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APPROPRIATE ALLOCATION OF CONTINGENCY USING RISK ANALYSIS METHODOLOGY

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ABSTRACT

Many cost overruns in the world of construction are attributable to either unforeseen events or foreseen events for which uncertainty was not appropriately accommodated. It is argued that a significant improvement to project management performance may result from greater attention to the process of analyzing project risks. The objective of this paper is to propose a risk analysis methodology for appropriate allocation of contingency in project cost estimation.

In the first step, project risks will be identified. Influence diagramming technique is employed to identify and to show how the risks affect the project cost elements and also the relationships among the risks themselves. The second step is to assess the project costs with regards to the risks under consideration. Using a linguistic approach, the degree of uncertainty of identified project risks is assessed and quantified. The problem of dependency between risks is taken into consideration during this analysis. For the final step, as the main purpose of this paper, a method for allocating appropriate contingency is presented. Two types of contingencies, i.e. project contingency and management reserve are proposed to accommodate the risks. An illustrative example is presented at the end to show the application of the methodology.

Keywords: Contingency, Influence Diagram, Linguistic, Risk.

PROBLEMS OF ESTIMATING AND CONTINGENCY ALLOCATION

It has long been realized that construction is unique compared to manufacturing or other businesses processes [1,2]. Even in construction itself, each project is different from others and presents a unique problem in the process. Many cost overruns are attributable to either unforeseen events or foreseen events for which uncertainty was not appropriately accommodated. It is argued that a significant improvement to project management performance may result from greater attention to the process of analyzing project risks.

An estimate is a forecast of a cost to be incurred in the future based on recorded company data from previous projects. The problem is that the future is not always predictable and such complete and perfect data are rarely available, especially when a contractor conducts an overseas project in which the project conditions are different from the ones in its home country. Thus, it is subject to considerable uncertainty, and perhaps for this reason that estimating, particularly in a competitive tendering situation, is considered as 'more an art than a science.'

The construction industry has a very poor reputation for coping with uncertainty. In estimating project cost, the tendency is that estimator rarely considers uncertainty and the final result mostly is a single-value estimate; there is an illusion of certainty [1]. It is generally observed that the estimator tends to be overly optimistic [3,4].

Contingency can be defined as a provision for those variations to the estimate basis which are likely to occur but which cannot be specifically identified at the time the estimate is prepared [3]. Obviously, each contractor assigns a portion of contingency in his estimate. It can be said that contingency is one way to manage uncertainty. The question is "How much contingency should be added?" Since the contingency allocation is largely judgmental and arbitrary, it is not surprising that the estimator finds it difficult to justify or defend his judgment, or to explain his perception convincingly about future uncertainties.

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Many contractors argue that analytical methods for contingency allocation tend to omit a market or competition factor [5]. Hence most of them cannot afford to include a contingency line item due to market forces. However, it should be taken into caution that to be competitive, a contractor must use competitive methods of construction and must accurately estimate the cost of using those methods. Contingent costs are reduced by learning more about a project or by selecting methods of construction for which one can accurately estimate costs. Contractors should be averse to large project risks; therefore, a contractor cannot be competitive unless it can reduce risk.

Contractors often make the mistake of simply underestimating contingent costs in order that their bids become more competitive. This does not reduce contingency; it only ignores it or simply leaves it out of the estimate. One must not confuse *ignoring* contingent cost with *reducing* contingent cost [6]. To effectively reduce contingency, contractors should know first the risk exposure in the project, and then decide the appropriate contingency based on it.

Therefore, a significance improvement to cost estimate may result from greater attention to the whole process of risk management; the process to identify, analyze and response towards the uncertainty [7,8]. Following this, the objective of this paper is to propose a method for allocating appropriate contingency using risk analysis methodology.

DEVELOPMENT OF METHODOLOGY

Figure 1 depicts a model for contingency allocation using risk analysis metodology, which will be detailed in the following paragraphs.

RISK IDENTIFICATION

The initial task in this step is to define a project breakdown structure (PBS) as the basis for development of cost elements. PBS is a task-oriented family tree of activities that organize, define, and display the work to be accomplished [9]. It partitions the project into manageable elements of work for which costs, budgets, and schedules can be established. This task is followed by assigning a base estimate for each element and computing the total project cost base estimate (BC).

