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Risk Analysis of Construction Project Scheduling Using Monte-Carlo Simulation

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ABSTRACT: Construction Industry is one of the booming industries of today that has a great impact on the economy of any nation. Large and complex construction projects always confront with risk, thus risk should be considered in determining construction project duration. Large construction projects if delayed can cause increase overall cost of the project. Hence risks and uncertainties must be considered for overall duration of the project. To organize and complete the projects in a timely, quality and financially responsible manner, it is need to schedule projects carefully. Effective project scheduling plays a crucial role in ensuring project success. This study focuses on risk identification, qualitative analysis and quantitative analysis. The objectives are to identify the key risk factors that affect the project schedule, and to determine the probability of completing the project within due date. Qualitative analysis is done by probability impact (PI) matrix and quantitative analysis is done by PERT and Monte Carlo simulation. A schedule risk analysis is performed using Monte Caro Simulation with crystal ball software.

KEYWORDS: PERT, Monte Carlo simulation, PI matrix

I. INTRODUCTION

A schedule may also involve the completion of the project with which the public has no interaction public prior to its completion. In project management, a formal schedule will often be created as an initial step in carrying out a specific project, such as the construction of a building, development of a product, or launch of a program. Establishing a project management schedule involves listing milestones, activities, and deliverables with intended start and finish dates, of which the scheduling of employees may be an element. A production process schedule is used for the planning of the production or the operation, while a resource schedule aids in the logistical planning for sharing resources among several entities.

Any construction project is expected to be completed within certain period of time. And if the project gets delayed it results in increase in cost of the project and contractor may have to face penalty for causing delay. Hence it is very important for both owner and contractor to follow project schedule.

Scheduling is an important part of the construction project management. Planning and scheduling of construction activities helps engineers to complete the project in time and within the budget. But construction activities possess uncertainties that may cause delay in performing certain activities or even increase in cost of the project. Hence it is Very important to develop a risk management process which deals with the risks in execution that affects the project schedule.

This study on risk management in construction schedule aims to identify key factors that causes delay in completion of certain activity, which if not attended may occur again and cause difficulties in completion of project and provide solution against those risk factors.

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Risk

Risk can be defined as an uncertain event or condition that when occurs affects one or more objectives of the project such as scope, time, cost, objective. Risk may have one or more causes and if it occurs it may have one or more impacts (PMBOK guide 6th edition). (Smith et al ,1999) defined following parameters that are associated with risk,

- Higher costs.
- Extension of the project.
- Failure to satisfy specified quality requirements.
- Failure to satisfy specified information requirements.
- Failure to satisfy specified organizational requirements.

Dynamic risks are the risks where risk takers are concerned about making opportunities. Dynamic risk means that there will be potential gains as well as losses. Dynamic risk is risking the loss of something certain for gain of something uncertain.

Static risks are the risks where people are concerned with potential losses and ways to minimize the losses. The unsystematic management of risks can affect the scope and success of the project since most risks are very dynamic throughout the project lifetime. (Flanagan & Norman, 1993)

Risk management(RM) can be defined as a process which helps us to control the arising risk at any point in the project without affecting time, cost, duration and scope of the project. Risk management is the identification, assessment, and prioritization of risks (ISO 31000). Risk management provides support to attain a better control over project scheduling, estimation, quality. This is because risk management gives us beforehand ideas about future events or outcomes that may occur so that decisions can be made as early as possible to avoid delay in the project.

Efficiency of risk management can be magnified by continuously developing RM process throughout the project. By this way risks will be identified and managed throughout project. The benefits from RM are not only reserved for the project itself, but also for the actors involved. The main incentives are clear understanding and awareness of potential risks in the project. Another benefit of risk management is increased level of control over the project and efficient problem solving. (Gajewska et al ,2011)

Although risk management is very efficient process there are limits in using RM process. The level of the risks are always bigger in bigger projects. Several other factors can stimulate risk occurrence. Even if all the potential risks are identified there may be several other risk that can occur during the project. Hence the project management team should not only focus on identified risks but also be alert for new risks that may occur.

According to (Flanagan & Norman, 1993) Risk management process consists of following components,

Risk identification- Identify the source and type of risks.

Risk classification- Consider the type of risk and its effect on the person or an organization.

Risk analysis- Evaluate the consequences associated with the type of risk or combination of risks by using analytical techniques.

