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RESEARCH PAPER

Schedule Risk Analysis Using Monte Carlo Simulation for Residential Projects.

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A B S T R A C T:
Scheduling is an essential part of construction project management. Planning and scheduling of construction tasks help engineers to complete the project on time and within the budget. Most of the construction project failed to finish within planned duration; one of the reasons is regarded to estimated project duration without considering uncertainties that may cause a delay in performing specific activities. Hence it is vital to develop a risk management process which deals with the risks of execution that affects the project duration. This study focused on Schedule Risk Analysis Using Monte Carlo Simulation for Residential Projects, by taking the construction of a residential house as a case study. The primary objective of this study analyzes the output of a project schedule risk simulation when Monte Carlo use to simulate the duration of individual activities of the project and compare the total project duration outputs graphically and through statistical analysis. Consequently, using the Critical Path Method (CPM) to determine the project duration, which is equal to 96 days. For deciding the activity duration, the researcher has made a form. The form consists of all house tasks and estimated quantity with three columns for estimating Optimistic Duration, Most Likely Duration, and Pessimistic Duration in accordance with the respondent's perception for establishing the project duration by using the Program Evaluation and Review Techniques (PERT) method, which is equal 103 days. Project duration with low risk equal to 103 days, with base risks equal to 107 days and with high-risk project duration equal to 111 days. The outcomes clearly show that it is extremely unlikely to complete the project within 98 days and there is 100% chance that the project will be completed in 115 days. The sensitivity analysis for residential construction house indicates that the project schedule is most sensitive to the activity of “Wall Ceramic Tiles”, which can influence the completion date because of the correlation coefficient of this activity reached to 0.39 and top-ranked of all other activities.

KEY WORDS: Schedule Risk Analysis, Monte Carlo simulation, Residential Projects.
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1. INTRODUCTION :

Development ventures are always exceptional, and risks raise from various distinctive sources. The accomplishment of development ventures is assessed dependent on such measures as creation quality, scope adequacy, social-ecological specialized usefulness, security necessities, planned completion time, and distributed spending plan (Ökmen and Öztaş, 2008).

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Today, viably overseeing risk is a fundamental segment of successful project management.
Appropriate hazard administration can help the project manager to alleviate both known and unforeseen risks on projects of different types (Carbone and Tippett, 2004).

The three-dimensional objective for any undertaking is outstanding, i.e., to finish the project on time, within budget, and with satisfactory performance or quality (Ganame and Chaudhari, 2015).

Any development venture is relied upon to be done inside a predefined timeframe. Also, if the task gets late, it increases the cost of the undertaking and contractor may have to face a penalty for causing the delay. Consequently, it is crucial for both the proprietor and the contractor to pursue the task plan. Planning is an essential part of construction project management. Scheduling and Planning of construction activities assist engineers in completing the task on time and within the financial plan. In any case, construction activities possess uncertainties that may cause a delay in performing particular tasks or even increment the cost of the venture. Thus, it is essential to working up a hazard administration process which manages the dangers of execution that influence the project plan (Ganame and Chaudhari, 2015).

This study focus on risk management in construction schedule aims to determine project duration and the extension of project duration.

1.1 Scheduling

Construction scheduling and planning is a consistent examination of a construction project together with exhaustive information of development techniques, materials, and practices. Schedules are produced in a deterministic way, i.e., activity durations are given as solitary esteem, usually the most likely duration. There is a supposition that the duration is known with some assurance; in any case, the timetable regularly contains significant uncertainty, particularly for unsafe tasks. To address this issue, Program Evaluation Review Techniques (PERT) was developed (Nasir et al., 2003)

(PERT), in conjunction with the Critical Path Method, were developed in the 1958's to address the uncertainty in project duration for complex projects (Kerzner, 2017). The total project duration was determined by adding all the duration values of the activities on the critical path. The Monte Carlo simulation provides distribution for the whole project duration and is, therefore, more useful as a method or tool for decision making (Visser, 2016).

1.2 Schedule Risk Analysis

Different modeling strategies are utilized to portray or evaluate the size of a particular risk. One of the most normally utilized strategies is Monte Carlo simulation, which is used for incorporating a hazard factor structure and likelihood dispersion model to evaluate uncertainty (Kerzner, 2017).

MCS is a statistical technique that could turn out to be progressively critical as a method for risk assessors to assess the uncertainty. Even though Monte Carlo simulation has been utilized since the 1940s, more powerful desktop computers have made it open and appealing for some new applications (Huang and Wang, 2009). Risky Project is a companion product that can be integrated with Microsoft Project Professional. Risky Project provides support for both qualitative and quantitative risk analysis techniques (Vajjhala, 2012).

Risky Project also provides support for performing Monte Carlo simulations. The availability of additional open source companion products such as the Monte Carlo simulation offers significant advantages for Microsoft Project Professional over using other software tools for project management. In this paper, Risky Project uses as a tool for the Monte Carlo simulation (Vajjhala, 2012).

1.3 Research Objectives

The primary objective of this study is:

1. Determine project duration by Critical Path method.
2. Collecting data and determine project duration by the PERT method
3. Analyze the output of a project schedule risk simulation when Monte Carlo use to simulate the duration of individual activities of the project and compare the total project duration outputs graphically and through statistical analysis.

1.4 Literature Review

Visser (2016), discussed the results of a project to investigate the output of schedule simulations when different distribution, e.g., triangular, normal, beta pert, are used to show the uncertainty in activity durations. The researcher used two examples to compare the output distribution; the first example is a network with ten activities in sequence, and the second is a network where some of the activities are performed in parallel. The result of this study was showed that there is no significant difference in the output distributions when different input distribution with the same mean and variance value is used.