Next is to identify the sources of risks. It requires the analyst to link environmental scanning data to the specific project under consideration. Two types of risks are considered here. In practice, during this step, one can isolate those risks that are likely to occur (first type). In other words, only risks with a reasonable probability of occurring that need to be identified. These risks will be covered by project contingency. On the other hand, though important, low probability but high cost-impact risks, such as *force majeures*, need to be defined separately. It is because these second type of risks will be accommodated by another type of contingency, i.e. management reserve. It is recommended that the process of identification be a group or project team discussion and not just the solely one opinion. (The two types of contingencies will be detailed later.)

The subsequent task is to elaborate the relationships between the identified first-type risks and the developed cost elements using influence-diagramming technique [10,11]. Another important point here is to detect the interdependency among the risks themselves [8]. Ren [12] identifies four basic patterns of risk

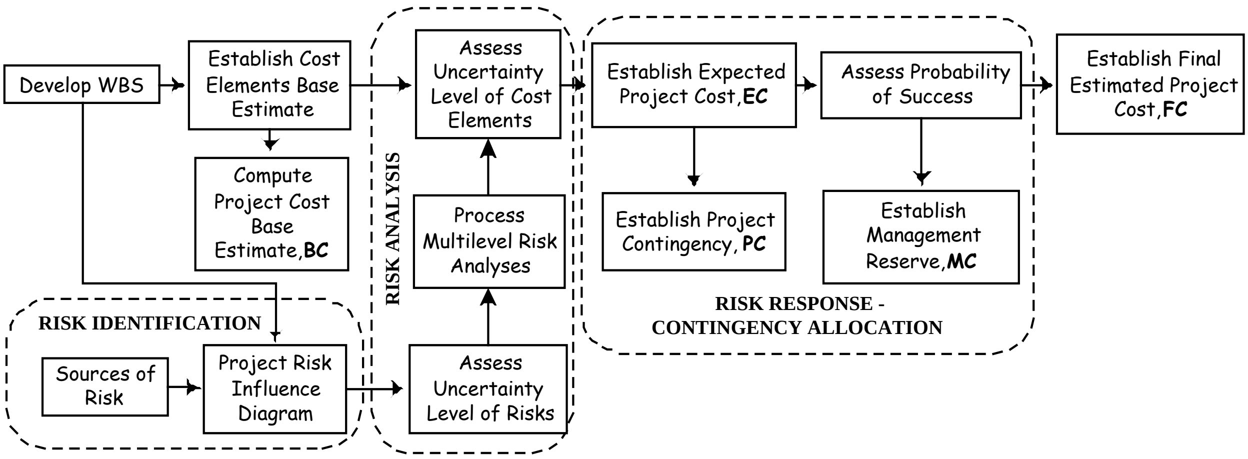

Figure 1. A Methodology for Contingency Allocation

relationship, namely independence, dependence, parallel, and series relationships, which are employed in the methodology. Figure 2 illustrates a concise example of risk identification using influence diagram in a PBS of building project. For the sake of clarity only three cost elements, with their related risks, are identified to be risky.

A risk is defined as independent if its occurrence is not influenced by other risks. For examples in Figure 2 are risks 'inadequate site investigation,' 'ground condition' and 'weather condition'. On the other hand, 'unavailability of materials' is called a dependent risk because its occurrence depends on the occurrences of other risks ('late delivery' and 'availability of vendor' risks). In other words, a dependent risk would definitely not take place if its predecessor(s) did not occur.

Triangle and diamond symbols in the figure indicate parallel and series relationships respectively. A parallel relationship denotes that the occurrence of one of a number of risks may cause the occurrence of one or more dependent risk events (for example, the occurrence of either risk ' late delivery' or 'availability of vendor' may trigger the occurrence of risk 'unavailability of materials'), whereas a series relationship signifies that a number of risk events should occur together to generate the occurrence of one or more dependent risk events (for example, risk 'inadequate site investigation' and risk 'ground condition' together lead to risk in 'foundation').

