The International Journal Of Engineering And Science (IJES)
|| Volume || 4 || Issue || 7 || Pages || PP -01-06|| 2015 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Cost Overrun Estimation of Construction Project with Significant Risk Factors

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ABSTRACT
The objective of this study is to generate fast, consistent and reliable outcomes for the risk analysis of construction projects. Proposed method uses discrete values for risk factors. Accordingly allots value range which influences cost figures in a bounded probability. The analysis formed on MS Excel add-in @Risk software creates the range of possibilities that generates probable scenarios. In addition, input data of the project simulated with Latin Hypercube Sampling (LHS) method. Effect of each factor can vary according to its influence degree on cost item. Conducted study simplifies the risk assessment on cost figures, which indicates the importance ranking of risk factor on cost item. Also, developed model concurrently provides better estimate for the total cost of project. Used method has applied on a real case study. The results of the case study indicates high risk of cost overrun. In order to complete without overrun probability is %0,3 which is contracted amount for the selected project cost. On the other hand, there is a %99,7 probability of cost overrun, which indicates maximum cost overrun is approximately %10,1 of contracted amount. Also, the analysis identified which risk factors are more effective on total cost of project.

Date of Submission: 06 July 2015 Date of Accepted: 30 July 2015

I. INTRODUCTION

One of the major problem of construction projects is cost overrun. Risk analysis can mitigate the risks to avoid negative impact on project cost. Contracted construction projects have some constrains, from the contractors perspective, completing the project on time and on budget are the main constrains. For the risk analysis, where unanticipated cost can go beyond limits to delay project and/or additional cost. In order to progress as planned and achieve project goals, risk analysis is an essential step for the completion of project. Also, identifying probabilistic effect of risk factors on project can support cost estimate. In this regard, intensive researches have conducted to find out risk factors and effect that causes cost overrun in construction industry. A research study points out cost overrun as 24.8% from 4 different cases [1]. Cost overrun is common and recurring problem for construction projects. Another recent research emphasized cost overrun mean as 12.22% for the total of 276 construction and engineering project [2]. It has been researched by many researchers what creates this gap between the contracted amount and actual cost [1] [3]. From this point, risk factors are the main reason which needs to be considered that can generate unexpected scenario for the project. Risk factor identification and its effect on projects are researched in studies in different countries [4] [5] [6] [7]. Determining the effect of these risk factors, also what causes delays, can change the work plan and/or to take possible precaution in advance. Otherwise projects' progress and completion time can be interrupted by the emphasized risk factors. Estimation of risk data can be noted as qualitatively or quantitatively. Nevertheless, combining these risk factors effect in different formats can create misunderstandings and confusion. It is one of the most challenging task to create fast and reliable data for the risk analysis. A practical way has to be used, to set up a uniform and useful data. Developed method aims to use individual effect of factors on cost items in order to identify most important factors which needs more attention to overcome possible problems. Effect of each factor can vary with the severity of risk factor and the probability of risk occurrence rate. Risk influence are multiplication of severity and frequency [8]. A practical way is to use the effect of risk factors on project as influence degrees of risk factors. One of the way to mitigate risk of project overrun is a contingency which is defined as [9] "the amount of funds, budget or time needed above the estimate to reduce the risk of overruns of project objectives to a level acceptable to the organization".

II. IDENTIFYING RISK FACTORS

Project activities are vulnerable by risk factors which can effect in terms of duration, cost or both at the same time [10]. Finding most probable risk factors on project and revealing severity can minimize project timing problems also reduces the risk of cost overrun. These risk factors have unique effect and has to be considered individually. Values assigned to each cost item vary with the risks involved. Also, interpreting data as quantitatively helps the project simulation of risk factors which shows the effect on the project. List of risk factors considered on Cost Items; Risk Factor No.1 :design changes inside the Firm, No.2 : design changes by the regional directorates, No.3 :design changes by the general directorates, No.4 : owner's delay in approving the design drawings and reports, No.5 : labour productivity inside the firm, No.6 :temporary or permanent absence of the firm's key designer staff, No.7 :bad weather conditions during the activities which must be carried out outside at the project site, No.8 :owner's delay in payment, No.9 :disputes between the project participants, no.10 :delay in the written communication within the owner's organization [9].