Ganame and Chaudhari (2015), focused on risk identification, qualitative analysis, and quantitative analysis. The goals are to distinguish the key risk factors that influence the venture schedule and to determine the probability of finishing the undertaking inside the due date. Survey frames were conveyed with 31 industry professionals with a shifting background from 1 year to 17 years. The subjective investigation is finished by a probability impact (PI) framework. Furthermore, the quantitative study is finished by PERT and Monte Carlo simulation. @RISK by Palisade Corp. is utilized for Monte Carlo simulation.

Rui-Mei (2015), focuses on the application of Monte Carlo strategy in project management as pursue: first, manages the evaluated scale with Wideband Delphi technique and gets the interim of expectation in the wake of making rehashed tests in accordance with the most part, received likelihood models; that makes sense of the outstanding tasks at hand as indicated by the management capacities and authentic date.

Madadi and Iranmanesh (2012), in this paper, proposed one index, and one technique is proposed to fulfill this necessity. The essential hypothesis is, consuming exertion on activities and controlling them effectively results in activities risk decrease. In light of this theory, the proposed index and strategy are contrasted with the existing index in the literature. Looking at results demonstrates that the proposed index and strategy emphatically outperform another index

Sadeghi et al. (2010) in this article examined the inadequacies of the available techniques and proposes a Fuzzy Monte Carlo Simulation (FMCS) system for hazard investigation of development ventures. In this system, they build a fuzzy cumulative distribution function as the ideal approach to speak to uncertainty. To check the plausibility of the FMCS system and exhibit its fundamental highlights, the authors have built up a unique purpose simulation template for cost extend assessing. This layout is utilized to decide the expense of a roadway bridge venture.

Huang and Wang (2009) analyzed the traditional likelihood investigation strategy for duration risk in program assessment and audit procedure. Based on that, it simulates the task's length and inspects the danger of development plan by the Monte Carlo simulation technique. Monte Carlo technique had been utilized to simulate the duration of each activity and overall project to accurately determine the completion probability of the project under considering the changeability and randomness of duration for each activity. The outcome demonstrates that the MCS strategy is helpful, powerful, and productive. It gives a logical premise to extend essential leadership and backings the decider intensely.

Bennett et al. (2001) discuss the inference of a PERT simulation model, which consolidates the discrete occasion demonstrating the approach and a rearranged essential action recognizable proof strategy. This has been done trying to overcome the limitations and enhance the computing efficiency of traditional CPM/PERT analysis. In this paper, a case study was conducted to validate the developed model and compare it to the traditional CPM/PERT analysis. The established model illustrates checked upgrade in analyzing the risk of project schedule overrun and determination of activity criticality. Furthermore, the beta distribution and its subjective fitting techniques are discussed to complement the PERT simulation model. This new answer for CPM network analysis can provide project management with a convenient tool to assess alternative scenarios based on computer simulation and risk analysis.

Mizuno et al. (2000), in this paper, the researchers proposed a new scheme for the characterization of risky projects based on a performance by the project manager. To acquire the relevant data to make such an assessment, they first designed a questionnaire from five viewpoints within the projects: requirements, estimations, team organization, planning capability, and project management activities. Each of these viewpoints consisted of a number of detailed questions. Then compute the responses to the questionnaires as provided by project managers by applying logistic regression analysis. The coefficients of the logistic model from a set of the questionnaire responses were determined. The experimental results using actual project data in Company A showed that 27 projects out of 32 were predicted correctly. Thus, researchers would think that the proposed describing plan is the initial move toward foreseeing which ventures are dangerous at an early period of the improvement.

2. MATERIALS AND METHODS

2.1. Schedule Risk Analysis Steps:

A research process consists of some sequential steps. The three steps to successful risk analysis are described:

2.1.1 Baseline Scheduling

When appropriate techniques are picked, and the uncertainty of their outcome is evaluated, then the outcome might be contrasted with some normal result, or to a rule, standard or baseline level. Both the PERT and CPM methods calculate the shortest path of a project network, the critical path, based on the network logic and the activity duration estimates made by the project manager. However, since estimates are often, if not always, subject to a margin of error, people feel more comfortable with a range of possible project outcomes rather than with a single point estimate like the critical path length. Moreover, the black-and-white view of the CPM methods on the critical activities should be more refined since noncritical (critical) activities have the potential to become critical (noncritical) during the progress of the project (Vanhoucke, 2012).

2.1.2 Determine the activity duration ranges:

The activity durations that are used to determine the critical path are usually thought of as the best guess length of time needed to complete the project known the planned resources. Experienced engineer managers know that the work might take more or less time than the estimate they have assumed for the critical path method calculation. These times make up the low and high ranges for risk analysis (Hulett, 1996).

Once the ranges, often called “3-point estimates,” are determined, the project manager must adopt a probability distribution shape for each risky activity. A probability distribution takes the three possible durations (low, most likely, and high) and expresses the relative likelihood of alternative outcomes within that overall range. That is, there are some potential durations which are more likely than others (Hulett, 1996).

Triangular distributions are often used in risk analysis because they are easy to specify (just needing three points and a straightedge) and to use in the analysis. Generally, triangular distribution is preferred when data submitted is judgmental in nature (Ganame and Chaudhari, 2015).

2.1.3 Monte-Carlo Simulation

Monte Carlo is a well-established method to represent a risk. Several commercial scheduling programs have a schedule risk analysis module. For some others, third-party software companies may have provided such capability. Not all network programs have risk analysis packages, however. The risk analyst using a network program that lacks the risk package will have to load the schedule into a network program that does (Hulett, 1996).

