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Risk Analysis in Construction Scheduling

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ABSTRACT: Large and complex construction projects always face uncertainties that lead to risks of delaying the project. Construction projects are of different sizes and of different nature and risk associated with them also vary. Schedules are very essential to the successful execution of projects. Without a schedule, it is difficult to coordinate the various activities found in a construction project. Most schedules are developed in a deterministic manner using Critical Path Method. Unfortunately, construction schedules are affected by various uncertainties. As a result, schedule delays are common in various construction projects. Therefore, it is important to find out probabilities of schedule delays. To evaluate the probability of construction time-overruns and Forecasting of appx. Accurate project completion date is a challenge to construction schedulers. Management of risks and uncertainties in construction projects is possible if risks have been identified and the potential impacts have been analyzed. The Critical Path Method (CPM), which is used to schedule construction activities, is deterministic with regard to the duration assigned to the execution of the activities and the results produced in certain values. Unfortunately, construction activities are performed under uncertain conditions. Project risks cause variations in activity duration, and in turn the entire network is affected by uncertainty. To evaluate construction networks by considering risk factors, nondeterministic scheduling methods such as the program evaluation and review technique (PERT), the probabilistic network evaluation technique (PNET), Critical Chain Scheduling (CCS), and Monte Carlo simulation (MCS) have been developed. In the present work, an attempt is made to study the effect of uncertainties in the project on the total duration of the project in an Indian context. For this, Monte Carlo simulation (MCS) technique is used. Effect of different distributions for different activities and the number of simulations on the total project duration are determined and compared with the CPM and PERT. Finally, sensitivity analysis is carried out to show the influence of each uncertain activity on the total project duration.

Keywords: Risk Management, Risk Analysis, Monte Carlo Simulation.

I. INTRODUCTION

In construction projects, risks play a significant part in decision making and may affect the performance of a project. If they are not dealt with sensibly, they may cause cost overturns, delays on schedule and even in poor quality. Each project has a different level and combination of risks and sites will adopt different strategies to minimize them because the characteristics of projects are unique and dynamic. Risks are very common in construction sector. Risk is the possibility of suffering loss and the impact on the involved parties. Risk is identified and then risk assessment and analysis is done. Then risk management and risk mitigation is carried out. Risk affect construction sector negatively and focusing on risk reduction measure it important. Compared with many other industries, the construction industry is subject to more risks due to the unique features of construction activities, such as long period, complicated processes, abominable environment, financial intensity and dynamic organization structures. Hence, effectively identifying and managing risks is very essential in a construction project as to deal with the risks related with variable construction activities. It has been becomes an important issue in project management as to achieve the successful delivery of a project and the objectives in terms of cost, time, quality, safety.

The success of construction projects is evaluated based on such measures as quality, scopes sufficiency, project functionality, safety requirements, planned completion duration, and budget. In order to realise these success criteria, various activities or tasks are performed throughout a project. Construction activities can be categorised as procurement, design, construction, and managerial, but cannot be standardized with typical norms because each construction project has unique features that differentiate it from even resembling projects. Construction techniques, design, contract types, liabilities, weather, soil conditions, politic-economic environment and many other aspects may be different for every new commitment. This this fuzzy atmosphere has been represented with the terms ‘uncertainty’ or ‘risk’ by construction managers and researchers. Risk is defined as any action or occurrence which will affect the achievement of project objectives. Risks and uncertainties inherent in the construction industry are more than any other industries. Risk is an integral component of any project. Risk is present in all projects irrespective of their size or sector. No project is totally free from risks. If risks are not properly analysed and strategies are not trained to deal with them, the project is likely to lead to failures. In addition to the uniqueness of each project, planning and scheduling become vital procedure for success, especially where target project time and budget are concerned. One important way to handle uncertainty in construction projects is to develop a reliable project estimates and schedules. Forecasting of reliable project completion date presents continuing challenge to construction schedulers. This reliability is dependent upon the accuracy of estimating the individual activity duration. If estimate of the individual activity duration is not accurate, then schedule overrun is unavoidable.