RISK ANALYSIS

The methodology in risk analysis uses a multilevel procedure, in which the analyses start with the independent risks then continue with the dependent risks and end with the cost elements. Figure 3 illustrates the procedure. There, cost element X is influenced by two risks, say risks A and B. Before evaluating the uncertainty level of the cost element, one should evaluate the degree of uncertainty of these two risks. Yet, as can be seen, the two risks

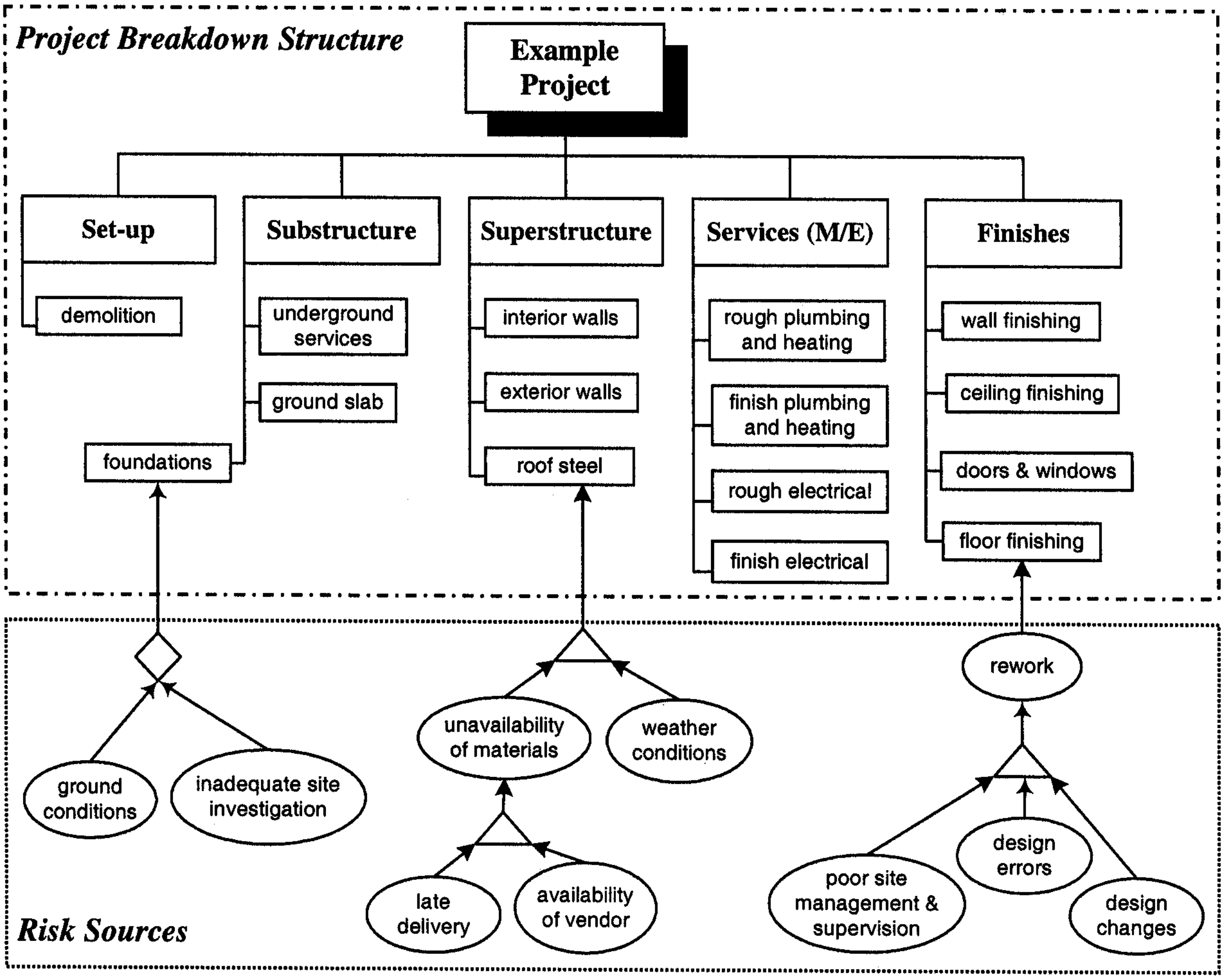

Figure 2. An Illustration of Risks Identification Using Influence Diagram

themselves cannot be assessed directly since they are also dependent on other risks, where risk B depends on risks D and E, and risk A depends on risks C and D. Hence one should step down to the first level and initially evaluates the three independent risks.