Monte Carlo Simulation methods have become famous amongst project managers and planners nowadays due to the availability of fast computers and software that is freely available, primarily as add-ins for spreadsheets like Microsoft Excel. The method is well documented and explained in various textbooks (Mun, 2006), (Cooper, 2005) and (Robert et al., 2010). Wood (2002) says Monte Carlo Simulation can be “applied in many diverse fields that require outcomes to be quantified statistically under conditions of uncertainty to aid in decision-making.” Various software programs for performing simulations are available to model uncertainty in the cost or duration of activities. Two standalone software programs that use discrete event simulation are Arena and GoldSim. Some add-in for performing simulations with MS Excel is @Risk, Crystal Ball, SimVoi, and RiskAmp (Visser, 2016). The tool used for this study is the Risky Project software add-in for Microsoft Project 2016. The probability distribution for each activity is selected as a triangle to match the traditional assumptions in PERT.

2.2 Sensitivity Analysis

Sensitivity analysis helps to determine which individual project risks or other sources of uncertainty have the most potential impact on project outcomes. It correlates variations in project outcomes with changes in elements of the quantitative risk analysis model (Guide, 2017).

One typical display of sensitivity analysis is the tornado diagram, which presents the calculated correlation coefficient for each element of the quantitative risk analysis model that can influence the project outcome. This can include individual project risks, project activities with high degrees of variability, or specific sources of ambiguity. Items are ordered by descending strength of the correlation, giving the typical tornado appearance (Guide, 2017)

2.3 Case study

A case study adopted is scheduling duration for construction a residential house 125 m² which consist of two stories. Risk schedule process consists of a number of sequential steps:

2.3.1 First step:

According to the house plan, the researchers could find and sequencing each activity, which includes activities established based on work breakdown structure, as shown in Table 1. Critical Path Method network developed at a level of detail that illustrates the important project structure. The Microsoft project 2016 has been used to build the CPM schedule. Firstly, we make the new project file and setting the starting project time on April 1, 2018, with six days as a working day per week from Saturday to Thursday. Secondly, enter each task name and their predecessors with the relationship between each task.

2.3.2 Second step:

The gathering of information about project risk is usually an included procedure. Most associations do not have databases that incorporate data reasonable for quantitative hazard examination, so interview methods were utilized, and the information are typically evaluated judgmentally. The data to be gathered comprise of 3-point estimates of duration (optimistic, most likely, and pessimistic scenarios).

For determining the activity duration, the researcher has made a form. The form consists of all house tasks and estimated quantity with three columns for estimating Optimistic Duration, Most Likely Duration, and Pessimistic Duration in accordance with the respondent's perception.

The researchers conducted an interview with expert engineers to estimate the three-point duration for each task according to their experience. After collecting data; the researcher calculates each task duration by using PERT calculations methods. The standard calculated values for PERT calculations (Mubarak, 2010) are as follows:

The weighted average activity time t:

$$t = (O+4M+P)/6$$

where:

O = optimistic activity time (1 chance in 100 of completing the activity earlier under normal conditions)

M = most likely activity time (without any learning curve effects)

P = pessimistic activity time (1 chance in 100 of completing the activity later

under normal conditions)

The calculation process will have done by using PERT Add-in to Microsoft project 2016. The initial calculations apply to each project activity, and then the calculations result in an analysis of the entire project.

2.3.3 Third step:

The tool used for this study is the “Risky Project professional 7 software add-in for Microsoft Project 2016”. By adding low and high estimates and distributions to each activity, simulation can be run. Monte Carlo simulations are utilized to assess the distribution of potential outcomes dependent on probabilistic inputs. Every simulation is produced by arbitrarily pulling a sample value for each information variable from its characterized probability distribution. These input sample values are then used to figure the outcomes (in Risky Project, it is projected schedule parameters: project duration, start and finish times, success date, and cost).

3. RESULTS AND DISCUSSION

3.1.Schedule Risk Analysis

By applying the Microsoft project 2016, the researchers built a schedule for determining the total duration of the project by critical path method. There is 32 sequencing activity, and the researchers estimate each activity average duration based on their experience as listed in Table 1, and it used as an entry table of Microsoft project 2016 which shows the work break structure code, duration, and predecessors for each activity. By entering the data from Table 1 to Microsoft project 2016, the network diagram of project and Gant chart of the project was drawn and determining the critical path, the total duration of project construction house by critical path method estimated 96 days. The Microsoft project outputs show in Figure 1 and Figure 2.

Table (1) Microsoft Project Entry Table

WBS Code	Task Name	Duration day	WBS Predecessors
A.1	Site Preparation	1	
A.2	Excavation	1	A.1
A.3	Concrete Foundation with curing	3	A.2
A.4	Solid Block Foundation with curing	3	A.3
A.5	Foundation Filling	1	A.4
A.6	Ground Floor Hollow Block Wall with curing	3	A.5
A.7	Ground Floor Slab with curing	12	A.6
A.8	First Floor Hollow Block Wall with curing	4	A.7
A.9	First Floor Slab with curing	12	A.8
A.10	Pent House Wall Hollow Block with curing	2	A.9
A.11	Pent House Slab with curing	9	A.10
A.12	Fencing block work	2	A.10[SS]
A.13	Rough Electrical Work (Cables layout)	3	A.11
A.14	Rough Mechanical Work (Plumbing - Pipes layout-ductwork)	3	A.11, A.12
A.15	Wall Ceramic Tile	12	A.14, A.13
A.16	Granit Façade Work	10	A.14
A.17	Flooring Tiles (Ground floor, first floor, and stair)	8	A.15, A.16
A.18	External and Garage Flooring Tile	2	A.17
A.19	Cement Plastering	5	A.17
A.20	Gypsum Plastering	3	A.19, A.18
A.21	Secondary Ceiling Work	5	A.20
A.22	Painting	2	A.21, A.20
A.23	Door (PVC)	2	A.21
A.24	Door (Wood)	2	A.21
A.25	Door (Steel)	1	A.21
A.26	Window (PVC)	2	A.21
A.27	Aluminum handrail for stair	1	A.21
A.28	Gate (2.8m*1.5m) steel	1	A.21
A.29	Finish electrical and Lighting Fixtures	4	A.22
A.30	Set Plumbing fixtures and trim	2	A.22
A.31	W.C and Bath Fittings	1	A.22
A.32	Kitchen furniture fixing	3	A.31, A.29, A.30, A.27, A.26, A.25, A.24, A.23, A.28

