Risk Analysis of Construction Project using Sensitivity Analysis

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Abstract—Construction process is complex and characterized by many uncertainties from beginning to end which inherits huge number of risks at various levels as compared to any other industries. Hence, construction projects fail to achieve their desired outcome of attaining project and business goals. Most stakeholders have developed a series of thumb rule that they apply to analyze the risks. These rules rely mostly on experience and judgment. Rarely do stakeholders quantify uncertainty and systematically assess the risks involved in a project. Furthermore, even if the risks are assessed, they even less frequently evaluate the consequences associated with these risks. This study aims to perform a systematic risk analysis of a construction project qualitatively and quantitatively. A residential project is considered as a case study upon which qualitative analysis is done by probability impact (PI) matrix method and quantitative analysis is done using expected monetary value (EMV) analysis. Sensitivity analysis is used to determine the effect of change in key risk variables that can influence the total expected monetary value of risks and to investigate its consequences.

Keywords—Risk, Risk Analysis, Sensitivity Analysis, EMV Analysis, Quantification of risks.

I. INTRODUCTION

Construction projects are exposed to risks at the time of their coming into existence. In the various stages, it must first of all be considered what risks the principal would like to counter with measures and how costly these measures are. For these risks, possible risk costs, measures and costs of the measures must be identified and suitable measures must be found in order to avoid errors in the future. The willingness of the stakeholders to take a risk that causes costs is common to all construction projects. The costs for risks are mostly not allowed for beforehand and thus reduce its profit margin. A consideration of the topic of risk management is worthwhile therefore and hence also the attempt to minimize costs due to a failure to take precautions or avoid these completely. Risk management in construction projects is of great importance. The risk potential analysis of a project states to what extent project risks influence the risk situation of the enterprise. Risk potential should be estimated without a detailed consideration of the individual risks at as little expense as possible. Depending on the assessment of the risk potential, the risk management process is set in motion.

The contingency sum, usually expressed as a percentage markup on the base estimate, is used in an attempt to allow for the unexpected. Construction and development is fraught with difficulty, and the basic notion of risk analysis is that it is useful to at least make an attempt to identify these risky items and attach some financial value to them. These amounts can then be added to a project budget as items of possible expenditure. The intention is that the project budget becomes a more realistic representation of the client’s likely outlay.

The practice of presenting project cost estimates as a deterministic figure comprising a base estimate and the addition of a single contingency amount (usually as a percentage addition) has been adopted in the construction industry for a long time for budgeting purposes. Usual practice is for this amount to be a single lump sum with no attempt made to identify, describe, and value various categories and possible areas of uncertainty and risk. Often the contingency amount allowed is merely a percentage of the overall project cost. In many cases it amounts to an educated guess at best.
There are a number of methods in risk analysis practice that are used to deal with uncertainty. For the purpose of this research, a quantification system of risks using expected monetary value (EMV) analysis is used to evaluate the total monetary value of project risks of a construction facility. Qualitative analysis is done using probability impact (P-I) matrix method and further sensitivity analysis is done upon the total monetary value to highlight the effects of changes in the variables.

II. PROBLEM DEFINITION

Checking research literature shows that in spite of several researches in the field of risk analysis on construction projects, there isn’t any logical and systematic approach for identification and quantification of critical risks. This research aims to provide a suitable and systematic approach for evaluating expected monetary value of the total project risks on construction projects and to determine the effect of changes in key variables to the total monetary value of risks.

III. CASE STUDY

A residential building project at P.W.D Ground premises in Ghatkopar, Mumbai is considered as a case study for this dissertation. It is a G+22 building constructed by Mumbai based firm Tirupati Construction and client being Rare Township Private Limited.

The total contract value of the work order is Rs. 19,43,79,750/- (Rupees Nineteen Crore Forty Three Lakhs Seventy Nine Thousand Seven Hundred and Fifty Only) arrived at lump sum rate of Rs. 1450/ Sq.ft for a construction area of approximately 1,34,055 sq.ft.

IV. METHODOLOGY

A simple yet effective system for risk quantification in construction projects based on Expected Monetary Value (EMV) analysis is used for analysis purpose. It is modified according to the literature in the area of risk management and for the simplicity so as to be used to various stakeholders. The methodology adopted is as follows:

1. Risk Identification – Risk identification was done by unstructured interview with the project manager as he is the person who has the overall responsibility for the successful initiation, planning, design, execution, monitoring, controlling and closure of a project. This will lead to a list of risks associated with the project depending upon his judgment and experience.

