Risk Assessment for Managing Risks in Infrastructure Projects

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Abstract

Construction projects are prone to complexity and uncertainty. Management of risks is a deciding factor in success or failure of the projects. Each construction project in itself is unique and very few similarities exist between any two projects, even if the construction is in the same sector. Every construction project has its own share of risks, and the risks will not be the same even if a similar project is executed in two different places with different terrain and topography. Risk management involves identifying risks, assessing them, and developing suitable strategies to manage them. An attempt has been made in the present study to analyze the risk scenario in the construction industry by meeting stakeholders and eliciting information from them for recognizing the risk factors that influenced the success of two projects - one thermal and one hydel project under construction in the state of Andhra Pradesh. Risks can be assessed qualitatively and quantitatively. This paper reviewed the various techniques used for quantifying risks and focused on evaluating the risks using the Risk factor and Priority model. The evaluation of risks will be an effective tool for prioritizing the risks for successful completion of the projects.

Keywords : risk, risk management, risk factor and priority model, thermal/hydel projects

JEL Classification : C14, C51, C65

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The construction industry is prone to risks, which is more in case of infrastructure projects. Risk management is becoming an increasingly challenging activity. Risk is defined as that variable, the occurrence of which has an impact on a project. The risk management process for any construction project involves risk identification, risk assessment, risk allocation, risk mitigation, and risk monitoring. In today's highly competitive world, effective management of risks is becoming utmost important for the success of a project. The focus of the managements is on methodologies for identifying risks for reliable evaluation of likelihood and impact of risk in a quantitative manner. Application of a risk informed approach to any infrastructure project is still in its infancy as far as India is concerned.

Literature Survey

Al-Bahar and Crandall (1990) used influence diagramming and Monte Carlo simulation techniques for assessment of project risks and suggested the implementation of risk managements strategies like risk transfer, risk avoidance, loss prevention, and insurance for mitigation of project risks. Chaphalkar, Shelar, and Patil (2011) used a risk factor and priority model for assessment of risks in real estate projects, and concluded that the model would be effective in prioritizing the risks based on extent of risk occurrence and its impact. Hariharan, Bhatt, and Sawant (2009) used the analytical hierarchy process model for assessment of risks for recognizing the risk factors that are the stumbling blocks in the progress of a project.

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Augustine, Ajayi, Ade, and Edwin (2013) developed the Risk Management Index (RMI) for assessment of risks and concluded that establishment of RMI will help develop a strategy to reduce risks in construction projects at all levels. Klemetti (2006) examined risk management in construction project networks, and concluded that a cooperative risk model would be much better where multiple actors would manage risks together, resulting in efficient and successful risk management. Hastak and Shaked (2000) developed a risk assessment model (ICRAM-1) which provides users with initial knowledge of edge of the degree of risk in the macro, market, and project levels in the examined country prior to conducting extensive market research and investment in the international construction market.

Osama and Salman's (2003) risk assessor model (RAM) was developed and computerized to determine the risks associated with a particular activity and the justification factor for the proposed remedy. Beckers, Chiara, Flesch, Maly, Silva, and Stegemann (2013) studied risk management and emphasized that risk assessment needs to be conducted early on in a project, and professional risk management needs to be undertaken throughout the life cycle of a project, which will yield significant results. Tipili and Ilyasu (2014) used ANOVA for the determination of the exposure rating level so as to correctly categorize the risks. Bogale, Pranay, and Sharma (2006) concluded that risk assessment and risk informed approach for managing risks in infrastructure projects was absolutely essential for effective risk mitigation and successful completion of a project.

Kansal and Sharma (2012) attempted to formulate an integrated risk assessment tool which would aid the decision makers in applying risk management effectively. Swarna and Venkatakrishnaiah (2014) conducted a study on risk assessment using fault tree analysis and concluded that there was a need for standardization, which addressed the issues of clarity, fairness, allocation of risks, dispute resolution in projects, and so on.