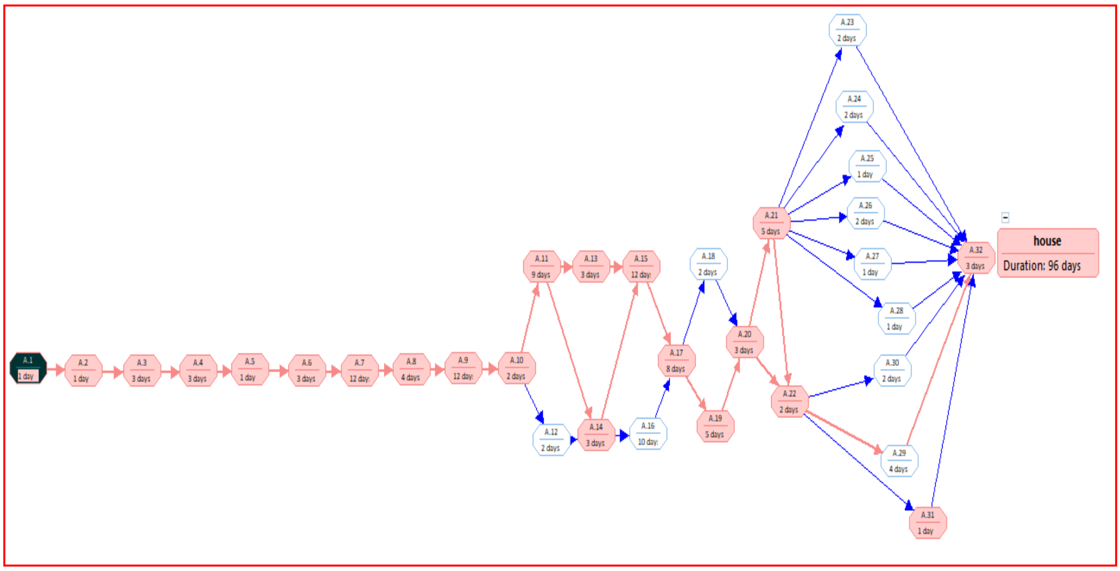


Figure 1: CPM Network Diagram for Residential House.