Critical path method is most used method for scheduling activity networks. This is due to its capabilities in showing the precedence relations between activities, exploring the critical activities, providing activity float times, and leading to optimise resource allocation. However, CPM is deterministic in nature because of the single duration values assigned to activities during network analysis, as if these duration values are known certainly and are not changed by various risk factors. all activities can be critical due to uncertainties, even those that are not critical according to deterministic Critical Path Method (CPM). This limitation may lead to imprecise critical path identification and completion time measurement.

In order to evaluate construction networks by considering risk factors, nondeterministic scheduling methods such as the program evaluation and review technique (PERT), the probabilistic network evaluation technique (PNET), Critical Chain Scheduling (CCS) and Monte Carlo Simulation (MCS) have been developed. These methods can be considered as schedule risk analysis tools to be used within risk management systems. Risk management is defined as a systematic controlling procedure for predicted risks to be faced in an investment or a project. It is a stepwise procedure consisting of risk identification, risk classification, risk analysis, and risk response tasks.

In the present work, an attempt is made to study the effect of uncertainties in the project on the total duration of the project. For this, Monte Carlo Simulation technique is adopted. Effect of different distributions for different activities and the number of simulations on the total project duration are determined and compared with the CPM and PERT methods. Finally, sensitivity analysis is carried out to show the influence of each uncertain activity on the total project duration.

II. OBJECTIVE

1. To find out the project completion time predictions given by the Monte Carlo Simulation (MCS) technique.
2. To determine the effect of different distributions for different activities and the number of simulations on the total project duration.
3. To study the effect of uncertainties in the project on the total duration of project.

III. UNCERTAINTIES IN ACTIVITY DURATION ESTIMATE

The project management body of knowledge identifies risk management as a key area; It includes the processes concerned with identifying, analysing, and responding to project risk. It includes maximizing the results of positive events and minimising the consequences of adverse events. Central to risk management is the issue of handling uncertainty. In different project management processes there are different aspects of uncertainty. The most obvious area of uncertainty is in estimating duration for a particular activity. This uncertainly arises from one or more shown in table 1.

IV. NETWORK ANALYSIS

To determine or predict the duration for any project it is necessary to program all the activities that make up the project. The most commonly used method in network analysis is the Critical Path Method. Once network is constructed, the network analysis can be carried out. The systematic analysis of a network sorts out critical and noncritical activities. The main goal of network analysis is to find out the Total Project Time. The total project time is the shortest time in which the project can be completed, and this is determined by a sequence of activities known as the critical path.

PERT realise on a formula for combining the estimates of three cases for an activity, namely, an optimistic time, which is considered to be the 'best' time given that all associated factors fall into place. A Pessimistic time, which is the 'worst-case' scenario, with everything going wrong. A most likely duration, which is the 'normal' time for the activity, based upon expert judgement, experience or other factors. The PERT group assumed that these three estimates would fall on a bell-shaped curve but there was no proof available for this assumption. PERT uses the Central Limit Theorem to find the expected project duration. It assumes normally distributed project duration and independent activity duration. it also does not take in to consideration the sub critical path in a network.

Monte Carlo simulation in the analysis of networks is a technique, where in values are sampled at random from the input quality distribution. Each set of samples is called iteration and the resulting outcome from that sample is recorded. Monte Carlo Simulation does this hundreds or thousands of times and the result is probability distribution of possible outcomes.

V. CASE STUDY

The project considered in the present study is the construction of a Residential building, located in Nashik. The project was chosen for a work because of it contains all of the information needed for analysis, such as the dependency of the activities and the estimates of each activity. The project is a twelve storey residential project. It has 192 residential flats. The project commenced in Jan, 2014 and its Planned Project duration is Dec, 2016.

VI. METHODOLOGY

Collect scheduling data

↓

Identify critical path

↓

Identify Various Risk and uncertainties
and their impacts

↓

MCS is carried out for critical activities

↓

Selection of Probability Distribution

↓

Selection of No. Iteration

Sensitivity Analysis

The scheduling data is obtained from the Residential Project. Computer package Primavera P6 is used to identify the critical path. The same computer package is used to schedule the project. For the case study, sub-critical paths are also verified and it is found that, the influence on the total duration of the project is negligible.