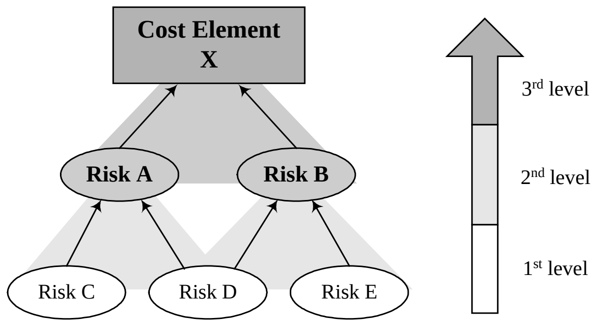

Figure 3. Multilevel Procedures in Risk Analysis

To assess the degree of uncertainty of the risks linguistically, fuzzy set is utilized as a basic framework. Fuzzy sets can generally be expressed mathematically as follows:

$$A = [x / \mu_A(x)] \quad (1)$$

in which A = fuzzy set, $\mu_A(x)$ = a membership value between zero and one, and x = an element of universe X. In order to make it simple, x can be defined as a scale element between zero and ten, which in this study is figured out as the degree, from lower to higher, of uncertainty.

In general, fuzzy sets for linguistic variables can be exampled as in Figure 4 below. It indicates three kinds of fuzzy sets, i.e. low, moderate and high, to describe the degree of uncertainty. For an example, 'low labor skills' is known to be a high risk. Considering the figure, it can be expressed as a fuzzy set that might take on membership values as follow:
A(low labor skills) = [0/0.0, 1/0.0, 2/0.0, 3/0.0, 4/0.0, 5/0.0, 6/0.1, 7/0.4, 8/0.8, 9/0.9, 10/1.0]
Shortly, it can be written as:
A(low labor skills) = [5/0.0, 6/0.1, 7/0.4, 8/0.8, 9/0.9, 10/1.0]

It has been realized that proper development of reliable membership functions appears to be the primary obstacle to application of the theory of fuzzy sets to practical project management. Commonly the membership values are assigned based on subjective judgment of expert and on available statistical data [14].

The principle of fuzzy set allows the extension union and intersection definitions [12]. The formulas are:

$$A \cup B = [x / \max(\mu_A(x), \mu_B(x))] \quad (2)$$
$$A \cap B = [x / \min(\mu_A(x), \mu_B(x))] \quad (3)$$

where $\cup$ and $\cap$ are fuzzy arithmetic operations of addition and multiplication respectively. Using these operations, one could evaluate the interdependencies between risks, in which the parallel dependency is related to addition, $\cup$, operation and, on the other hand, series dependency is represented by multiplication, $\cap$, operation. Therefore, it is possible to calculate the uncertainties of risk factors at the higher level, i.e. the dependent risks, and also the uncertainty of each cost element.

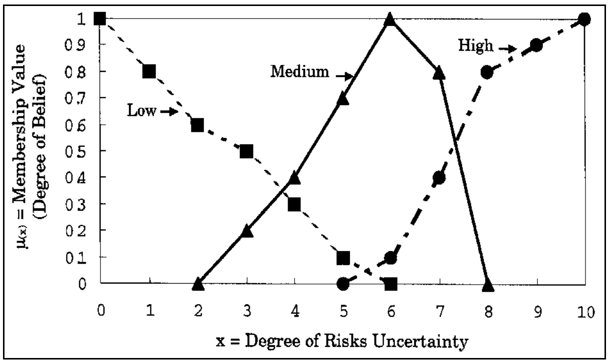

Figure 4. An Example of Fuzzy Set Graph of Cost-Risks (Adapted from [13])

Take, for examples, A as a medium-uncertain risk with a fuzzy set of [2/0.0, 3/0.2, 4/0.4, 5/0.7, 6/1.0, 7/0.8, 8/0.0], and B as a high-uncertain risk with a fuzzy set of [5/0.0, 6/0.1, 7/0.4, 8/0.8, 9/0.9, 10/1.0]. Thus,

A ∪ B = [2/max(0.0, 0.0), 3/max (0.2, 0.0), 4/max (0.4, 0.0), 5/max(0.7, 0.0), 6/ (1.0, 0.1), 7/max (0.8, 0.4), 8/max (0.0, 0.8), 9/max(0.0, 0.9), 10/max(0.0, 1.0)]
= [2/0.0, 3/0.2, 4/0.4, 5/0.7, 6/1.0, 7/0.8, 8/0.8, 9/0.9, 10/1.0], and

A ∩ B = [5/min(0.7, 0.0), 6/min(1.0, 0.1), 7/min(0.8, 0.4), 8/min(0.0, 0.8)]
= [5/0.0, 6/0.1, 7/0.4, 8/0.0].