Effect of Risk Factors on Cost Items

Total cost of project has divided into cost items as demonstrated in Table 2, as a result each cost item has to be analyzed individually to define its effect on total cost. Influence degree of risk factors on cost figures are researched in study of “Plain Pumping Irrigation Project Design Job”. Risk factors can change the cost figure in each cost item by the severity of risk factor. However, for this case influence degrees have considered as input data of simulation.

Methodology

Risk assessment on project cost estimation have represented in this developed model to provide fast, applicable and easy to interpret. Risk factor has different effect on each cost item, which is predefined by influence degree of factor. For the case of “Plain Pumping Irrigation Project Design Job”, assigned risk values have distributed probability with @Risk LHS method. Risk factors and cost items have defined by MS Excel table where cell shows the effect of specific risk factor on cost item. Simplified version of risk assessment is applied on the actual cost data of a “Plain Pumping Irrigation Project Design Job” [11]. As shown in Table 1 risk factors effect on cost item, considered the risk factors that exist in each cost item and distributes total value of risk among effective risk factors.

Cost Item / Risk#	Risk No1	Risk No2	Risk No3	Risk No4	Risk No5	Risk No6	Risk No7	Risk No8	Risk No9	Risk No10
Cost Item 1	5	10	0	10	5	10	5	5	5	10
Cost Item 2	10	10	0	10	5	10	2	10	10	10
Cost Item 3	5	5	0	2	5	2	2	2	2	10
Cost Item 4	10	10	0	10	5	10	2	5	10	10
Cost Item 5	5	10	10	5	5	10	10	10	10	10
Cost Item 6	10	10	5	5	5	10	5	10	10	10
Cost Item 7	5	5	2	2	5	2	0	2	2	5
Cost Item 8	5	5	2	2	5	2	0	2	2	5
Cost Item 9	5	5	2	2	5	2	0	5	2	5
Cost Item 10	5	5	2	2	5	2	0	5	2	10
Cost Item 11	2	0	0	0	5	2	0	2	0	2
Cost Item 12	2	0	0	0	5	0	0	2	0	2
Cost Item 13	0	0	0	0	5	0	0	2	0	2
Cost Item 14	0	0	0	2	2	0	0	2	2	0
Cost Item 15	0	0	0	0	2	0	0	2	0	2

Table 1. Cost influence degree of risk factors

Cost estimate of project cost items have three scenarios, where shown below in Table 2. as optimistic, most likely and pessimistic figures. Total cost of project is summation of cost items, therefore, any increase on any cost item has direct effect on the total cost of project. The given optimistic and pessimistic figures limits the cost figures that can occur in best and worst case scenarios where indicates severity of risk on cost items.

#	Cost Item Decription	Minimum expected cost (TL)	Most likely expected cost (TL)	Maximum expected cost (TL)
1	Preliminary report	50.000	63.680	80.000
2	General layout plan	20.000	23.880	30.000
3	Upper plain plans and calculations	20.000	23.880	30.000
4	Pre-application projects	25.000	31.840	40.000
5	Post application projects	150.000	199.000	300.000
6	Hydraulic structure projects	150.000	214.920	300.000
7	Operation and maintenance roads	14.000	15.920	18.000
8	Access road projects	5.000	7.960	9.000
9	Post-application projects of pump plans and elevation lines	25.000	31.840	35.000
10	Architectural and static projects of pumping stations	40.000	47.760	60.000
11	Channel cost estimation and measurement reports	30.000	39.800	50.000
12	Hydraulic structure and pumping station cost estimation and measurement reports	30.000	39.800	50.000
13	Green dossier, project reports	12.000	15.920	20.000
14	Submission, approval and reproduction of project originals	20.000	23.880	30.000
15	Final measurements and payment certificate	12.000	15.920	20.000
	Total Project Cost	**603.000**	**796.000**	**1.072.000**

Table 2. Project cost (optimistic, most likely and pessimistic)

Influence degree of risk factors have been defined as, “No”, “Low”, “Medium” and “High” in prepared cost influence sheet and values distributed in between “0 to 10”. Created discrete values, as demonstrated in Equation 1-2-3-4-5, developed by @Risk software. In addition, influence degree of risk factors changes with each iteration with following probabilities,

$$= \mathbf{RiskDiscrete}(\{\mathrm{X1}, \mathrm{X2}, \ldots, \mathrm{Xn}\}, \{\mathrm{p1}, \mathrm{p2}, \ldots, \mathrm{pn}\}) \tag{1}$$

The representation of discrete distribution X stands for the value and a weight p is the probability (weight of the value).

