OPTIMIZATION OF PROJECT DURATION AND CONSTRAINT RESOURCE USING MONTE CARLO METHOD

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UNIVERSITI SAINS MALAYSIA
2017

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By

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This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

As partial fulfilment of requirement for the degree of

BACHELOR OF ENGINEERING (HONS.)
(CIVIL ENGINEERING)

School of Civil Engineering,
Universiti Sains Malaysia

June 2017

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my supervisor, Professor Ir. Dr. Md Azlin Md Said. I would like to thank him for letting me experience practical issues beyond the textbooks, patiently corrected my writing and helping me in developing my background in project management. Without his guidance and persistent help this dissertation would not have been possible.

I would also like to thank Ir. Dr. Goh from M.E.I who willing to provide me a real case study and brief me about the project. My special appreciation goes to Mr. Khor from M.E.I for his patience guidance throughout my research programme and his caring and concern about my dissertation.

Finally, I would like to express my appreciation to my family who always support me and encourage me throughout the research programme. Without the blessings and encouragement from my parents, I would not have been able to finish my work.

ABSTRAK

Pengunaan pemantauan jadual dan kawalan merupakan alat pengurusan dan program pengurusan yang penting. Alat-alat ini adalah untuk mengelakkan kegagalan dalam pembinaan bangunan yang boleh menjejaskan prestasi projek pembinaan. Kajian ini mengkaji pendekatan sebagai alternative untuk mengira laluan kritikal dalam projek pembinaan dengan menggunakan Monte Carlo Simulation kaedah untuk menentukan kritikal aktiviti, kemungkinan tempoh penyiapan projek dan juga menganggarkan jumlah kos projek pada projek yang sebenar di Bayan Lepas, Pulau Pinang. Kaedah laluan kritikal menunjukkan hubungan antara aktiviti dan penjadualan aktiviti pembinaan. Walau bagaimanapun, analisis CPM adalah satu proses berketentuan yang tidak mengambil kira pembolehubah rawak. Oleh itu, analisis lanjut menggunakan Primavera P6 untuk menjana hasil CPM serta menggunakan Microsoft Excel untuk mensimulasikan kritikal daripada aktiviti dan kos untuk setiap aktiviti. Perbandingan Kaedah Laluan Kritikal konvensional dengan Monte Carlo Simulation menunjukkan hasil yang lebih realistik yang berhampiran dengan projek sebenar. Sumber kekangan dianggar menggunakan Monte Carlo Simulation supaya kedua-dua hasil dalam aspek masa dan aspek kekangan boleh dibandingkan dan dioptimumkan untuk memberikan tempoh penyiapan paling lama dengan kos yang minimum.

ABSTRACT

The use of schedule monitoring and control is an important management tools and program management. Tools are available to prevent failure in construction of building that can affect the performance of the construction project. This study reviews as alternative approach to calculate the critical path in a construction project by using Monte Carlo Simulation Method to determine the criticality of the activities, forecast a most probable completion duration of a project as well as estimate the total cost of the project on a real project in Bayan Lepas, Penang. Critical Path Methods provides interrelationships of activities and scheduling of construction activities. However, CPM analysis is a deterministic process which does not account random variables. Thus, further analysis using Primavera P6 to generate CPM results as well as using Microsoft Excel to simulate the criticality of the activities and the cost of each activities. Comparing the conventional Critical Path Method with Monte Carlo Simulation Method, Monte Carlo Simulation Method shows more realistic results which close to the actual project progress. The restraint resources is estimated using Monte Carlo Simulation Method so that both result in duration wise and resource wise can be compared and optimized to provide a longest probable completion duration with minimum cost.

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NOMENCLATURES

ES_j	Earliest start
EF_{ij}	Earliest finish
LS_{ij}	Latest start
LF_{ij}	Latest finish
t_{ij}	Activity duration
TF_i	Total float
C_T	Total project cost
$C_i(D_i)$	Direct cost-duration function
$C_I(D_L)$	Project indirect cost-duration function
$P(D_L)$	Penalty-duration function
$B(D_E)$	**B**onus-duration function
Z	Standard normal random variable
$\Phi(z)$	Standard distribution
$N(0,1)$	Random interger between 0 to 1
a	Optimistic duration
m	Most probable duration
b	Pessimistic duration
μ	Mean
σ^2	Variance

CHAPTER 1

INTRODUCTION

1.1 Introduction

Construction industry projects involve complex packages of work for which the design and contracting organization are responsible. The industry make particular demands to the planning and scheduling technique that needs to be developed to serve it (Abeyasinghe, 2001). This management process begins for the general contractor after the estimating and bidding phase, and it concludes only upon successful project closeout. The process consists of three consists of three separate management functions which are planning, monitoring and controlling.