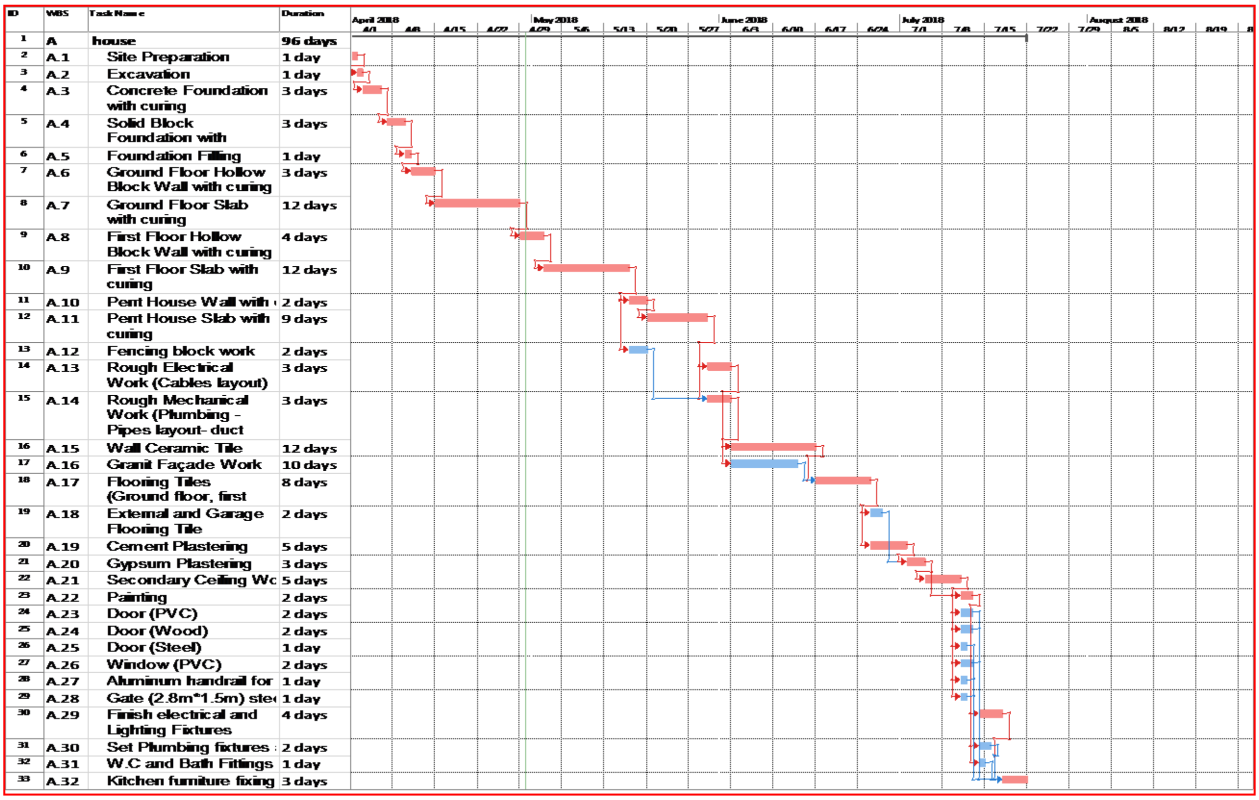


Figure 2: Gant Chart for Residential House

Secondly, determine the activity duration ranges. The researcher collected three points estimated duration for each task of the project by an interview with 26 civil engineers. The engineers asked to estimate Optimistic duration, most likely duration and Pessimistic duration for each task.

Table (2) First Response (R1) Expected Three Point Duration

Task name	Duration (t)	Optimistic Dur.	Expected Dur.	Pessimistic Dur.
Site Preparation	1.42	0.5	1	4
Excavation	1.58	0.5	1.5	3
Concrete Foundation with curing	1	0.5	1	1.5
Solid Block Foundation with curing	1.42	0.5	1.5	2
Foundation Filling	0.71	0.25	0.75	1
Ground Floor Hollow Block Wall with curing	2.5	2	2.5	3
Ground Floor Slab with curing	7.42	6.5	7	10
First Floor Hollow Block Wall with curing	2.5	2	2.5	3
First Floor Slab with curing	7.42	6.5	7	10
Pent House Wall Hollow Block with curing	1.08	0.5	1	2
Pent House Slab with curing	5.17	4	5	7
Fencing block work	0.54	0.25	0.5	1
Rough Electrical Work (Cables layout)	2	1	2	3
Rough Mechanical Work (Plumbing - Pipes layout-ductwork)	4.17	3	4	6
Wall Ceramic Tile	10.17	7	10	14
Granit Façade Work	4.17	3	4	6
Flooring Tiles (Ground floor, first floor, and stair)	6	5	6	7
External and Garage Flooring Tile	2.17	1	2	4
Cement Plastering	3.33	2	3	6
Gypsum Plastering	9	7	9	11
Secondary Ceiling Work	3.83	2	4	5
Painting	6	4	6	8
Door (PVC)	2	1	2	3
Door (Wood)	2.58	1.5	2.5	4
Door (Steel)	1.08	0.5	1	2
Window (PVC)	1.08	0.5	1	2
Aluminum handrail for stair	1.58	0.5	1.5	3
Gate (2.8m*1.5m) steel	1.92	0.5	2	3
Finish electrical and Lighting Fixtures	3	2	3	4
Set Plumbing fixtures and trim	1.58	0.5	1.5	3
W.C and Bath Fittings	1.08	0.5	1	2
Kitchen furniture fixing	1.08	0.5	1	2

Duration

Furthermore, based on the responded result, the researcher could find the average duration for each activity, table 3 illustrates how determined the site preparation duration.

Table (3) Site Preparation duration calculation

Response No.	Optimistic Dur.	Expected Dur.	Pessimistic Dur.
R1	0.25	0.5	1
R2	1	2	2
R3	0.5	0.75	1
R4	0.25	0.5	1
R5	0.5	1	2
R6	0.5	1	2
R7	0.5	1	4
R8	0.5	1	3
R9	1	2	3
R10	1	2	3
R11	1	2	3
R12	1	1	2
R13	0.5	1	2
R14	0.5	1	2
R15	0.5	1	3
R16	0.5	1	1
R17	0.5	1	1
R18	0.25	0.5	2
R19	0.25	0.5	1
R20	0.4	0.6	1
R21	0.5	1	1
R22	1	1	2
R23	1	1	2
R24	1	1	1
R25	1	2	5
R26	0.25	1	2
Total	16.15	28.35	53
Average	0.62	1.09	2.04

The standard calculated values for PERT calculations used to determine site preparation duration as follows:

$t = (O+4M+P)/6$
$t = (0.62+4*1.09+2.04)/6$
$t = 1.17$ day

The researcher preceded the same procedure for calculating each task duration, and the result demonstrated in table 4.

