COST OVERRUN ASSESSMENT FOR GREEN CONSTRUCTION PROJECT

C. S. Arun*, Lakshmi Narayanan, Ashish Gaurav and Neethu Krishna
Department of Civil Engineering, National Institute of Technology Calicut, India

ABSTRACT

Green construction projects are initiated in complex and dynamic environments resulting in circumstances of high uncertainty and risk, which are compounded by demanding cost and time constraints. This paper describes a systematic way to consider and quantify uncertainty in green construction process based on LEED rating system adopted by Indian Green Building Council (IGBC). The system incorporates knowledge and experience acquired from many experts, project-specific information, decision analysis techniques, and a simulation model to predict risks for different green ratings in the construction schedule at the initiation of a project. The model provides sensitivity analyses for different outcomes wherein the effect of critical and significant risk factors can be evaluated. The study focuses on lessons learned from past projects and describes a risk assessment process involving typical inputs and expected outputs. The paper also investigates practical applications of risk management in green construction industry.

Keywords: *Uncertainty, Risk, Cost, Green Construction.*

1. INTRODUCTION

A 1992 worldwide survey reported that the majority of construction projects fail to achieve the objectives of the schedule (Cooper, 1994). For many projects schedule overrun analysis was not seem adequate at the beginning of the project. However schedule targets are vanished because of unforeseen events that even experienced construction managers could not anticipate. However, schedule target dates are more often missed because of events, such as design problems and industrial disputes, that were predictable but their likelihood and effects are difficult to predict with any precision because no two construction projects are the same (Thompson and Perry, 1992).

A survey by Laufer *et al.* (1992) of forty U.S. construction managers and owners indicated that for scope and design objectives only 35% of the projects considered had low uncertainty and the remaining 65% had medium to very high uncertainty at the beginning of construction. The costs of the projects averaged $5,000,000 which confirmed another report by Laufer and Howell (1993). It also concluded that approximately 80% of projects at beginning of construction possessed a high level of uncertainty.

The aim of green construction is primarily to minimise demand on non renewable resources and maximise utilisation efficiency of resources when in use. Secondly it aims at maximising reuse and recycling of available resources, and improving indoor environment quality thereby aiming to lower the operational and maintenance cost. The challenge of a green building is to achieve all its benefits at an affordable cost.

The amount of uncertainty in internal and external environments of a green construction project is an important factor in determining the likelihood of schedule overrun. However, attempting to consider realistically the uncertainty in construction schedules poses three challenges. The first challenge is that systems are not endorsed professionally or available commercially such that it can be used to structure project uncertainty and measure the effects on the project schedule. The second challenge is lack of easily accessible information and documentation of experience of construction industry or the knowledge scattered within a corporation. The third challenge is difficult motivating involvement of senior project management team to address adequately schedule risks. Project teams generally are too preoccupied with solving current problems involved with getting work done and therefore have insufficient time to think about, much less time to carry out, a formal risk assessment program (Oglesby *et al.*, 1989).

* Corresponding Author: E-mail- arun@nitc.ac.in

This paper explores all the important risk factors contributing to cost and time overrun and identifying the critical elements in green construction sector so that appropriate mitigation measures can be devised. The study also provides new insights about the variation of cost and time overrun by establishing distribution curves based on the field data.

The study envisages analysis at three levels primarily the planning, execution, and the closing down phases in green construction process with respect to the primary data obtained from professionals through questionnaires and personal interviews. The indicators obtained from the above analysis are further scrutinised and analysed with the aid of secondary data and by which general solutions and observations are formulated. This study will pave way for further research in risk assessment, cost and time overruns in green construction industry.

2. PROBLEM STATEMENT

Various attempts have been made to understand the present status of the green construction industry. This has thrown light on lack of exploration of various cost management strategies, tools and techniques adopted in green construction process, apart from certain case studies highlighting various problems associated with the lack of efficient risk management leading to time and cost overruns.

During the study, 34 factors were identified and analysed for assessment of potential overruns associated with duration and cost in the green construction industry. The status of cost and time overruns in green construction industry is untouched, and this study offers an insight into identification of risk for project time and cost overruns in green construction sector.