Risks in Construction Projects

(1) Gestation Stage : The main risk involved during this stage relates to the costs being incurred in the research, appraisal, and development of the concept of the project, and the high degree of probability that the proposal may be scrapped, thereby making the costs incurred towards the formulation of the study as a bad and irrecoverable investment.

(2) Development Stage : The following are the main risks involved in the development stage of a project :

- Rejection of proposal by the concerned government or authority,
- Delay in obtaining requisite approvals to commence the project,
- Delay in mobilization of finances,
- Delay in acquisition of land,
- Possibility of alteration in scope of the project due to inadequate research at the gestation stage,
- Inability to obtain suitable contractor(s) on suitable price and terms,
- Inability of finding suitable equity investors in the project vehicle.

(3) Construction Stage : Risks during this stage are categorized into :

(a) physical, (b) construction, (c) design, and (d) technology risks.

- Physical risks relate to ground conditions, natural conditions, adverse weather conditions, physical obstruction, and other physical conditions that adversely affect the implementation of construction activities at the project site.

- Construction risks relate to availability of resources, industrial relations, quality of raw materials and construction, safety during construction, delay in supplies, usage of relevant construction techniques, failure to comply with construction milestones, cost of construction, and so forth.

↳ Design risks relate to incomplete design, assumed design life, availability of relevant information for design, compliance with standards, and viability of design.

↳ Technology risk relates to obsolescence of technology, project inappropriate to handle the projected demand, project inappropriately designed to meet the socioeconomic needs, which results in escalation of costs.

(4) Operation Stage : Risks during this stage can be categorized into :

(a) operation, (b) maintenance, (c) revenue, and (d) personnel risks.

↳ Operation risks relate to the condition in which the facility is operated, supply of raw materials, plant performance, standard procedures in operation of plant/facility, interruption of operation for various reasons, fluctuation in costs associated with continued operations of facility, and idleness or otherwise of the facility.

↳ Maintenance risks relate to the ability to conduct the required maintenance of facility at the stipulated standards. These risks encompasses availability of spares, availability of resources, availability of sufficient time for carrying out the maintenance, expenses related to maintenance activities, frequency of maintenance to be carried out, and the degree of maintenance required.

↳ Revenue risks relate to demand for the output from the project, tariff mechanism for determination, revision, levy, collection of tariff to be charged by the project company from the users of the facility.

↳ Personnel risks relate to the availability of trained and suitable personnel to carry out the activities related to this stage.

In addition to the risks mentioned above, the following risks may also be prevalent :

↳ Political and social risks (inability of the government, inconsistent policy, civil/political problems),

↳ Force majeure risks (natural disasters like earthquakes, floods, tsunamis, volcanic eruptions, and so forth).

The Risk Management Process

Risk management is defined as management of all events which has a potential to cause a risk, and to estimate its likelihood and impact. The risk management process involves identifying opportunities and mitigation strategies to reduce the likelihood of the occurrence of an event and its potential effect, if it were to occur. It is a systematic way of protection against the resources of an organization so that the objectives can be achieved. It is an orderly process which involves identifying, analyzing, and responding to risky events from the concept to the commissioning of a project so that risky events can be avoided or mitigated to the most possible extent. In construction projects, the four corner pillars, that is, scope, time, cost, and quality are subjected to risk and uncertainty, and these four parameters pose a deleterious effect on the viability of a project, if not controlled. Risk management is thus directly related to the successful completion of a project within or equal to the budgeted cost. The steps involved in risk management are as follows:

(1) Risk Identification : This involves determination of various risks involved, which has the potential to adversely affect the outcome of a project. Risk identification is defined as "process of identifying, categorizing, and assessing the initial significance of risks associated with a construction project". The methods for risk identification could include (a) brainstorming, (b) interviews, (c) questionnaires, (d) previous experience, (e) discussion with the subject experts.

(2) Risk Assessment : The purpose of risk assessment is to understand and quantify the likely effect of any potential risk. This assessment phase comprises of :

(i) Qualitative Assessment : In this assessment, source, cause, and the effect of potential risk is reviewed and described in detail, and in this process, a risk register is compiled, where the status of each risk is updated on a regular basis.