Table (4) Average Response Estimated Three Point Duration

WBS	Task name	Duration (t)	Optimistic Dur. day	Most likely Dur. day	Pessimistic Dur day
A	**House**				
A.1	Site Preparation	1.17	0.62	1.09	2.04
A.2	Excavation	1.7	1.04	1.62	2.7
A.3	Concrete Foundation with curing	3.68	2.96	3.48	5.19
A.4	Solid Block Foundation with curing	2.87	1.96	2.81	4.04
A.5	Foundation Filling	1.7	0.97	1.65	2.65
A.6	Ground Floor Hollow Block Wall with curing	4.74	3.23	4.75	6.19
A.7	Ground Floor Slab with curing	10.44	8.85	10.15	13.19
A.8	First Floor Hollow Block Wall	4.86	3.65	4.75	6.54
A.9	First Floor Slab with curing	10.28	8.73	10.04	12.81
A.10	Pent House Wall with curing	3.57	2.33	3.71	4.25
A.11	Pent House Slab with curing	6.61	5.35	6.46	8.46
A.12	Fencing block work	2.67	1.44	2.85	3.17
A.13	Rough Electrical Work (Cables layout)	4.44	3.25	4.37	5.92
A.14	Rough Mechanical Work	5.35	3.81	5.29	7.15
A.15	Wall Ceramic Tile	11.11	9	10.62	15.15
A.16	Granit Façade Work	8.36	6.31	8.19	11.08
A.17	Flooring Tiles (Ground floor, first floor, and stair)	7.37	5.46	7.19	10
A.18	External and Garage Flooring Tile	2.85	1.5	2.94	3.85
A.19	Cement Plastering	4.39	2.96	4.38	5.85
A.20	Gypsum Plastering	7.17	5.42	6.9	10
A.21	Secondary Ceiling Work	4.88	3.88	4.63	6.88
A.22	Painting	4.01	2.67	3.9	5.77
A.23	Door (PVC)	4.68	3.06	4.63	6.48
A.24	Door (Wood)	3.71	2.48	3.77	4.71
A.25	Door (Steel)	2.16	1.44	2.1	3.11
A.26	Window (PVC)	4.63	3.38	4.54	6.21
A.27	Aluminum handrail for stair	2.18	1.4	2.13	3.15
A.28	Gate (2.8m*1.5m) steel	2.54	1.71	2.44	3.79
A.29	Finish electrical and Lighting Fixtures	3.05	1.73	3	4.6
A.30	Set Plumbing fixtures and trim	2.55	1.6	2.48	3.77
A.31	W.C and Bath Fittings	2.1	1.29	2.06	3.1
A.32	Kitchen furniture fixing	4	2.88	3.85	5.69

By entering the data to Microsoft project 2016 with PERT add-in and using the same CPM relationship between tasks project expected duration was determined, the result showed the house building will be finish with 103 working days and illustrated in figure 3.

Furthermore, quantitative risk analysis uses a model that simulates the combined effects of individual project risks and other sources of uncertainty to evaluate their potential impact on achieving project objectives. Simulations are typically performed using a Monte Carlo analysis. After calculating the average of responded optimistic most likely, and pessimistic time, all the three durations are inserted in Risky Project Professional 7 Add-In Microsoft Project 2016 of each responded. The output is defined, and triangle simulation is run for each responded data based on the following Monte Carlo parameters:

• The maximum number of simulation (600) sample.

• Converged when mean and standard deviation changes by less than 0.15% and Over 20%
• Low and high time and duration are calculated based on Percentile (10) and percentile (90).

The result of project durations by Monte-Carlo simulation for average response estimated duration with no risk equal to 103 days, project duration with low risk equal to 103 days, with base risks equal to 107 days and with high-risk project duration equal to 111 days as shown in Table 5.

Table (5) Risky Project Output

Start Time		Duration
No RISKS	Cur. Schedule	102.96 days
With Risks	Low	102.72 days
	Base	107 days
	High	110.65 days

Simulation.

Figure 4 and Figure 5 shows the descriptive, frequency statistics and percentage of completion of the construction project for various durations, the mean completion time of the project is nearly equal 107 with 576 number of the sample (iterate).

The 10% chance that duration will be less than 103 days and 90% chance that duration will be less than 111 days. The minimum and maximum completion times are 98 days and 115 days respectively shows that the percentage of completion of the construction project for various durations.

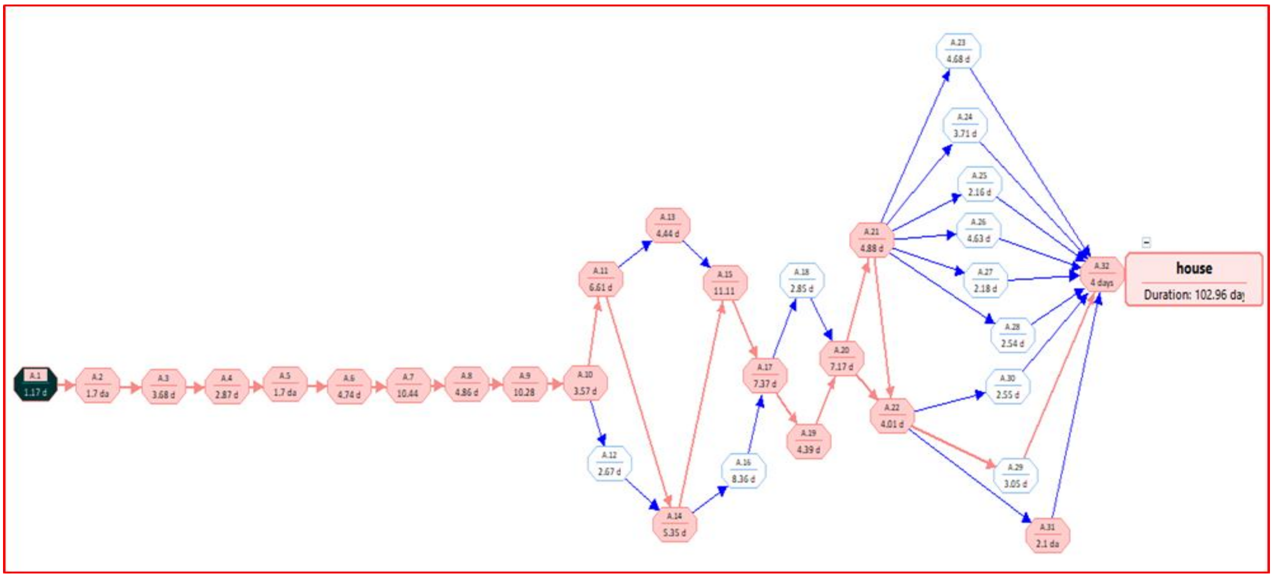


Figure 3: Estimation of Construction Duration by Using PERT

The results show that it is extremely unlikely to complete the project within 98 days. Moreover, there is a 100% chance that the project will be completed in 115 days. Table 6 shows the experience, education level and calculated total project duration by a PERT method for each response and Monte Carlo simulation result, the software run the result of each response data according to their estimation.