After evaluating the final results in fuzzy set (uncertainties of all cost element) the next step is translation of the fuzzy sets back into linguistic terms (for example, medium uncertainty of cost element X). "Euclidean distance" technique [11] can be applied to find an appropriate natural language expression for the estimated fuzzy set. It calculates the Euclidean distance from the given fuzzy set to each of the fuzzy sets representing the natural language expression. The formula is:

$$d(X,A)=\left\{\sum_i\left[X(i)-A(i)\right]^2\right\}^{\frac{1}{2}}\quad, i = 1 \text{ to } n \qquad (4)$$

where d = Euclidean distance between two fuzzy sets; i = an integer between 1 and n; n = an integer that defines the highest value of the fuzzy set universe [11]. The application of this technique is more clearly shown by an illustrative example later in the paper.

RISK RESPONSE – CONTINGENCY ALLOCATIONS

There are two types of contingencies considered here. The first is allocated individually in each cost element based on its degree of uncertainty obtained from the previous step. It is further called "project contingency." The second is termed "management reserve," which is allocated for the overall project cost and is usually assigned by the top management level.

Project Contingency

To assign the project contingency, the three estimates technique, used in PERT approach, is employed. Table 1 shows an example of the range estimate.

Table 1. Assessment of Uncertainty Level in Cost element

Uncertainty Level in cost element	Probable Error Range (Characteristic)	
	Lower bound (c_a)	Upper bound (c_b)
Low Uncertainty	- 5%	+ 20%
Medium Uncertainty	- 15%	+ 40%
High Uncertainty	- 25%	+ 60%

Using Table 1 one thus can assess the probable range of each cost element. The range estimates (c_a and c_b) are calculated based on percentage values from the base estimate (c_m). For example, a cost element A with estimated cost (base estimate) of $1,000 is indicated by the fuzzy set to be medium uncertain. Thus, its possible cost range estimates are $850 to $1,400, representing the pessimistic (c_a) and optimistic (c_b) estimates, respectively.

It can be seen that the assessment of probable error range remains subjective. However, the accuracy of such assessment can be continually enhanced through a process of constantly reviewing and adjusting database as new and better data become available. In addition, one may seek opinions from knowledgeable personnel that may help the quality of his estimates. An intelligent knowledge-based system or expert system provides a great promise in dealing with the problem of subjective risk assessment [4].

The procedure continues following the PERT approach [15,16] to obtain parameters for each elemental cost estimate, i.e. expected cost ($c_e = (c_a + 4c_m + c_b)/6$), variance ($s^2 = (c_b - c_a)^2/10$), and also for total project cost estimate, i.e. expected project cost (EC), total variance (S^2) and total standard deviation (S). Hence, the total project cost estimate is not a single value anymore. Instead, provided by the central limit theorem, it has a distribution that tends to the standard normal [17]. The project contingency, PC, can then be calculated by subtracting the base estimate cost, BC, from the expected project cost, EC:

$$PC = EC - BC \qquad (5)$$

Management Reserve

A management reserve, MC, is an additional allowance, which is provided to produce a very high confidence that the project cost will not be overrun. Its purpose is to accommodate the second-type risks. It is calculated as a percentage of the EC and is important since there is a-fifty-percent probability that the actual project cost, C, will exceed the expected one. Figure 5 derives this concept.