High Risk Rate

$$\mathrm{High} = \mathrm{RiskDiscrete}(\{8\backslash 9\backslash 10\}; \{0{,}3\backslash 0{,}4\backslash 0{,}3\}; \mathrm{RiskStatic}(10)) \tag{2}$$

Medium Risk Rate

$$\mathrm{Medium} = \mathrm{RiskDiscrete}(\{4; 5; 6; 7\}; \{0{,}2; 0{,}3; 0{,}3; 0{,}2\}; \mathrm{RiskStatic}(5)) \tag{3}$$

Low Risk Rate

$$\mathrm{Low} = \mathrm{RiskDiscrete}(\{1\backslash 2\backslash 3\}; \{0{,}3\backslash 0{,}4\backslash 0{,}3\}; \mathrm{RiskStatic}(2)) \tag{4}$$

No Risk Rate

$$\mathrm{No} = 0 \tag{5}$$

Generated values from Table 1 is linked to risk factors effect on cost items table to compute the individual effect of each risk factor on each cost item. The cost item and risk factor value on table indicates cost risk on cost item.

Influence of risk factors values as average of total value on project provides a percentage share of weight. Percentage share of weight of risk factors on cost items are computed individually, and it is expressed as

$$\bar{\boldsymbol{I}}_{\boldsymbol{k}} = \sum_{i=1}^{n} \boldsymbol{CI_i RF_k} \div \sum_{i=1}^{n}\sum_{j=1}^{m} \boldsymbol{CI_i RF_j} \ ; \qquad \mathbf{i = 1 \ldots n;\ j = 1 \ldots m} \tag{6}$$

Calculation of percentages of risk factors shows frequency of risk factors which have greater probability to occur. Therefore, percentage share of risk factors on project that has shown below in Figure 2.

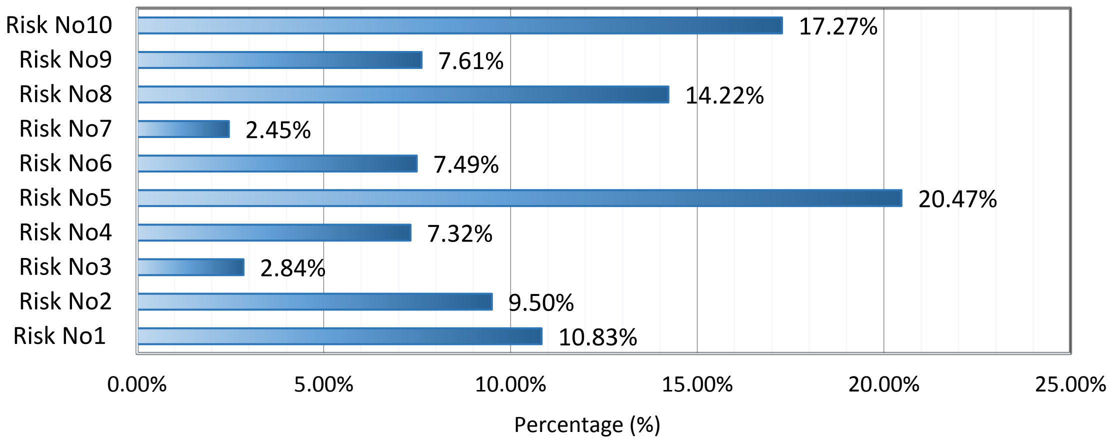

Figure 1. Percent Average of Risk Factors Influence on Project Cost

Computed average of risk factors on overall influence is shown in Figure 1. Where shows the influence weight of risk factors on total cost of project. Project outcomes computed with the formulas represented in Equation 6, as shown in Figure 1. highlighted risk factors influence weight on project cost figures are Risk No5, Risk No10, Risk No 8 and Risk No1 respectively which are above %10 (mean).