Risk attitude- Any decision about risk will be affected by the attitude of the person or organization making the decision

Risk response- Consider how the risk should be managed by either transferring it to another party or retaining it.

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II. LITERATURE REVIEW

1. **“Risk Analysis of construction project scheduling using PERT and Monte Carlo Simulation: A case study on NIOSH campus” Nurazrin Jupri, Muhammad Rozi Malim, International Journal of Accounting and Business Management, April 2013.**

Large and complex construction projects always confront with uncertainties, thus risk and uncertainties should be considered in determine construction duration. The construction of NIOSH Campus was behind schedule and would not be completed on time. The main problem that delayed the project was the Pump house. This study focuses on three elements of risk management; risk identification, qualitative risk analysis, and quantitative risk analysis. The objectives are to identify the key risk factors that affect the project schedule, and to determine the probability of completing the project within due date. Structured interview, questionnaire, and simulation were used in collecting and analyzing the data. The findings indicate that the two main sources of risks are “approval and permits”, and “labor shortage” throughout the construction of the Pump House. Also, there is a very low probability that the Pump House will be completed on time.

2. **“Construction Building Schedule Risk Analysis Using Monte-carlo Simulation” Pratik Ganame, Pravin Chaudhari, International Research Journal of Engineering and Technology, July-2015.**

This study focuses on risk identification, qualitative analysis and quantitative analysis. The objectives are to identify the key risk factors that affect the project schedule, and to determine the probability of completing the project within due date. Questionnaire forms were distributed among 31 industry practitioners with varying experience from 1 year to 17 years. Qualitative analysis is done by probability impact (PI) matrix. And quantitative analysis is done by PERT and Monte Carlo simulation. @RISK by Palisade corp. is used for Monte Carlo simulation. For the probability of completing the Hostel building within the due date, the simulation using @RISK software had shown that there is zero probability for the project to be completed within 282 days (most likely duration). This shows that the due date based on most likely durations that had been used by the construction management team was not significant in an uncertainty environment; it is unlikely to be achieved. The uncertainties lead the project management to risks and problems. The construction schedule should be revised regularly, and the changes of due date may occur repeatedly.

3. **“Risk Assessment in construction project in and around Chennai during pre construction period”, P.Dayakar, P.Manju, International Journal of Biotech Trends and Technology-Vol2, June 2012.**

When a construction project is initiated lot of uncertainty and risk is expected before the completion of the project. Due to demand and technology the construction industry has changed significantly over the past several years. Any construction project is vulnerable to the several technical and management risks that often represent greater exposures than those that are traditional. To overcome these risks the risk assessment is needed. In this study a questionnaire survey is made by personnel meeting. Statistical package for social science is used to analyze the questionnaire. From the analysis it is concluded the need to pay more attention on market risk and financial risk is required when compared to other risks.

4. **“Risk Assessment of Plan Schedule by Monte Carlo Simulation”,Zhaoni Kong, Jianping Zhang, International Conference on Information Technology and Management Innovation (2015).**

In this paper, a practical example, construction and installation engineering in cargo area of Kunming Changshui international airport project is studied to show explicitly the benefits of using Monte Carlo simulation to assess risk in practical scheduling.

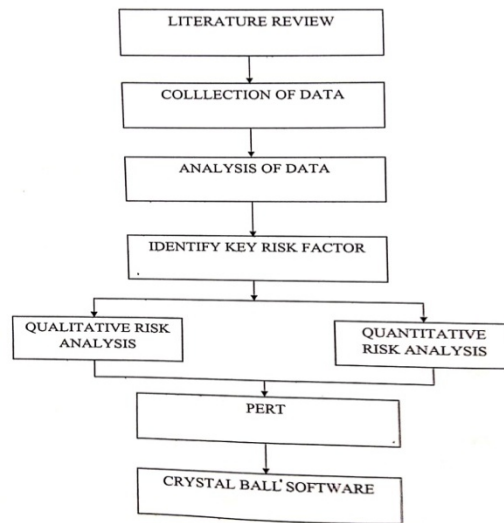
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III. METHODOLOGY



1. Risk identification:

Risk identification Level in characteristics (Flanagan & Norman, 1993) was followed for risk identification at the site. A team of experts were formed including both contractor's and owner's site engineers, sub-contractor. And few workers were interviewed.