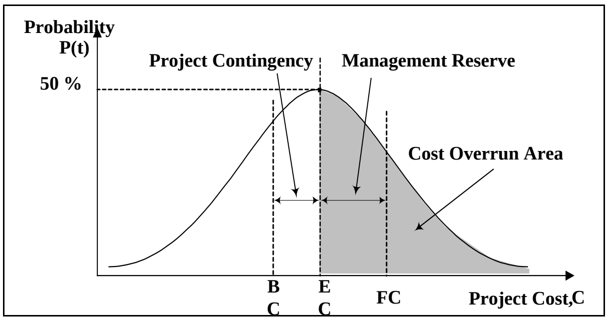

Figure 5. Contingency Allocations and Cost Overrun Area

In Figure 5, the EC divides the assumed normal curve into two equal areas. Therefore, based on the probability theory, the probability of actual project cost falling within the expected cost is not more than 50%. In other words, there is only maximum 50% probability that the project will be finished under the expected cost. In addition, this figure shows also the position of EC to the base estimate, BC, which is separated by the project contingency.

The extent of the management reserve allocation is completely subjective and influenced by the top management's view of the project. It indicates his attitude toward risk and the confidence of achieving the budgeted cost of the project. Although subjectively allocated, it is recommended that the management reserve would be gradually reduced as the project progressing and the availability of information increasing. Moreover, it should reflect the uncertainties existing at that time. With the use of standard normal distribution from statistical book and the known parameters, EC and S, one can draw a representative curve for a specific project that figures out the management reserve versus its probability of success.

AN ILLUSTRATIVE EXAMPLE

Risk Identification

To illustrate the application of the methodology, the PBS presented in Figure 2 will be used here. There, fifteen cost elements, ten project risks and their relationships have been identified.

Risk Analysis

The analysis starts with the independent risks, i.e. "late delivery," "availability of vendor," "weather conditions," "design changes," "design errors," "poor site management and supervision," "inadequate site investigations" and "ground conditions." Their degree of uncertainties are assessed individually based on available data, past experience, and subjective judgment. These are assumed in Table 2.

Table 2. Uncertainty Degree of Independent Risks

Risks	Uncertainty
late delivery	medium
availability of vendor	high
weather conditions	high
design changes	medium
design errors	high
poor site mgt & supervision	low
inadequate site investigations	low
ground conditions	medium

Application of Fuzzy Set

The following expressions, as taken from Figure 4, are assumed to be representative of the degree of risk in Table 2.

Low = [0/1.0, 1/0.8, 2/0.6, 3/0.5, 4/0.3, 5/0.1, 6/0.0]
Medium = [2/0.0, 3/0.2, 4/0.4, 5/0.7, 6/1.0, 7/0.8, 8/0.0]
High = [5/0.0, 6/0.1, 7/0.4, 8/0.8, 9/0.9, 10/1.0]

Next, the uncertainties of the upper levels, i.e. dependent risks and cost elements, can be assessed using fuzzy sets operations. They are evaluated step by step in the followings.

Cost element "Roof Steel"

Before proceeding with this cost element, risk "unavailability of material" [UM] will be evaluated first by applying (2) for addition operation of risks "late delivery" [LD] and "availability of vendor" [AV]:

[UM] = [LD] $\cup$ [AV] = [2/0.0, 3/0.2, 4/0.4, 5/0.7, 6/1.0, 7/0.8, 8/0.8, 9/0.9, 10/1.0]

Uncertainty of cost element "roof steel" [RS] thus can be obtained by adding factors [UM] and "weather conditions" [WC] as follow:

[RS] = [UM] $\cup$ [WC] = [2/0.0, 3/0.2, 4/0.4, 5/0.7, 6/1.0, 7/0.8, 8/0.8, 9/0.9, 10/1.0]

The final step is to translate the fuzzy sets back into linguistic terms using Euclidean distance technique. Applying (4), the Euclidean distance between fuzzy set [RS] and the predefined fuzzy sets (low, medium, and high) can be estimated:

$$d(RS, Low) = [(0-1)^2 + (0-0.8)^2 + (0-0.6)^2 + (0.2-0.5)^2 + (0.4-0.3)^2 + (0.7-0.1)^2 + (1-0)^2 + (0.8-0)^2 + (0.8-0)^2 + (0.9-0)^2 + (1-0)^2]^{1/2} = 2.56$$

$$d(RS, Medium) = [(0-0)^2 + (0-0)^2 + (0-0)^2 + (0.2-0.2)^2 + (0.4-0.4)^2 + (0.7-0.7)^2 + (1-1)^2 + (0.8-0.8)^2 + (0.8-0)^2 + (0.9-0)^2 + (1-0)^2]^{1/2} = 1.57$$

$$d(RS, High) = [(0-0)^2 + (0-0)^2 + (0-0)^2 + (0.2-0)^2 + (0.4-0)^2 + (0.7-0.1)^2 + (1-0)^2 + (0.8-0)^2 + (0.8-0)^2 + (0.9-0)^2 + (1-0)^2]^{1/2} = 1.29$$