(ii) Quantitative Assessment: The effect of risk is analyzed in detail along with the effect on the overall outcome of the project. The purpose of undertaking such an exercise is to calculate the most likely and worst scenarios. The purpose of this assessment is also to determine which of the risks are of minor nature which can be avoided.

(iii) Risk Allocation : After identifying and assessment of project risks, a table is to be drawn up for allocation of risks to the party which can handle risks effectively.

(iv) Risk Mitigation : In order to mitigate the potential impact of any risk, the designated manager must consider alternative courses of action and evaluate the consequences - should that action be taken ? The main aim of response and mitigation strategy is to initiate and implement appropriate actions to prevent risks from occurring or the most can minimize the potential damage the risks may cause.

(v) Risk Monitoring : Monitoring and controlling of risks is integral to the success of a project. Effective communication, timely reporting of risks, and swift action play an important role in risk monitoring.

(vi) Risk Factor and Priority Model : Risks are assessed either qualitatively or quantitatively . Qualitative analysis involves the description of the impact and likelihood of identified risks, and quantitative analysis involves numerical scales rather than descriptive scales.

In order to determine the relative importance of risks, the present study conducted a questionnaire survey of the identified risk factors in the selected thermal/hydel projects to the respondents who were involved in the execution of the projects. Survey responses were analyzed using "Risk factor and Priority model," where the risks were quantitatively evaluated in terms of their probability of occurrence. This model gave an overview of the risks that (a) posed a threat to the project, wherein the intervention of the management was needed immediately, and (b) action plans to be developed for future activities and facilitated the allocation of resources accordingly.

The significance of risk is termed as the "risk factor". Risk factor for each identified risk is calculated by converting descriptive scale to numerical measure P (probability of occurrence) ranging from and C (consequence) and substituting the values in the below equation :

$$RF = P + C - (P*C)$$

where,
RF = Risk factor,
P = Probability of occurrence on a scale of 0 to 1 (obtained by dividing the score by 5 since there are 5 scales),
C = Consequence (impact) on a scale of 0 to 1(obtained by dividing by 5).

The risk factor *(RF)* ranges from 0 (low) to 1 (high), and it reflects the action to be taken as follows:

- **Insignificant =** Risk is of no importance and can be ignored (= 0 on scale of 0 to 1),
- **Catastrophic =** Risk needs serious attention of the project manager (=1 on a scale of 0 to 1).

Risk factors 'critical,' 'medium,' and 'marginal' lie in between these two extremes. These are presented in the Table 1.

Methodology

The study is based upon a questionnaire survey, wherein a questionnaire was used to elicit data from the contractors/clients/project managers/consultants and so forth regarding the risks involved in two projects - one thermal and one hydel project under construction in the state of Andhra Pradesh. The thermal and hydel projects

Table 1. Scale for Risk Likelihood

Value on Scale	Probability of Occurrence *(P)*	Consequence of Impact *(C)*
1	*Rare*	*Insignificant*
2	*Unlikely*	*Marginal*
3	*As likely as not*	*Medium*
4	*Probable*	*Critical*
5	*Highly Probable*	*Catastrophic*

Table 2. Responses Obtained from the Questionnaire

Q.No	Question	Thermal Project		Hydel Project	
		Occurrence	Impact	Occurrence	Impact
1	Getting clearance on time	2	4	1	4
2	Reliability of detailed project report	1	4	1	4
3	Land acquisition	2	3	3	4
4	Finalization of decision from client side	1	2	2	2
5	Experience of design team	2	3	1	3
6	Faulty design	2	4	1	4
7	Practicality of concept	1	2	2	4
8	Change in scope of the project	1	3	2	3
9	Geological effects	2	3	3	4
10	Type of contract	1	2	1	2
11	Safety aspects	1	3	3	3
12	Quality as per standards	1	4	1	3
13	Mobilization of finances	2	3	2	3
14	Dispute settlement mechanism	3	3	4	4
15	Breakdown of machinery/equipments	2	3	1	3
16	Delegation of clear cut authority and responsibility at different levels	1	2	1	1
17	Legal and regulatory environment	1	3	1	4
18	Cost and time overrun	3	4	3	5
19	Loss of fertile land/ flora and fauna	2	4	2	4
20	Resettlement and rehabilitation	2	3	3	4
21	Interpretation of requirements of client	1	3	1	2
22	Frequent changes in Govt. policy	1	2	1	2
23	Use of proper earthing for electrically operated machines and connected through ELCB	2	2	2	3
24	Proper stacking and storing of combustible materials	2	4	2	4
25	Effectiveness of warning devices in case of force majeure events	2	3	1	4