1. Labor productivity inside the firm (%20,47)
2. Delay in the written communication within the owner's organization (%17,27)
3. Owner's delay in payment (%14,22)
4. Design changes inside the Firm(%10,83)

Effect of risk values have determined proportionally based on cost difference of pessimistic and optimistic values provides the total cost risk of risk factors on that cost items. By adding the risk factors influence on project cost and running a simulation can interpret more possibilities. In addition to influence of the cost figures, for each cost item have an assigned triangular distribution for the simulation with LHS. Chosen data taken from a project which contracted cost of the project is 796,000 TL. As shown in table 1 influence degrees of risk factors and table 2 for cost figures into the software for the analysis of 1,000 simulation iteration with LHS method. During the simulation, figures are changing with the effect of influence value, also triangular distribution with LHS gives another probabilistic input that increases outcomes.

$$\boldsymbol{CIRF_{ij}} = (\boldsymbol{RF_{ij}} \,/\, \sum_{k=1}^{n} \mathbf{CI}_i\mathbf{RF}_k\,) \times (\boldsymbol{P}-\boldsymbol{O})_i \quad ;\mathbf{i} = \mathbf{1} \ldots \mathbf{n} \quad ;\mathbf{j} = \mathbf{1} \ldots \mathbf{m} \tag{7}$$

Where, n denotes the number of cost item and m the number of risk factors. $CIRF_{ij}$ formula takes RF for each estimate and computes its ration in terms of risk on cost item, which is based on pessimistic and optimistic difference.

III. RESULTS

Percent share of listed risk factors influence average is shown in Figure 2, which points out risk factors on total cost of project. However, other factors importance can change during analysis. Input data of project transferred to software for simulation. Estimate shows the influence of risk factors that have different effect on each cost item. As a result, effect of each risk factor can vary with it cost item value. However, it show which factors have more value as a weight on average on the project cost items, but it does not represents the effect on the total cost of project.

Consequently, defining each cost item as individual effect on total cost can identify the actual effect in terms of cost. Represented formulas are based on the weight of cost and the influence degrees of the risk factors. In the Equation 7 uses input as the value of risk factor and its proportion on total and distributes accordingly. Simulation of project cost figures are summarized with the tornado graph as in Figure 2.

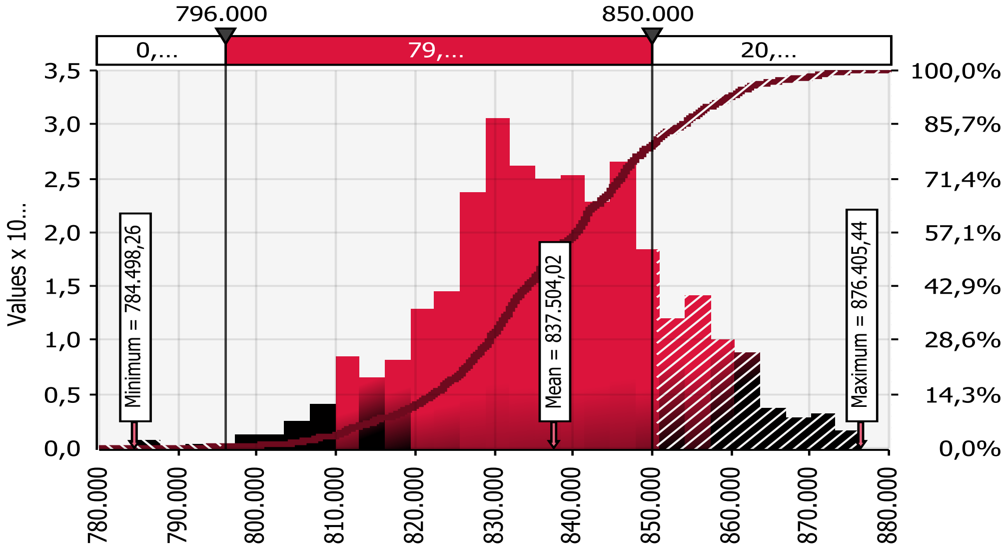

Figure 2. Cost of project with risk factors

Most optimistic scenarios are also included in the simulation of project as shown on Figure 2, and there is 0.3 percent probability to complete this project under contracted amount. Therefore, project seems highly possible to face with cost overrun. Estimation shows that for the %80 intersection is 850,000 TL, to overcome cost overrun there is 54,000 TL additional cost can be covered with contingency. Contingency gives chance to complete project without additional bank credit or other financial resources. Chosen percentage value changes the project cost overrun risk as demonstrated in Figure 2. Project cost frequency increases over 820,000 TL, and mean of simulated cost is 837.504 TL.