Once the critical path is determined, the activities in the critical paths are assumed to be affected by uncertainties. Monte Carlo Simulation is chosen for this purpose.

Monte Carlo Simulation is carried out using the crystal ball simulation computer package. For the purpose, the trial version of the software has been used. Crystal ball is a suite of easy to use Microsoft Excel add-in software that helps to analyse the uncertainties associated with the Spreadsheet models. Crystal ball provides over twenty-one probability distribution functions that allow the specification of nearly any type of uncertainty. It allows any number of iterations in a simulation.

VII. SELECTION OF THE PROBABILITY DISTRIBUTIONS

There are various probability distributions such as Normal, Log-normal, Beta PERT, Triangular and Uniform).In this case, Beta PERT, Triangular and Uniform distributions are used. Beta PERT distribution is used; when it is not possible to meaningful define different distribution to model the duration of the particular activity. When it is required to show a more pessimistic view of the duration, Triangular distribution is used. Uniform distribution is preferred, when it is required to show that the duration of that particular activity had an equal possibility to be any number between a minimum and a maximum value. For most of the activities in the case study, the above mentioned distributions are used. Monte Carlo Simulation is carried out for the above mentioned distributions and the output is shown in table. From the output, it is observe that Beta PERT distribution has the least value of project completion for a given probability (say 0.8) and uniform distribution has the highest value of project completion for the same probability and the same three point estimate. Triangular distribution lies in between to these two distributions. Based on these results, Beta PERT distribution is adopted for the case study.

VIII. SELECTION OF NUMBER OF ITERATIONS

To investigate the effect of different number of iterations on the total duration of the project and to decide the number of iterations to be carried out for the case study , the project duration is simulated with of Beta PERT, Triangular, Uniform distribution for 100, 1000, 10000, number of iterations. From table, it is observed that, As the number of iterations increase, duration at the extreme are varying ,that is in the range of less than 10 % and greater than 90 %. Rest of the part is almost overlapping. It is also observed that as the number of iterations increases; Mean standard error goes on decreasing. And to reduce the sampling error, 10000 iterations are found to be sufficient for the case study.

IX. SENSITIVITY ANALYSIS

The output of the sensitivity analysis, showing the contribution of individual activity on the variance of the total duration of the project. It shows the activities that are more critical. The decision maker may plan his strategy to reduce the uncertainty of the activity and ultimately the total duration.

RESULTS

From Graph 2 (Beta pert), it can be observed that Beta Pert, distribution cumulative curves at 100 iterations show a relatively variable path. From 1000 to 10000 iterations, as the number of iterations increase, the cumulative curves of the simulations tend toward more regular curves. This shows that by increasing the number of iterations, a reduction of the sampling variability can be attained.

From these figures, it can also be seen that the percentile values from 10% to 90% are approximately the same at 1000 and 10000 iterations and only the minimum (less than 10%) and the maximum (greater than 90%) percentile values are different. This fact is irrespective of the type of probability distribution function specified for the activity durations. The project duration range (maximum minus minimum) is increased as the number of simulations increase.

The Triangular, Uniform and Beta distributions are the distributions with a boundary, so the project duration range will converge at certain points (the minimum and maximum values). For example, in Graph 2 (comparison of different iteration for Beta Pert distribution), the minimum percentile value decreases as the number of simulations increases until it converges at 1225 days. In contrast, the maximum percentile value increases as the number of simulations increases until it converges at 1388 days. These results mean that assuming a Beta Pert distribution for the individual activity duration, The consider Residential Construction Project is impossible to complete in 1225 days or less and it can be completed in 1388 days with 100% confidence.

Table's No. 3 (Beta pert distribution with different iteration) give quantitative results and from these it can be seen that the results from 100 iterations are different from 1000 iterations in the same assumed distribution. It can also be observed that in the tables, the results of the overall properties (accept the minimum and the maximum values) and the percentile values at 1000 and 10000 iterations are nearly similar.

These results show that for consider Residential Construction Project analysed, 1000 iterations provide sufficiently accurate results. For a further increase in confidence, results at 10000 iterations are used for further comparison throughout

CONCLUSION

1. Planned Project duration of considered project was 1095 (3 years) days, but forecast duration of project given by MCS is 1388 days (max). There is very less Probability to consider project is completed within planned duration.