Table 3. Calculation of Risk Factors for the Projects Under Study

Q.No	Thermal Project					Hydel Project				
	Occurrence	Score *(P)*	Impact	Score *(C)*	Risk Factor (*P+C-P*C*)	Occurrence	Score *(P)*	Impact	Score *(C)*	Risk Factor (*P+C-P*C*)
1	2	0.4	4	0.8	0.88	1	0.2	4	0.8	0.84
2	1	0.2	4	0.8	0.84	1	0.2	4	0.8	0.84
3	2	0.4	3	0.6	0.76	3	0.6	4	0.8	0.92
4	1	0.2	2	0.4	0.52	2	0.4	2	0.4	0.64
5	2	0.4	3	0.6	0.76	1	0.2	3	0.6	0.68
6	2	0.4	4	0.8	0.88	1	0.2	4	0.8	0.84
7	1	0.2	2	0.4	0.52	2	0.4	4	0.8	0.88
8	1	0.2	3	0.6	0.68	2	0.4	3	0.6	0.76
9	2	0.4	3	0.6	0.76	3	0.6	4	0.8	0.92
10	1	0.2	2	0.4	0.52	1	0.2	2	0.4	0.52
11	1	0.2	3	0.6	0.68	3	0.6	3	0.6	0.84
12	1	0.2	4	0.8	0.84	1	0.2	3	0.6	0.68
13	2	0.4	3	0.6	0.76	2	0.4	3	0.6	0.76
14	3	0.6	3	0.6	0.84	4	0.8	4	0.8	0.96
15	2	0.4	3	0.6	0.76	1	0.2	3	0.6	0.68
16	1	0.2	2	0.4	0.52	1	0.2	1	0.2	0.36
17	1	0.2	3	0.6	0.68	1	0.2	4	0.8	0.84
18	3	0.6	4	0.8	0.92	4	0.8	4	0.8	0.96
19	2	0.4	4	0.8	0.88	2	0.4	4	0.8	0.68
20	2	0.4	3	0.6	0.76	3	0.6	4	0.8	0.92
21	1	0.2	3	0.6	0.68	1	0.2	2	0.4	0.52
22	1	0.2	2	0.4	0.52	1	0.2	2	0.4	0.52
23	2	0.4	2	0.4	0.64	2	0.4	3	0.6	0.76
24	2	0.4	4	0.8	0.88	2	0.4	4	0.8	0.88
25	2	0.4	3	0.6	0.88	1	0.2	4	0.8	0.84

Table 4. Risk Priority

Risk Priority	Risk factor	Thermal Project (Question Nos)	Risk Priority	Risk factor	Hydel Project (Question Nos)
1	0.92	18	1	0.96	14,18
2	0.88	1,6,19,24,25	2	0.92	3,9,20
3	0.84	2,12,14	3	0.88	7,24
4	0.76	3,5,9,13.15,20	4	0.84	1,2,6,11,17
5	0.68	8,11,17,21	5	0.76	8,13,23
6	0.64	23	6	0.68	5,12,15,19
7	0.52	4,7,16,10,22	7	0.64	4
8	--	--	8	0.52	10,21,22
9	--	--	9	0.36	16

Table 5. Mean and Standard Deviation of Risk Factors

Parameter	Thermal Project	Hydel Project
Mean	0.73	0.76
Standard Deviation	0.637	0.768
Coefficient of Variation	0.872	1.00