Research has described the percentiles of completion with and without cost overrun. Average of influence degree of risk factors are the key on project cost estimation. Risk factors effect can be seen on the Figure 3, where shows the cost item and which risk factors are threat for the total cost of project.

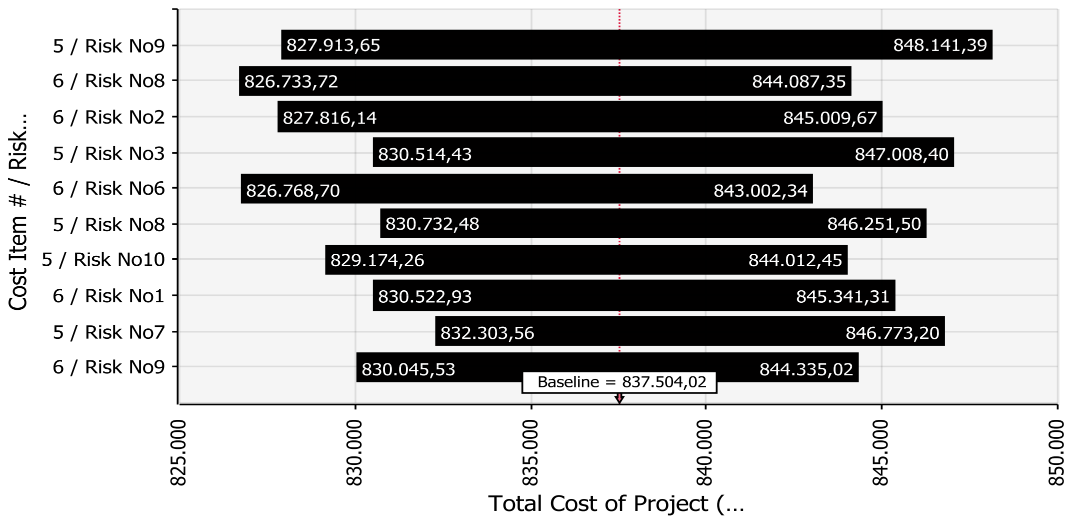

Figure 3. Sensitivity of risk factors on total cost (Ranked effect)

As a result of analysis, most sensitive risk factors on total cost of project are identified. These risk factors are totally different than the computed average influence ranking. In Figure 3 only cost item 5 and 6 dominate the top 10 sensitive cost item on total cost of project. The importance of cost items and risk factors are represented in Figure 3. Risk factors are decisive on the total cost of project as seen in Figure 3. Outcomes of performed simulation, indicates the importance ranking of risk factors on which cost items is more effective on total cost of project. Ranked "risk factor-cost item" sensitivity on total cost of project are listed below;

1. RF 9 on CI 5 (Disputes between the project participants - Post application projects)
2. RF 8 on CI 6 (Owner's delay in payment - Hydraulic structure projects)
3. RF 2 on CI 6 (Design changes by the regional directorates - Hydraulic structure projects)
4. RF 3 on CI 5 (Design changes by the general directorates - Post application projects)
5. RF 6 on CI 6 (temporary or permanent absence of the firm's key designer staff - Hydraulic structure projects)
6. RF 8 on CI 5 (Owner's delay in payment - Post application projects)
7. RF 10 on CI 5 (Delay in the written communication within the owner's organization -Post application projects)
8. RF 1 on CI 6 (Design changes inside the Firm - Hydraulic structure projects)
9. RF 7 on CI 5 (Labor productivity inside the firm - Post application projects)
10. RF 9 on CI 6 (Disputes between the project participants - Hydraulic structure projects)

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