2. Classification of Identified Risks – The classification of risks helps in dividing the identified risks in different categories for analysis purpose. For the purpose of this research, classification of risks is done as listed below
   a. Technical Risks
   b. Construction Risks
   c. Physical Risks
   d. Organizational Risks
   e. Financial Risks
   f. Political Risks
   g. Environmental Risks

3. Qualitative Analysis of Identified Risks – To evaluate individual risk responses subjectively, Qualitative Risk Analysis (QRA) sheet is generated which contains the list of identified risks along with their classification. It shall ask for probability and impact of each risk in a subjective way. For probability and impact assessment, a scale shall be used. The scale shall be used respectively for the range from 1 to 5 as 1-very low, 2-low, 3-medium, 4-significant and 5-high for the probability of occurrence and the corresponding impact to the total project cost.

   The QRA sheet shall be filled with only tick marks in appropriate boxes against the individual risk listed along with their classification as shown in Table-1 below.
Table 1. QRA Sheet (Qualitative Risk Analysis Sheet)

<table>
<thead>
<tr>
<th>Identified and Classified Risk</th>
<th>Probability</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1-Very Low, 2-Low, 3-Medium, 4-Significant, 5-High)</td>
<td>(1-Very Low, 2-Low, 3-Medium, 4-Significant, 5-High)</td>
</tr>
<tr>
<td>Technical Risks</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>R1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction Risks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The responses of QRA sheet shall be further analyzed using Probability-Impact (PI) Matrix method. It consists of vertical columns for probability and horizontal column for impact using the scale from 1 to 5. This matrix method gives combined effect of probability and impact associated with each risk. This combined effect will result into a P-I factor evaluated by product of both the probability and impact values allotted by the respondent.

Table 2. Probability – Impact Matrix

<table>
<thead>
<tr>
<th>Probability</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>12</td>
<td>16</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>15</td>
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<tr>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

4. Quantification of Risks – For the purpose of this research, the risks whose P-I values are 10 and above are termed as critical risks and shall be considered for further quantification.

4.1 Basic Occurrence Probability of Critical Risks – The probability of occurrence of the critical risks shall be decided after reaching consensus by the respondent depending upon his knowledge and judgment.

4.2 Scale for probabilities for different cost consequences – The scale of cost consequences shall be used where a range of cost consequences in terms of percentage of total project cost shall be given and associated probabilities shall be filled by the respondent. The scale is shown below in Table 3.

Table 3. Scale with Range of Cost Consequences and associated probabilities

<table>
<thead>
<tr>
<th>Cost Consequences</th>
<th>0-1% of total project cost</th>
<th>1-3% of total project cost</th>
<th>3-5% of total project cost</th>
<th>5-10% of total project cost</th>
<th>10-20% of total project cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Associated Probability</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</table>
Experience shall influence while filling the above table and effectiveness of the analysis shall also be dependent upon the capability and judgment of the respondent.

4.3 Calculation of Expected Monetary Value (EMV) of risks – Basically, EMV is a product of event probability and its cost consequences. Here, the cost consequences are described in range and hence the mid-point of each class is taken as cost consequence for calculation.

For Class 0-1% - 0.5% of total project cost is to be taken and so on.

So, EMV for every critical risk is calculated using following formula

\[ \text{EMV}_1 = \text{Cost consequence of risk} \times \text{Probability of this cost consequence} \]

(Addition of all the mutually exclusive class is done to evaluate the \( \text{EMV}_1 \))

Next, basic occurrence probability of each risk is multiplied with \( \text{EMV}_1 \) so as to get the final Expected Monetary Value termed as EMV.

\[ \text{EMV} = \text{Basic occurrence probability} \times \text{EMV}_1 \]

5. Sensitivity Analysis – It is done to determine the effect on total expected monetary value of the project risks by changing one of its risk variables to highlight its effect.

V. RESULTS AND DISCUSSION

After application of the above methodology on a case study project, initially 39 project risks were identified. Further classification and qualitative analysis lead to 7 critical project risks which had significant impact on project cost as PI factor was above prescribed value. Quantification of those critical risks produced the expected monetary value according to the degree of response which was to be \( \text{Rs.1,15,07,281} \). Sensitivity analysis was done to determine the effect of change on the EMV evaluated. After changing values within a specific limit, the range was between 6% to 9% of the total project cost which is acceptable as usually contingency is 10% of the project cost to overcome the risks.

VI. CONCLUSION

Quantification of risks is essential to determine expected monetary value (EMV) of the total project risks which may be helpful for the provision of amount of contingency funding for a construction project. Risk analysis using sensitivity analysis helps to determine the effect of change in risk variables to the total expected monetary value of project risks so as to determine the range within which the risks on a project in total terms of cost may vary.

REFERENCES