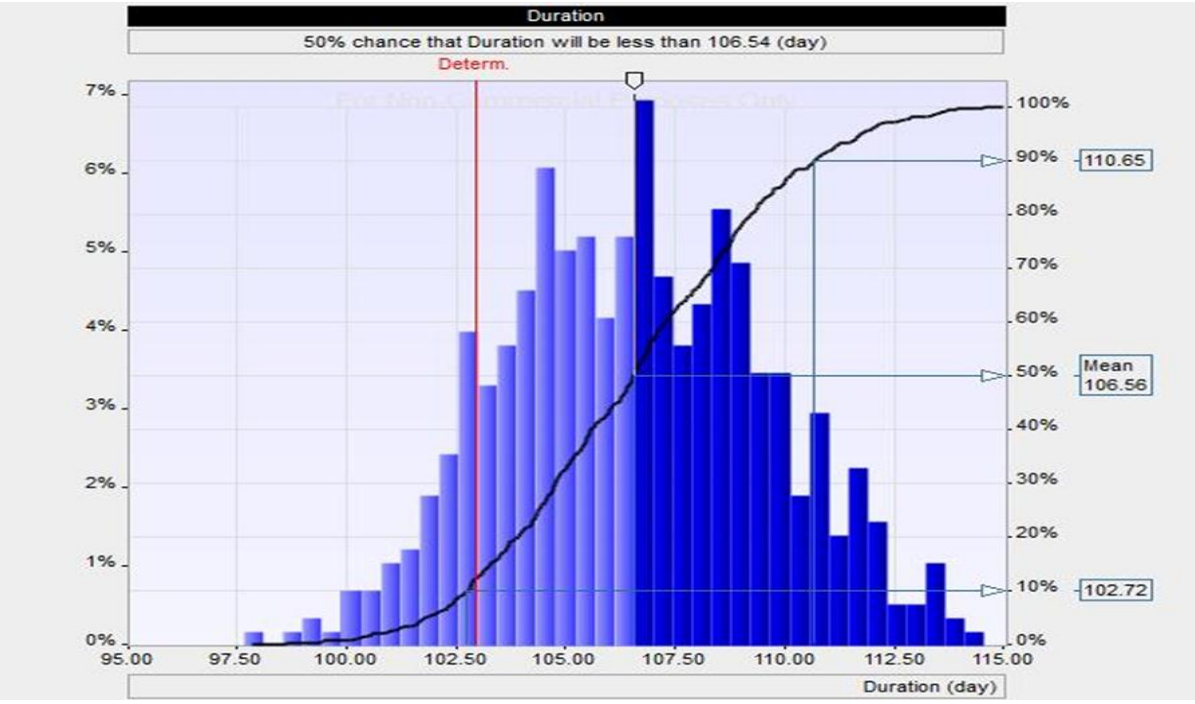
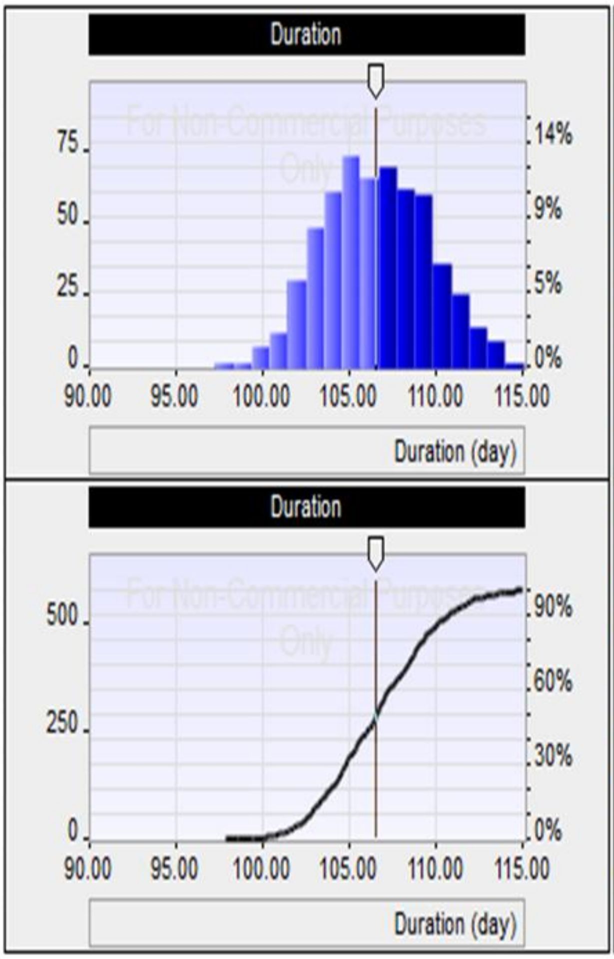


Figure 4: Frequency and Cumulative Probability, Frequency and Cumulative.