2. After a certain number of iterations (1000 iterations for the examples studied), the percentile values from 5% to 95% approximately tend to be similar and increasing the number of iterations only affects the minimum (less than 5%) and the maximum (greater than 95%) percentile values

3. The project duration range (maximum minus minimum) is increased as the number of simulations increase.

4. Monte Carlo simulation method can accommodate the different distribution forms for the duration of individual activities and with large samples it can provide more conservative results.

5. The overall properties of each distribution generated by the Crystal ball package show a characteristic probability distribution for the different distributions. The Crystal ball package executes in a way that correctly generates the random number according to the assigned distributions.

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Table. 1 The project Duration Analysed by PERT

Activities in critical path	Optimistic Duration	Most Likely Duration	Pessimistic Duration	Mean Duration	Variance	Standard Deviation
SOP	0	0	0	0	0	0
Preparation of Plan & Estimate	8	10	15	10.5	1.3611111	1.1666666
Approval of Plan From Local Authority	20	30	45	30.833	17.361111	4.1666667
Clean & Level Site	3	4	6	4.17	0.25	0.5
Taking Electrical Connection	5	7	10	7.1666667	0.6944444	0.8333333
Watchman shed Construction	1	2	3	2	0.1111111	0.3333333
Land Survey By Surveyor	4	5	6	5	0.1111111	0.3333333
Pile Location Marking by Surveyor	2	3	4	3	0.1111111	0.3333333
Placing Order For Construction Material	2	3	4	3	0.1111111	0.3333333
Mix design for concrete M20, M30	4	8	29	10.833333	17.361111	4.1666667
Pile Chiseling, Reinforcement, & Casting	90	100	120	101.66667	25	5
Excavation for Pile Cap	5	7	9	7	0.4444444	0.6666667
Pile Breaking Upto 1 Feet	4	5	7	5.1666667	0.25	0.5
Pile Cap	12	17	21	16.833333	2.25	1.5
Tie Beam	8	12	15	11.833333	1.3611111	1.1666667
Column Dogla	2	3	4	3	0.1111111	0.3333333
Plinth Beam	8	11	14	11	1	1
Murrum Filling & soling	2	4	7	4.1666667	0.6944444	0.8333333
Compaction	2	3	4	3	0.1111111	0.3333333
Concrete pouring For PCC	1	1	2	1.1666667	0.0277778	0.1666667
Podium slab	30	40	50	40	11.111111	3.3333333

Podium Slab shuttering work	29	38	46	37.83333333	8.027777778	2.833333333

Podium Slab Concrete Pouring	2	3	4	3	0.1111111	0.3333333
2nd Floor Slab	30	40	50	40	11.111111	3.3333333
3rd Floor Slab	30	40	50	40	11.111111	3.3333333
4th Floor Slab	30	40	50	40	11.111111	3.3333333
5th Floor Slab	30	40	50	40	11.111111	3.3333333
6th Floor Slab	30	40	50	40	11.111111	3.3333333
7th Floor Slab	30	40	50	40	11.111111	3.3333333
8th Floor Slab	30	40	50	40	11.111111	3.3333333
9th Floor Slab	30	40	50	40	11.111111	3.3333333
10th Floor Slab	30	40	50	40	11.111111	3.3333333
11th Floor Slab	30	40	50	40	11.111111	3.3333333
12th Floor Slab	30	40	50	40	11.111111	3.3333333
Terrace Slab	30	40	50	40	11.111111	3.3333333
BBM 12th Floor slab	9	13	15	12.666667	1	1
Internal Plaster 12th Floor slab	6	8	10	8	0.4444444	0.6666667
Concealed Electric Pipe Fitting	22	30	45	31.166667	14.644444	3.833333
Concealed Plumbing Pipe Fitting	26	32	50	34	16	4
Tiles 1st Floor Slab	20	26	32	26	4	2
Tiles 2nd Floor Slab	20	26	32	26	4	2
Tiles 3rd Floor Slab	20	26	32	26	4	2
Tiles 4th Floor Slab	20	26	32	26	4	2
Tiles 5th Floor Slab	20	26	32	26	4	2
Tiles 6th Floor Slab	20	26	32	26	4	2
Tiles 7th Floor Slab	20	26	32	26	4	2
Tiles 8th Floor Slab	20	26	32	26	4	2
Tiles 9th Floor Slab	20	26	32	26	4	2
Tiles 10th Floor Slab	20	26	32	26	4	2
Tiles 11th Floor Slab	20	26	32	26	4	2
Tiles 12th Floor Slab	20	26	32	26	4	2
Gypsum 12th Floor Slab	18	21	25	21.166666	1.3611111	1.1666667
Internal Painting	40	50	60	50	11.111111	3.3333333
Door Frame & Door Fitting	25	32	39	32	5.4444444	2.3333333
TOTAL	**990**	**1294**	**1653**			
Project Duration				**1303.1667**		