3. RISK IDENTIFICATION

A perusal of the guidelines on green rating systems included Leadership in Energy and Environmental Design (LEED) India – CS & Green Rating for Integrated Habitat Assessment. Expert opinions from LEED professionals and other green experts utilised to identify a number of time and cost overrun causes in the green construction industry scenario. In India 80 green projects are registered under LEED of which only 28 have been completed. Five experts from different parts of India, who had more than ten five years experience as Project Manager for green building construction project presented the opinion of the factors affecting the overrun. Three iteration of the expert opinion in Delphi methodology, thirty four (34) factors were finalised to be made part of the survey questionnaire.

Three types of questionnaires were prepared based on the guidelines prescribed by LEED INDIA-CS & GRIHA. In this study the three main aspects taken into account are: (i) Planning Stage, (ii) Construction Stage, and (iii) Closing down Stage.

A survey was conducted through internet, postal mail and personal interviews in which respondents were asked to rank and score these factors according to their experience along with the cost overruns during the projects they had undertaken. Twenty five (25) construction firms were approached for these surveys out of which seventeen (17) responses were received with the response rate of 68%.

4. COST OVERRUN FACTOR ANALYSIS

In totality 34 risk factors were identified and the respondents ranked them for duration and cost overruns. The risks are qualitatively those that have both the highest impact on the project and are most likely to occur. Here the impact, probability, and severity (criticality) of each risk factor were quantified into zones in the probability-impact matrix (Graves, 2000).

The risks associated with the construction industry were extensively analysed using factor analysis with multiple regression models, ANOVA and T-tests (Sundarajulu *et al.*, 2007). The values used for probability and impact are indices that represent combined effect of the risks. The quantitative assessment is based on the mean values which was proposed by Sundarajulu *et al.*, 2007 This study incorporates nonnumeric probability scale (a three-level scale), where, 1=Low Probability, 2=Intermediate Probability, 3=High Probability, and impact is measured as deviation in project schedule, which is also represented on a nonnumeric scale of 1-3 where, 1=Low Impact, 2=Intermediate Impact, 3=High Impact which is presented in Table 1. The impact on the project schedule was measured for the schedule project delay on a scale of 1-3 (Graves, 2000).

Table 1: Rating Risk Impact on a Three-Level Scale

Scale	**1**	**2**	**3**
Risk Impact	Less Delay	Some Delay	Delay
Risk on schedule of project	Overall project delay<5%	Overall project delay<5-25%	Overall project delay>25%

In conjunction with this, a list of 34 risk factors was provided to the respondents to rank and score them according to the severity on the scale of 1 to 10 and they were instructed to rate score 1 to the factors which they find least contributing towards the time and cost overrun and a score of 10 to those factors they regard as most significant towards generating project time and cost overruns, and rating of in between to mark the severity of factor ranging from low to high.

Impact of each factor is calculated by

$$impact = \frac{\sum f_i \times i}{n} \qquad \text{(Eq: 01)}$$

Where:

i –the severity score from 1 to 10
f_i -the frequency of factor getting score i
n –number of responses

Figure 1 indicates the resultant impact ranking of the time and cost overrun factors as depicted by the survey analysis, impact ranges were divided into three regions, range of 0 to 2.5 (on severity impact axis) is neglected from the analysis due its insignificance and ranges are developed for severity impact as low, medium and high.

Low severity range (with impact score of 2.5 to 5), medium severity range (impact score of 5 to 7.5) and high severity range (ranges from 7.5 to 10).Results represents that very few (3) factors were rated as low severe, majority of the scores lies in the high medium severity**.**

5. HIGH SEVERITY RISK COST OVERRUN DISTRIBUTION

The cost overrun data obtained from the questionnaire survey was plotted to obtain the cost overrun probability distribution for high severity risks. It was established that high severity risk for a green construction projects follows Weibull distribution and the results are presented in Figure 2. Probability-Probability (P-P) graphs were plotted for the distribution of the input data (Pi) vs. the distribution of the result (F(xi)). Also Quantile-Quantile (Q-Q) graphs were plotted for percentile values of the input distribution (xi) vs. percentile values of the result (F-1(Pi)). Since the plots were nearly linear, the fit is "good".