Among the three predefined fuzzy sets, the set "high" uncertainty has the closest Euclidean distance to the fuzzy set [RS]. Therefore the cost element "roof steel" could probably be predicted to be "high uncertain" due to the influence of risks.

Cost element "Floor Finish"

Uncertainty of this cost element (FF) can be estimated by adding the three risks, "design changes" (DC), "design errors" (DE), and "poor site management and supervision" (PSM).

[FF] = [DC] $\cup$ [DE] $\cup$ [PSM]
= [0/1.0, 1/0.8, 2/0.6, 3/0.5, 4/0.4, 5/0.5, 6/1.0, 7/0.8, 8/0.8, 9/0.9, 10/1.0]

The estimated Euclidean distances for d(FF, Low), d(FF, Medium) and d(FF, High) are 2.11, 2.13 and 1.97, respectively. Hence, it might be concluded that cost element "floor finish" is "high uncertain," since the Euclidean distance of this set has the smallest value.

Cost element "Foundations"

Cost element "foundations" (F) is influenced by two risks "inadequate site investigations" (ISI) and "ground conditions" (GC) in which they form a 'series' relationship. Therefore 'intersection' operation (see (3)) is used to estimate the uncertainty of the activity.

[F] = [ISI] $\cap$ [GC] = [2/0.0, 3/0.2, 4/0.3, 5/0.1, 6/0.0]

Using the same technique, the Euclidean distances can be estimated as 1.45, 1.42 and 1.66 for d(F, Low), d(F, Medium) and d(F, High), respectively. For this cost element, the Euclidean distance of set "medium" is the closest to the fuzzy set [F]. In other words, cost element "foundations" contains a 'medium' degree of uncertainty.

Risk Response

Project Contingency

Based on the assumed probable error range in Table 1, the followings in Table 3 are the lower (c_a), middle (c_m) and upper (c_b) bound values, and also the expected value (c_e) and variance (s^2) for each cost element.

As shown at the bottom of the table, the total project base estimate, BC is $420,000; the total expected project cost, EC is $432,333; and the total variance, S^2 is 160,650 (S = 12,675). Note that the figures here are rounded. Given the numbers with the risks embedded and the help of a table of the standard normal distribution [e.g. 15], it can be calculated that the probability, P(c), of completing the project within the project base estimate (BC) is only 16.53%, which is a relatively small probability of success.

Table 3. Three-Estimated Values in Cost Elements

ID	Cost Elements	Uncer-tainty	c_a ($000)	c_b ($000)	c_m ($000)	c_e ($000)	s^2
011	Demolition	Low	19.0	24.0	20	20.5	2.50
021	Foundations	Medium	25.5	42.0	30	31.3	27.23
022	Underground services	Low	9.5	12.0	10	10.3	0.63
023	Ground slab	Low	28.5	36.0	30	30.8	5.63
031	Exterior walls	Low	57.0	72.0	60	61.5	22.50
032	Interior walls	Low	28.5	36.0	30	30.8	5.63
033	Roof steel	High	15.0	32.0	20	21.2	28.90
041	Floor finishing	High	15.0	32.0	20	21.2	28.90
042	Ceiling finishing	Low	28.5	36.0	30	30.8	5.63
043	Doors and windows	Low	9.5	12.0	10	10.3	0.63
044	Wall finishing	Low	28.5	36.0	30	30.8	5.63
051	Rough plumbing & heating	Low	28.5	36.0	30	30.8	5.63
052	Finish plumbing & heating	Low	38.0	48.0	40	41.0	10.00
053	Rough electrical	Low	28.5	36.0	30	30.8	5.63
054	Finish electrical	Low	28.5	36.0	30	30.8	5.63
					420	432.33	160.65

The project contingency is calculated using (5). Figure 6 illustrates this project contingency.

