirements and standards.	Jarkas and Haupt (2015).