Project Variance	**319.36111**
Project standard deviation	**17.870677**

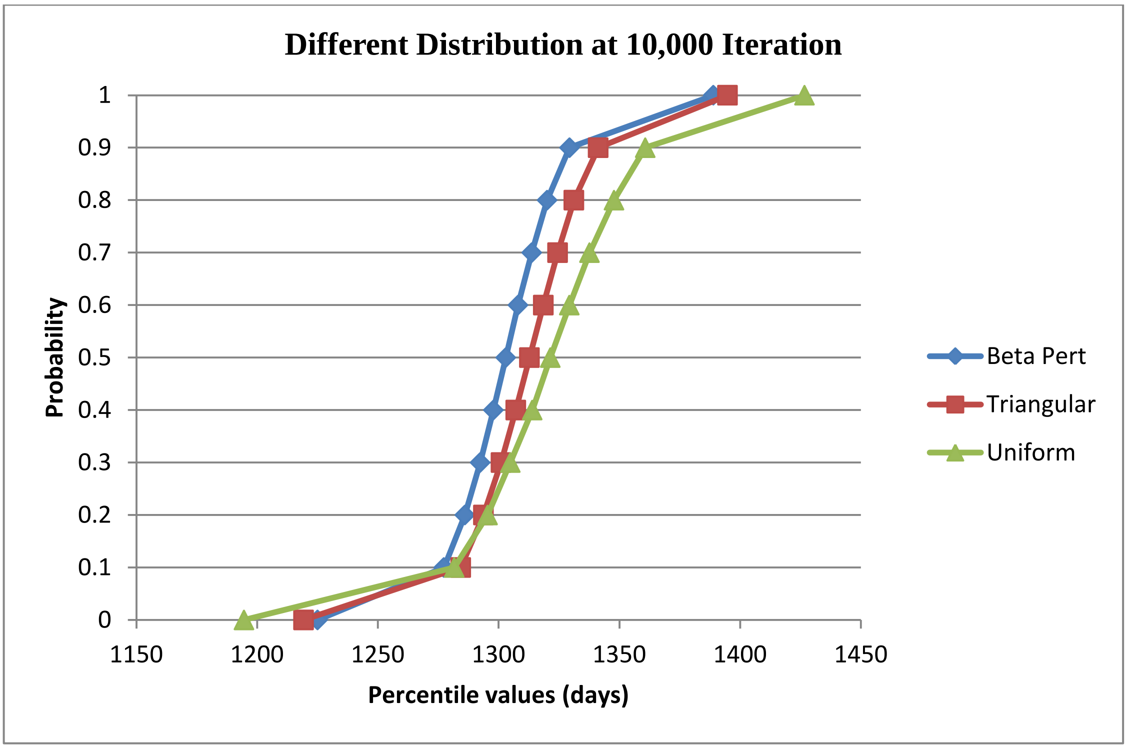
Table 2: Comparison of Different Distribution at 10000 Iterations