Table 6. Categories of Risks

Project	Catastrophic	Critical	Medium	Marginal	Insignificant
Thermal	1	2,3 &4	5 & 6	7	---
Hydel	1 &2	3, 4 &5	6 &7	8	9

which were selected for the study are located in Andhra Pradesh, and the project sites are located where the accessibility is poor. Moreover, the locations are a stronghold of the Naxals, and inspite of the threat by the Naxals, the project authorities decided to go ahead with the projects, considering their contribution to the overall improvement of the underdeveloped regions. Twenty five (25) questions covering all aspects - from the gestation stage to the operational stage were formulated and sent to 100 respondents, and 30 responses were received. The time period of the study was between January - March 2013 in united Andhra Pradesh. The response rate was low as there was unrest in the projects owing to the land acquisition problem, and hence, the authorities were involved in solving this burning problem, and the same was given top priority.

The questions framed are furnished in the Table 2. The respondents were asked to give their opinions on a scale ranging from 1 *(rare)* to 5 *(highly probable)* for the probability of occurrence; and from 1 *(insignificant)* to 5 *(catastrophic)* for the consequences of the impact. These scores were then converted from scale 1 to 5 to scale 0 to 1 by dividing the numerical score assigned by the respondent by 5 (highest score). Scores obtained on the scale of 0 to 1 for probability and occurrence and consequence of impact were used to calculate the risk factor. These calculations are depicted in the Table 3.

Results

The risk priority (Table 4) gives an idea as to the importance that is to be assigned to the risk. For example, the first priority is to be given to the cost and time overrun in the thermal and hydel projects, and also to the dispute settlement mechanism in case of the hydel project.

Based on risk priority, risks are classified as follows for thermal and hydel projects (number refers to the relevant question). The nature of the risks varies from project to project. For example, in case of the thermal project, the risk factor for Resettlement and Rehabilitation is 0.76 (0.4 + 0.6 - (0.6*0.4)) ; whereas, the same for the hydel project is 0.92 (0.6 + 0.8 - (0.6*0.8)) as per the formula given in the model $P + C - P*C$

Land acquisition and geological problems are given second priority in the hydel project ; whereas, getting clearances, faulty design, proper stacking of combustible materials, and effectiveness of warning devices receive second priority in the thermal project ; thereby implying that the priorities are different in each project. In this way, each project has its own risk priorities.

The mean risk factor was arrived at by adding the risk factor of all parameters and dividing the same by 25. The standard deviation was arrived at by using the formula $\sqrt{((x\text{- mean risk factor})^2/ n)}$, where x is the risk factor for each parameter and n is 25.

Findings

- Against each questionnaire, the risk factor in a thermal project is less than what it is in a hydel project.
- The mean, standard deviation, and coefficient of variation of risk factor of a hydel project is more than that of a thermal project, implying that hydel projects are subjected to greater risks than thermal projects (Table 5).
- It can be clearly inferred from the Table 6 that risks under critical and medium category were the same in both the projects.
- It is concluded that knowledge of significant risk variables provides valuable information to all stakeholders involved in the construction of such projects regarding the risk factors involved in each and every parameter, and attention can be focused upon those aspects which may lead to better planning of the projects. Such studies are useful for the managements of organizations undertaking such projects as the same gives a deep insight in deciding the nature of risks and treatment/remedies of the same which are of critical/ serious nature.

Limitations of the Study and Scope for Further Research

The study is confined to a thermal power and hydel power plant of the same state where topography and geographical conditions are not very different. Had the projects been undertaken in different states, the outcome would have been completely different, as risk priorities would have changed. The study was conducted when there was unrest in the both the projects regarding the issue of land acquisition and hence, there was a poor response to the questionnaires. The figures might have undergone a change had the response been fairly good.

The same parameters could be utilized by future researchers for performing an assessment of those risks which are of critical/catastrophic nature for determining the amount of contingency to be inserted in the estimate so that the risks can be controlled.

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