Num. of samples	576
Minimum	97.84 days
Mean	106.56 days
Maximum	114.52 days
Range	16.68 days
P1/P99 range	13.39 days
P5/P95 range	9.98 days
P10/P90 range	7.94 days
P20/P80 range	5.31 days
P30/P70 range	3.59 days
Variance	73.48 days
Std.Deviation	3.03 days
Semi Std.Dev.	2.99 days
Skewness	0.071176
Kurtosis	-0.410145



5th Percentile	101.72 days
10th Percentile	102.72 days
15th Percentile	103.28 days
20th Percentile	103.9 days
25th Percentile	104.36 days
30th Percentile	104.74 days
35th Percentile	105.18 days
40th Percentile	105.56 days
45th Percentile	106.13 days
50th Percentile	106.55 days
55th Percentile	106.87 days
60th Percentile	107.23 days
65th Percentile	107.79 days
70th Percentile	108.34 days
75th Percentile	108.75 days
80th Percentile	109.21 days
85th Percentile	109.75 days
90th Percentile	110.65 days
95th Percentile	111.71 days

Figure 5 : Descriptive, Frequency Statistics, and Percentage of Completion of The Construction Project for Various Durations

Table (6) Respondents Profile and Perception of Estimated Duration

Response Number	Experience Year	Educational level	PERT	duration with Risks		Day
				Low	Base	High
R1	15	BSc	79	78	82	85
R2	10	BSc	80	79	81	84
R3	10	MSc	84	84	87	90
R4	8	BSc	85	83	84	86
R5	17	BSc	85	83	85	87
R6	21	BSc	88	90	93	97
R7	21	BSc	88	86	89	92
R8	5	BSc	89	90	92	95
R9	17	BSc	90	89	91	93
R10	8	BSc	91	92	95	96
R11	30	Ph.D.	93	90	94	98
R12	30	BSC	95	92	96	101
R13	8	BSc	95	91	94	97
R14	7	BSc	97	94	98	103
R15	15	BSc	98	97	100	103
R16	8	BSc	99	100	107	115
R17	8	BSc	106	105	112	120
R18	10	BSc	118	117	120	125
R19	11	BSc	122	122	129	135
R20	21	Ph.D.	123	125	131	137
R21	37	BSc	136	134	137	141
R22	30	BSc	138	142	144	146
R23	9	BSc	143	141	148	155
R24	15	BSc	148	149	151	153
R25	7	BSc	152	146	155	165
R26	10	BSc	153	153	164	176

3.2 Sensitivity Analysis

The tornado diagram is a different bar chart that is utilized as a part of sensitivity analysis. The sensitivity analysis is a modeling technique that figures out which risks have the most impact on the project. As one of the tools used in the sensitivity analysis, the tornado diagram is used to compare the importance of different variables. The sensitivity analysis for residential construction house indicates that the project schedule is most sensitive to task number 15 which is Wall Ceramic Tile, which can influence the completion date because of the correlation coefficient of ceramic wall tile equal to 0.39.

The project's second highest sensitivity is Gypsum Plastering, which can affect the completion date, as illustrated in Figure 6. Knowing that this is where the most schedule sensitivity lies and to find which activity is riskier, we may decide to pay delivery premiums for materials, and perhaps pay for additional overtime, etc., for the contractors to expedite construction.

Tas...	Task Name	Coefficient	Correlation between finish times
15	Task: Wall Ceramic Tile	0.39	
20	Task: Gypsum Plastering	0.33	
9	Task: First Floor Slab with curing	0.32	
11	Task: Pent House Slab with curing	0.29	
21	Task: Secondary Ceiling Work	0.29	
17	Task: Flooring Tiles (Ground floor, first floor and stair)	0.28	
7	Task: Ground Floor Slab with curing	0.28	
6	Task: Ground Floor Hollow Block Wall with curing	0.25	
22	Task: Painting	0.21	
19	Task: Cement Plastering	0.21	
14	Task: Rough Mechanical Work (Plumbing - Pipes layout- duct work)	0.20	
29	Task: Finish electrical and Lighting Fixtures	0.19	
2	Task: Excavation	0.16	
8	Task: First Floor Hollow Block Wall with curing	0.16	

Figure 5: Sensitivity to Finish Times of Other Tasks

4. CONCLUSIONS

This study develops the methodology for schedule risk analysis of building construction. The Residential House 125 m² construction project was investigated to recognize the risks that affect the project completion time, and furthermore to determine the probability of completing the project within the due date. Based on the researchers of other scholars, this paper analyzed the traditional probability analysis method for duration risk in PERT. Firstly, the researchers determined the project duration by the critical path method, which is equal to 96 days. Secondly, for determining the project duration by PERT method, a questionnaire form prepared, to estimate three durations for each activity by different expert engineers the average optimist, most likely and pessimistic duration of all responses was determined, the project duration equal to 103 days after calculated the responses data by PERT method.

Monte Carlo method was used to simulate the duration of each activity and the overall project to accurately determine the completion probability of the project under considering the changeability and randomness of duration for each activity. Project duration with low risk equal to 103 days, with base risks equal to 107 days and with high-risk project duration equal to 111 days. The results show that it is doubtful to complete the project within 98 days. Moreover, there is a 100% chance that the project will be completed in 115 days. In the end, for knowing that where is the most schedule sensitivity lies, the tornado graph was determined. The sensitivity analysis for construction Residential house indicates that the project schedule is most sensitive to Wall Ceramic Tile, which can influence the completion date because of the correlation coefficient of ceramic wall tile equal to 0.39 and top-ranked of all tasks.

The project duration should be determined by the PERT technique in conjunction with CPM to develop a probability distribution of possible completion dates and its quantified risks and opportunities. As a result, there are two primary types of risk analysis; qualitative and quantitative assessments.

A qualitative assessment is an evaluation that does not make use of schedule iteration techniques as used in this paper but instead relies on the experience and knowledge of key project stakeholders to identify items that have the potential to impact the schedule. A quantitative assessment makes use of probabilistic analysis techniques were considered in this paper, as the Monte Carlo simulation. The process requires building a logical activity network model where risks are identified from a variety of sources.

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