Distribution	Beta Pert	Triangular	Uniform Distribution
Statistic			
Trials	10,000	10,000	10,000
Base Case	0	0	0
Mean	1,303.17	1,312.81	1,321.37
Median	1,303.03	1,312.83	1,321.46
Mode	'---	'---	'---
Standard Deviation	20.14	22.08	30.69
Variance	405.59	487.33	941.72
Skewness	0.0401	0.0309	-0.0167
Kurtosis	2.95	2.91	2.86
Coeff. of Variation	0.0155	0.0168	0.0232
Minimum	1,225.06	1,219.29	1,194.61
Maximum	1,388.97	1,394.83	1,426.72
Mean Std. Error	0.2	0.22	0.31
Percentile			
0%	1,225.06	1,219.29	1,194.61
10%	1,277.37	1,284.37	1,281.67
20%	1,286.07	1,293.77	1,295.48
30%	1,292.40	1,301.06	1,304.89
40%	1,297.88	1,307.17	1,313.96
50%	1,303.02	1,312.82	1,321.46
60%	1,308.08	1,318.57	1,329.33
70%	1,313.77	1,324.48	1,337.68
80%	1,320.14	1,331.22	1,347.84
90%	1,329.42	1,341.28	1,360.78
100%	1,388.97	1,394.83	1,426.72

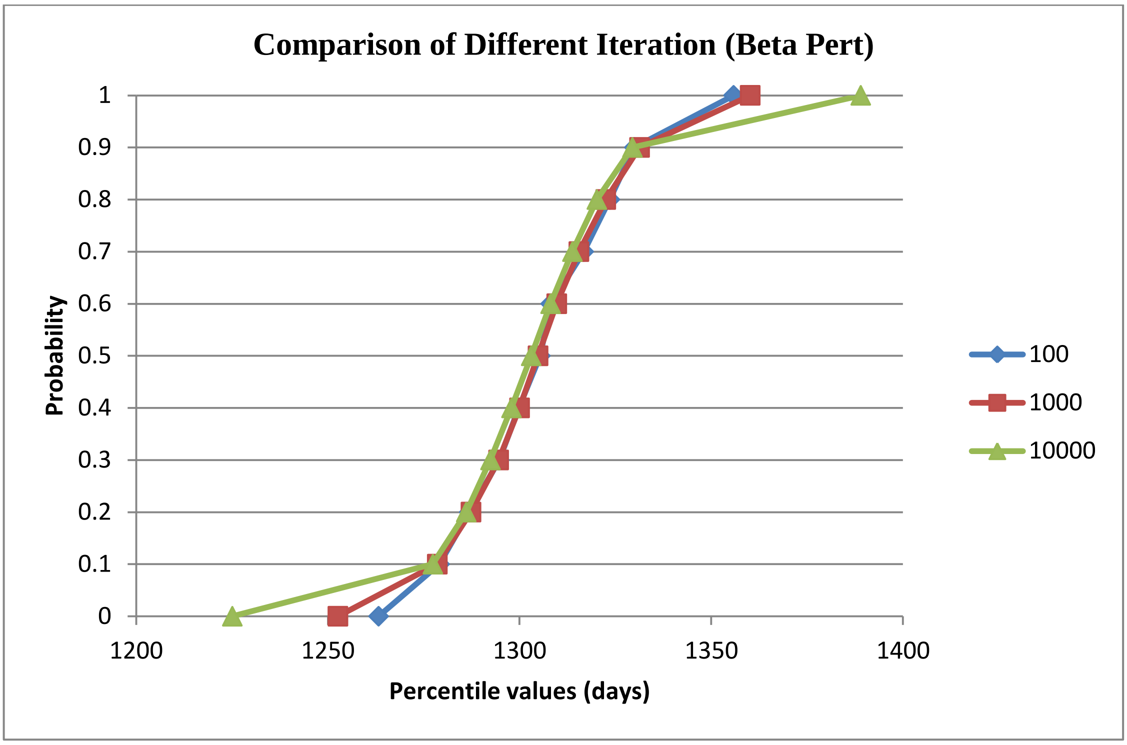
Table 3: Comparison of Beta Pert Distribution at 100, 1000, 10000 Iterations

Trials	100	1,000	10,000
Base Case	0	0	0
Mean	1,305.95	1,304.88	1,303.17
Median	1,305.40	1,304.80	1,303.03
Mode	'---	'---	'---
Standard Deviation	20.5	20.06	20.14
Variance	420.45	402.51	405.59
Skewness	0.1574	-0.0013	0.0401
Kurtosis	2.48	2.61	2.95
Coeff. of Variation	0.0157	0.0154	0.0155