2. Risk classification:

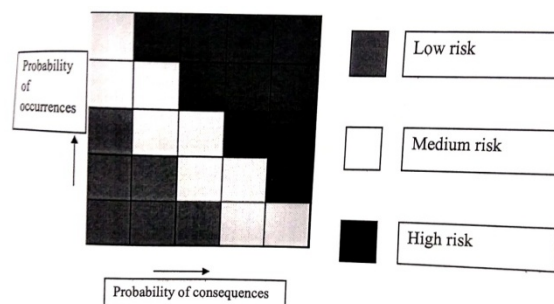
After the risks were identified and listed out along with their possible effects, they were further classified on the basis of their source and effect on project.

3. Qualitative Risk analysis:

Here probability assessment means likelihood of occurrence of a risk and impact assessment deals with impact of the particular risk on project objective such as time, cost, scope. For performing probability-impact analysis, identified risk were listed along with its effect on project in a tabular form. Team of respondents was formed including site engineers from both owner and contractor's side and few members of signing authority. They were asked to grade identified risks in terms of probability and impact by grading them from 1 to 5.

Following diagram represents intensity of risk according the grading system

Table 1: RISK MATRIX



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Table-2: Pessimistic and optimistic duration

Risk type	Estimation duration	
	Optimistic	Pessimistic
Low risk	-5%	+20%
Medium risk	-15%	+50%
High risk	-20%	+100%

Next, a schedule risk analysis is performed using Monte Carlo simulation with @Risk software. Firstly all the three durations (optimistic, most likely and pessimistic) are entered in the software. Then probability distribution is assessed (uniform, triangular, normal or other). Generally triangular distribution is preferred when data submitted is judgmental in nature. Ten thousand iterations had to be performed to predict the completion time.

4. Quantitative analysis:

A network diagram for the hostel building is constructed using the estimated durations of the activities. The expected duration for each activity is estimated using three-point estimation; optimistic, most likely, and pessimistic. The estimated duration for each activity depends on the types of risks.

IV. RESULT AND DISCUSSION

Qualitative analysis is used to prioritise risks according to their severity so that the risks can be further subjected to quantitative analysis.. After calculation of optimistic and pessimistic time, all the three durations are inserted in software. An output is defined and beta simulation is run at 10000 iterations.

Key risk factor of the project

No	Source of risk	Earthwork and Foundation	Shuttering and plinth beam	RCC and steel work	Electrical services
1	Heavy Rain	✓	✓	✓	
2	Approval permit	✓	✓		
3	Delayed payment		✓	✓	
4	Financial risk		✓		
5	Labor skill deficiency		✓	✓	✓
6	Safety issues			✓	✓

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7	Improper estimation	✓		✓	
8	Equipment Failure			✓	

The commercial building project having the high risk factors containing activity are shuttering ,plinth beam, RCC work, steel work and the medium risk factors containing the activity are earth work, foundation, electrical services.

Sl.no	Task name	To	Tm	Tp	simulated time
1	Drawing issuance up to FF slab	6	7	11	7.5
2	Mobilization time	13	15	23	16
3	Earth work phase 1	21	25	38	26.5
4	PCC work P1	20	25	50	28.33333
5	Steel work P1	24	30	60	34
6	RCC for Foundation in P1	38	45	68	47.66667
7	RCC pedestal work	36	45	90	51
8	Shuttering for P1 plinth beam	20	25	50	28.33333
9	Steel for PB for P1	20	25	50	28.33333
10	RCC for PB in P1	24	30	60	34
11	RCC column P1	24	30	60	34
12	Shuttering for RCC slab	20	25	50	28.33333
13	Steel for RCC slab span portion 1	20	25	50	28.33333
14	Electrical conduit work portion 1	3	3	5	3.333333
15	RCC slab P1 GF portion 1	2	3	6	3.333333
16	Shuttering for RCC slab (11portion)	20	25	50	28.33333
17	Steel for RCC slab 1 span portion 1	18	22	44	25
18	Electrical conduit work portion 1	4	5	8	5.333333
19	RCC slab P1 GF portion 2	2	3		2.333333
20	Steel work for SF for column	12	15	30	17
21	RCC for column	12	15	30	17
22	Shuttering for SF slab portion 2 GF	24	30	60	34
24	Electrical conduit works	5	6	9	6.333333