PC = EC – BC = 432333 – 420000 = $12,333.

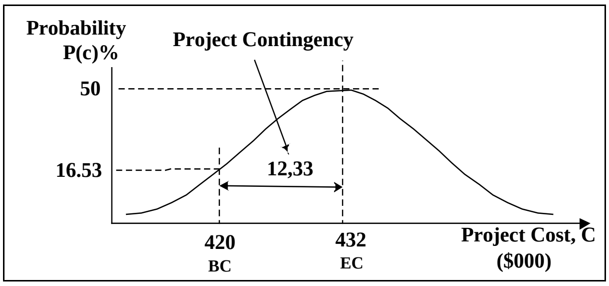

Figure 6. Project Contingency of the Example Project

Management Reserve

As aforementioned, there is only 50% maximum chance that the project would be finished under the expected project cost, EC, obtained in this stage. The next step is the management-level's responsibility to decide management reserve. If he is certainly sure that the project could be finished within the expected time, no project contingency allocation is needed. On the other hand if he wants to increase the probability of success, some reserve should be added into EC. This is intended to accommodate unpredictable and unknown risks in the project. Figure 7 shows the relationship between management reserve (as percentage of EC) and probability of success for this example project.

Supposed that the manager wants an 80% probability that the project can be finished within cost then an approximately 2.47% management reserve has to be added into the expected project cost.

MC = 2.47% × EC = 2.47% × 432333 = \$10,669.45 ≈ \$10,670.

The final project cost, FC, therefore could be estimated:

FC = EC + MC = 432333 + 10670 = \$443,003 ≈ \$443,000.

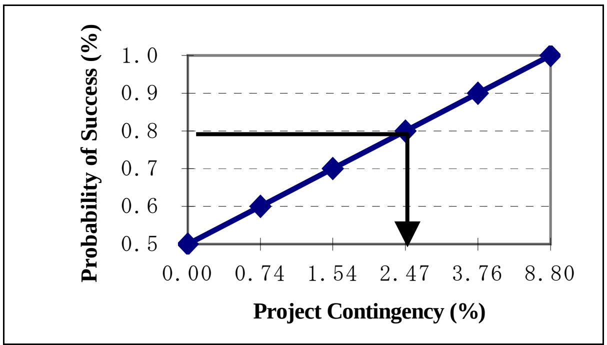

Figure 7. Management Reserve Versus Probability of Success of Example Project

It is recommended that the management reserve be rather allocated at the project level than distributed at the cost elements. This is to avoid the tendency of someone to expend the reserve, as said in Parkinson's Law [18].

CONCLUSIONS

Given the complexity and unique characteristics of construction project environments, the intuitive and unsystematic approach generally used by most estimators during the estimating processes has often failed to anticipate and respond effectively to project uncertainties. This intuitive approach relies on a series of "rules of thumb" that estimators have developed based on their past experience and personal judgment. This paper has presented an alternative method for allocating appropriate contingency using the three-steps process of risk management; i.e. the process to identify, analyze and response towards the uncertainty.

Incorporating sources of cost risks and the typical PBS with the use of influence diagrams served an invaluable picture of systematic identification of cost-risks factors influencing each project cost elements. In addition, the relationships among the risks themselves could be identified.

The use of fuzzy set approach allowed the assessment of degree of uncertainty linguistically. The uncertainty could be termed as low, medium, or high, without its precise value. More importantly, this approach could perform a multilevel, step-by-step risk analysis. The analysis started from the independent risks by assessing their degree of uncertainty linguistically. After that it continued evaluating the dependent risks by performing fuzzy arithmetic operations, i.e. union or intersection, to the independent risks. The operations performed depended on the type of risks-relationship, either series or parallel. And finally, using the same procedures, the degree of uncertainty in each cost element could be obtained.

Two types of contingencies were proposed: project contingency and management reserve. Project contingency was allocated individually into each cost element by means of a range estimate, as used in PERT technique. The expected project cost was estimated to have a 50% probability that it could be achieved. The second contingency was supposed to be allocated as a management's reserve to prevent unknown and unpredictable risks. It would significantly increase the probability of success, i.e. project cost under run.

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