Minimum	1,263.21	1,252.60	1,225.06
Maximum	1,355.80	1,360.13	1,388.97
Mean Std. Error	2.05	0.63	0.2
Percentile			
0%	1,263.21	1,252.60	1,225.06
10%	1,279.12	1,278.52	1,277.37
20%	1,286.88	1,287.31	1,286.07
30%	1,294.67	1,294.52	1,292.40
40%	1,299.80	1,299.98	1,297.88
50%	1,305.39	1,304.80	1,303.02
60%	1,308.11	1,309.68	1,308.08
70%	1,316.70	1,315.45	1,313.77
80%	1,323.52	1,322.46	1,320.14
90%	1,329.94	1,331.28	1,329.42
100%	1,355.80	1,360.13	1,388.97



Graph 1 Different Distribution at 10000 Iteration



Graph 2 Comparison of Different Iteration (Beta Pert)

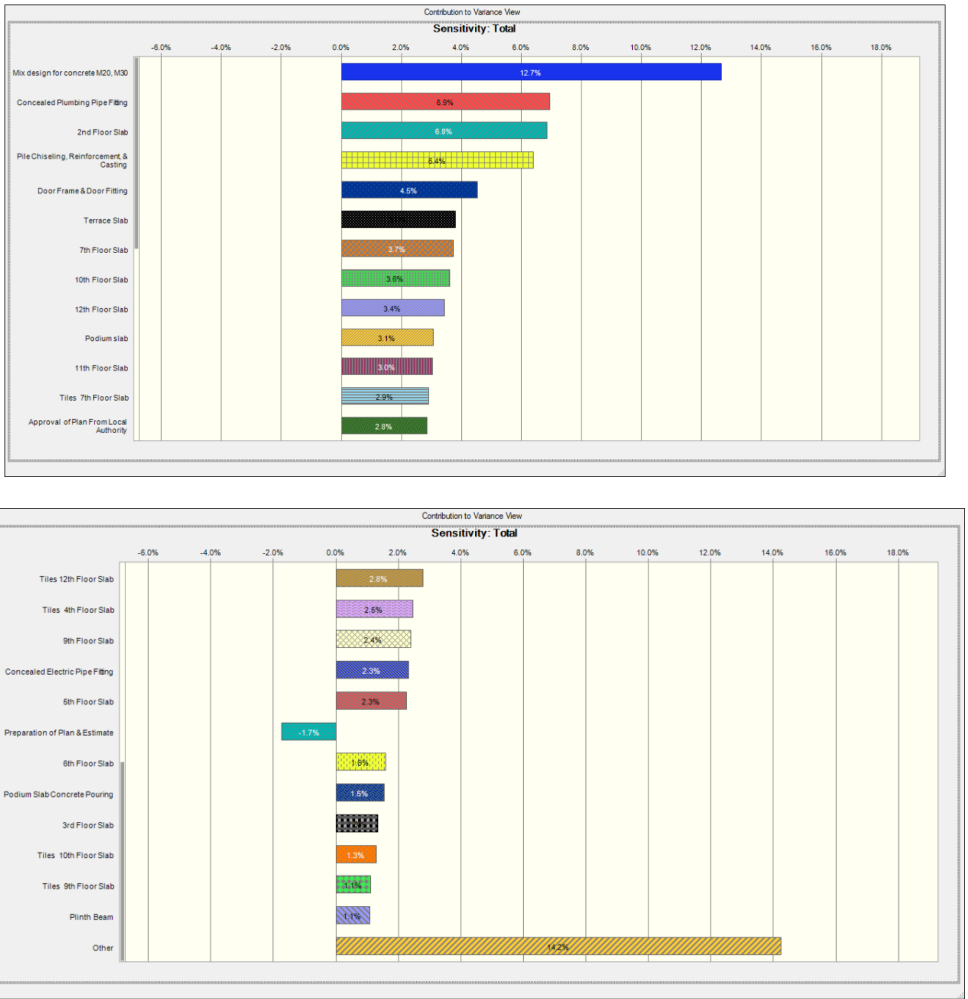


Fig 1: Sensitivity Chart