6. MEDIUM SEVERITY RISK COST OVERRUN DISTRIBUTION

The cost overrun data obtained from the questionnaire survey was plotted to obtain the cost overrun probability distribution for medium severity risks. It was established that high severity risk for a green construction projects follows Log Logistic distribution and the results are shown in Figure 3.

Probability-Probability (P-P) graphs were plotted for the distribution of the input data (Pi) vs. the distribution of the result (F(xi)). Also Quantile-Quantile (Q-Q) graphs were plotted for percentile values of the input distribution (xi) vs. percentile values of the result (F-1(Pi)). Since the plots were nearly linear, the fit is "good".

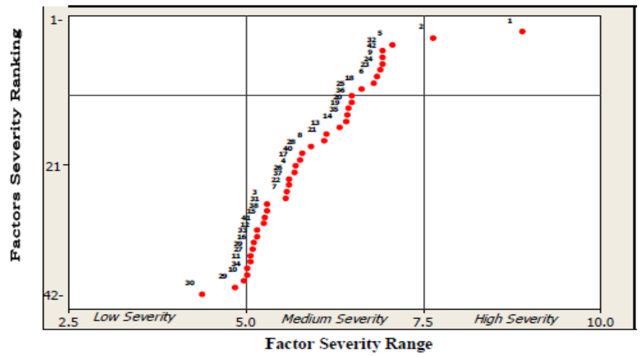

Figure 1: Severity Analysis

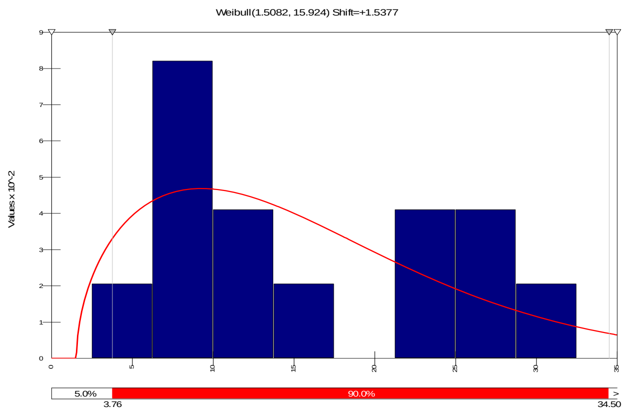

Figure 2: Weibull Distribution for High Severity Risk for Green Construction Projects

7. TIME OVERRUN DISTRIBUTION

The time overrun data obtained from the questionnaire survey was plotted to obtain the time overrun probability distribution for green construction projects. It was established that high severity risk for a green construction projects follows Beta distribution and the results are indicated in Figure 4. Probability-Probability (P-P) graphs were plotted for the distribution of the input data (Pi) vs. the distribution of the result (F(xi)). Also Quantile-Quantile (Q-Q) graphs were plotted for percentile values of the input distribution (xi) vs. percentile values of the result (F-1(Pi)). Since the plots were nearly linear, the fit is "good".