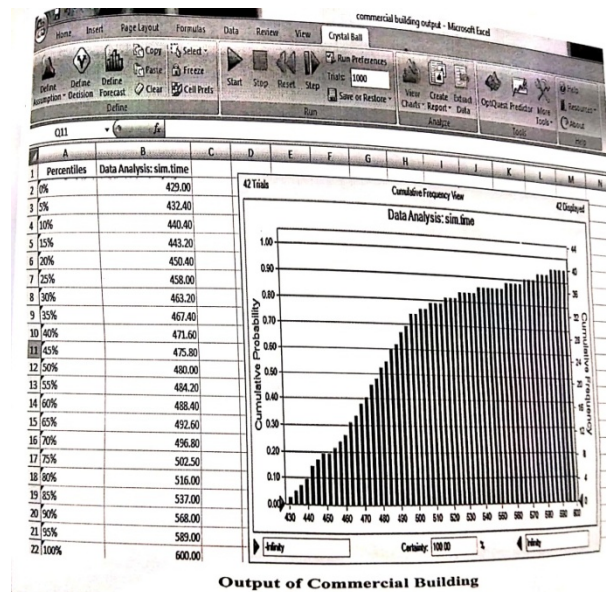
25	RCC slab portion 1 SF p1	2	2	4	2.333333
26	Steel for column SF P1	24	30	60	34
27	RCC column P1 SF portion 1	24	30	60	34
28	Shuttering for RCC slab(first portion)	24	30	60	34
29	Steel for RCC slab1 span portion 1	32	40	80	45.33333
30	Electrical conduit work portion1	2	2	3	2.166667
31	RCC slab P1 SF portion 1	2	3	6	3.333333
32	Earth work phase 2	24	30	60	34
33	PCC work P 2	36	45	90	51
34	Steel work P 2	36	45	90	51
35	RCC for foundation in P 2	32	40	80	45.33333
36	RCC pedestal work P 2	32	40	80	45.33333
37	Shuttering for P 2 plinth beam	32	40	80	45.33333
38	Steel for PB for P2	32	40	80	45.33333
39	RCC for PB in P 2	32	40	80	45.33333
40	RCC column P2	32	40	80	45.33333
41	Shuttering for RCC slab(first portion)	36	45	90	51
42	Steel for RCC slab P1 GF span portion	36	45	90	51
	completion time	429	533	651	599.75

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V. SUMMARY AND REMARKS

Using Monte Carlo simulation with Excel offers a tool that enables also non-statisticians to model and simulate events, activities and outcomes of real life projects. Especially in the area of risk analysis we are fitted out with an extensive instrumentation for analyzing separate and aggregate risk impacts and probabilities. Amongst the major advantages underlined in this paper we count the relative cost-effective availability and spread in virtually every business and household on the globe of the Excel or equivalent software packages. Another advantage is that of overcoming some of the traditional challenges of classic analysis instruments such as PERT assuming unique critical paths, given distributions and independency of the individual activities. As we showed in the two cases, it is very easy to implement given conditions between stochastic events just by using the internal condition functions within Excel. Because all the Microsoft products, like Excel, offer you the opportunity to use VBA-macros, you also have the possibility to create your own special functions, your own menus, or whatever you like, to configure your individual model. This also gives you the opportunity to create libraries with pre-defined functions/macros that makes the use of this technique more efficient. One of these libraries can for example try to handle the problem of correlations in a much wider sense than the one we showed here by using correlated normal distributions. One can consider here to create libraries for the Cholesky decomposition of a given correlation matrix or the more sophisticated approach of Iman and Conover. However, let there also be a message of warning to those that might fall into a “figure trap” and rely heavily on theoretical models and simulations in taking real world decisions. These have to be backed by intuition, common sense and leadership skills. The fabric of the project context is woven in an intricate pattern, many decisions require trade-offs and compromises, and the human influence factor is rarely quantifiable in a figures model. You always have to keep in mind that a mathematical model is always only a model of the reality that handles simplifications and reductions of the real world problem.

VI. CONCLUSION

The uncertainties lead the project management to risks and problems. To avoid delay in construction project the risk and uncertainties were considered while scheduling. The schedule of a four different structure was collected with minimum of twenty five activities. The key risk factors will be identified. The qualitative and quantitative risk analysis

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is completed. Finally determined the probability of completing the project within the agreed period by using crystal ball software.

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