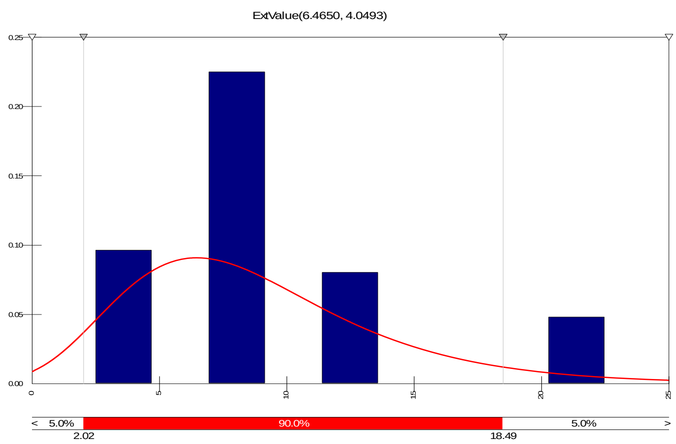

Figure 3: Medium Severity Risk follows Log-Logistic Distribution

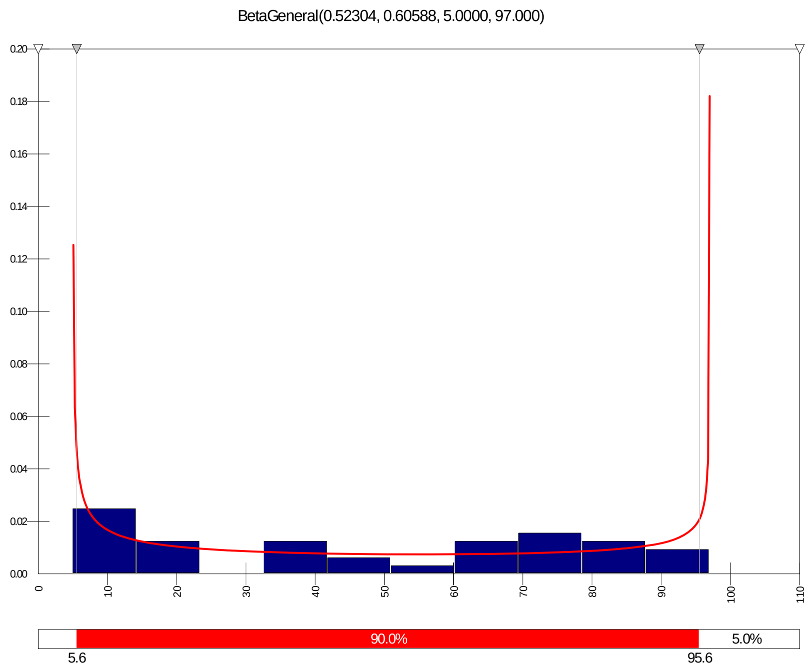

Figure 4: Time Overrun-Beta Distribution

8. SIMULATION FOR RISK PREDICTION

In this study, range for random variable for each of the factors was identified based on the probability distribution curves developed from the primary survey. Cumulative probability of occurrence of each risk is calculated based on the response received in the survey. A random number generated is linked to a risk based on the class intervals decided by the cumulative probability obtained from survey.

Monte Carlo Simulation was used as an effective tool for risk prediction. Simulation runs of 1000, 10000, 50000 and 100000 were tabulated to predict the risks identified using survey response. All the inputs were taken from green experts to take the process more close to the real world. Simulation was carried out varying the number of runs to determine any converging trend in the overruns associated with cost and duration for various types of rating according to LEED INDIA CS. The results based on this simulation analysis are presented in Table 2. The result based on the simulation model indicates that minimum credits that are required for each type of rating with most likely overrun with respect to cost and duration. It is evident from the study that the duration overrun associated with the project targeting Platinum rating is comparatively lesser than the Silver rating while the cost overrun associated with a Platinum rated green building is more in comparison with silver rated building. This is due to the fact that the execution of various activities associated with the Platinum rated building is carried out with an efficient technology and advanced materials. However there is only a marginal variation when Platinum rated building is compared with the Gold rated construction. This is due to the fact that the variation in credit requirement is minimal in between the two certifications. However a large overrun is observed in the case of Green Certified building compared to the higher rating even though the credit requirement according to LEED NC is lowest for this group. This is due to higher degree of randomness associated with this type of construction. It was observed during the simulation study that as the higher rating system is target for a building, the randomness associated with various parameters is reduced.

Table 2: Simulation Results

Type of Certification		100 runs	1000runs	10,000runs	50,000runs
Platinum Rated Green Building	Total Credits	59	59	59	60
	Duration Overrun (%)	13.42	7.84	12.04	11.43
	Cost Overrun (%)	23.96	13.99	21.49	20.40
Gold Rated Green Building	Total Credits	44	48	46	48
	Duration Overrun (%)	11.53	18.19	16.19	67.09
	Cost Overrun (%)	10.65	4.78	12.06	23.34
Silver Rated Green Building	Total Credits	38	33	34	33
	Duration Overrun (%)	1.75	27.94	39.60	89.02
	Cost Overrun (%)	2.45	10.96	13.23	12.43
Certified Green Building	Total Credits	32	31	30	31
	Duration Overrun (%)	10.45	98.56	93.95	15.99
	Cost Overrun (%)	17.89	17.57	16.76	89.76

Based on the analysis the risks identified are ranked according to the likelihood of occurrence and impact on the project which is targeting various rating. The various intends required for the green rating is rated based on the cost impact and duration impact from lower value to higher value on the project based on the simulation study. The results obtained in this study presented in Table 3 indicates for obtaining any rating, the reduction in site disturbance has the lowest impact on the project with respect to cost and duration while the next higher impact is for the factor site selection amongst various factors that need to be considered in Sustainable sites.

9. CONCLUSIONS

The study was carried out based on various green building construction projects in India and abroad. However emphasis was given in developing a risk modelling tool that can predict the overrun associated with duration and cost of Green Building. The survey results indicated that the majority of cost overrun factors (89%) lie in medium severity impact range. However these factors need to be attended as they tend to increase in the cost of the project compared to the initial estimation. Even though the likelihood of cost overrun for construction projects targeting green rating is high, minimum range of cost overrun in percentage of the estimated cost is found to be 8%. The cost overrun for high severity risks occurring in green construction sector was found to follow Weibull Distribution. Similarly, cost overrun for medium severity risks in green construction industry was found to follow a Log- Logistic distribution. Time overrun in green construction industry was found to follow Beta distribution. The highest risks were associated with Reduced Site Disturbance, Innovative Waste Water Technologies, Renewable Energy, Construction Waste Management, Indoor Chemical and Pollutant Source Control, LEED^{TM} Accredited Professional. Care and proper mitigation measures should therefore be taken while including the factors with lower rank in risk factors.

Table 3: Risk Ranking for Different Green Ratings of the Building

		Credits	Certified	Silver	Gold	Platinum
Sustainable Sites	Reduced Site Disturbance	1	1	1	1	1
	Site Selection	1	2	2	2	2
	Alternative Transportation	1-3	3	4	3	3
	Storm water Design, Quantity Control	1	4	3	4	4
	Development Density & Community Connectivity	1	5	5	5	5
	Brownfield Redevelopment	1	6	6	6	6
	Heat Island Effect, Roof	1	8	8	8	8
Water Efficiency	Water Efficiency	1-2	2	2	2	2
	Water Efficiency in Air-conditioning System	1	4	4	3	3
	Innovative Waste Water Technologies	1	1	1	1	1
	Water Use Reduction	1-2	3	3	4	4
Energy and Atmosphere	Optimize Energy Performance	1-10	5	5	1	5
	Renewable Energy	1-3	1	1	2	1
	Additional Commissioning	1	2	2	3	2
	Ozone Depletion	1	3	3	4	3
	Measurement and Verification	1	4	4	5	4
Materials and Resources	Building Reuse	1-3	4	4	6	4
	Construction Waste Management	1-2	1	1	4	1
	Resource Reuse	1-2	2	2	1	2
	Recycled Content	1-2	6	6	2	6
	Local / Regional Materials	1-2	3	3	3	3
	Rapidly Renewable Materials	1	5	5	5	5
	Certified Wood	1	7	7	7	7
Indoor Environmental Quality	Outdoor Air Delivery Monitoring	1	3	3	3	3
	Increased Ventilation	1	4	4	4	4
	Construction IAQ Management Plan	1-2	5	5	5	5
	Low-Emitting Materials	1-4	6	6	6	6
	Indoor Chemical and Pollutant Source Control	1	1	1	1	1
	Controllability of Systems	1-2	7	7	7	7
	Thermal Comfort, Design	1	8	8	8	8
	Thermal Comfort, Verification	1	9	9	9	9
	Daylight and Views	1-2	2	2	2	2
Innovation in Design	Innovation in Design	1-4	2	2	2	2
	LEED^{TM} Accredited Professional	1	1	1	1	1

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