The Project Management is a process that includes planning, putting the project plan into action, and measuring progress and performance. It involves identifying the project requirements, establishing project objectives, balancing constraints, and taking the needs and expectations of the key stakeholders into consideration. Planning is one of the most important functions you'll perform during the course of a project. It sets the standard for the rest of the project's life and is used to track future project performance (Heldman, 2015). Monitoring and Controlling process is concerned with monitoring all the process in the Initiating, Planning, Executing, and Closing process groups. Collecting data, measuring results, and reporting on performance information are the activities performed during this process (Heldman, 2015). Monitoring involves defining the various work activities that comprise the project, developing time estimates for the activities, and expressing these activities in some time-scaled logical form so that the performance requirements for each contractor are readily ascertainable. Controlling involving documenting the progress of the job, comparing the actual progress with planned progress, analyzing any differences between actual and planned progress, and recommending remedial action when these differences will have any adverse effect on the stated objectives of the project (Project Management Institute, 2017).

Construction projects contain numerous inter-dependent and inter-related activities. The fast changing environments of the present era impose numerous financial, legal, ethical, environmental and logistic constraints. They interact technically, economically and socially within the environment as well as with other organisation, structures and systems. However, these constraints exist in every construction projects without our awareness has put aside the emphasis on the goal of the project. These projects employ voluminous resources. But they have in-built difficulties, uncertainties and risks with multi-party participation. Thus, resources constraint is selected to be the primary issue which affects the project duration. Due to the resource-driven nature of construction management, managing a project with constraint is really a difficult task. The construction manager must develop a plan of action for directing and controlling resources of workers, machines and materials in coordinated and timely manner in order to deliver a project within the frame of limited funding and time (Nagaraju and Reddy, 2012).

Planning and scheduling of construction activities enables the engineers to monitor and control the time and resource constraints throughout the construction period (Hendrickson, 1998). But construction activities possess uncertainties that may cause delay in performing certain activities or even increase in cost of the project, exceeding the limited resources. Hence it is very important to develop a managing process which deals with the risks in execution that affects the project schedule and the resource allocation. This study aim to forecast the project duration in order to allocate proper resources without exceeding the constraint resources.

1.2 Problem Statement

Traditionally, project managers are using critical path methods to determine the longest path of the project by calculating the earliest time and the latest time of complete duration of a project. However, critical path methods is deterministic, means getting the same results for a given set of initial conditions. In reality, all project activities will display variation due to factors such as poor estimating, unexpected events or undefined customer expectations. This variation creates risk because of its potential to affect the project schedule.

Thus, creating a probabilistic model of the project schedule, where activity durations are described as probability distributions. Monte Carlo simulation is used to generate random values for inputs that are processed through a mathematical model in order to generate multiple scenarios (Kwak, 2007). Then, a probability distribution is developed for each activity on the critical path and the mathematical model is the sum of all the activities on the critical path.

1.3 Aim of Study

The aim of this study is to use Monte Carlo in scheduling for planning, monitoring and controlling the resources and duration of a construction project.

The main focus of the study is to

I. To determine all the duration of the activities including the optimistic and pessimistic durations.
II. To evaluate the probable complete duration time.
III. To determine the probable project cost.
IV. To propose the nearest completion duration accordance to the highest probable resources and completion time.

1.4 Significant of Research

The benefits of this analysis are to determine which activities most influence the project duration, reducing the amount of time needed to refine estimates. It also finds out which activities least influence the duration, so that they can be ignored and develop realistic schedule models that increase the accuracy of results.

The significant way of controlling the project resources and duration is to build up reliable project estimates and schedules. The optimization of project duration and constraint resource using Monte Carlo method is viewed from a reliability perspective. The random simulation allows checking the project risk (delay and constraint resources) as a constraint. It is assumed that a liaison always exists between existing risks resided in a project and related activity‘s time. A combination of risk management and critical chain schedule model is applied to choose the best schedule reliability for a project.

1.5 Scope of Study

There are many elements that contributed to a good project scheduling network, such as estimate time, planning, design and etc. However, this study mainly focuses on the monitoring and controlling in network analysis diagram and contribution to efficient project scheduling.

1.6 Study Area

This research is about the factory extension construction management project of constructing a canteen and extending an existing building (B4 BUILDING) for AMBU SDN. BHD. This project is currently handled by M.E.I Consultant SDN. BHD and M.E.I Project Engineers SND. BHD, a consultancy firm located in Georgetown, Penang. For further information, this project of AMBU SDN.BHD. is located on the Bayan Lepas Industrial Area, in northern peninsular Malaysia, Penang Island.

In the planning stage, M.E.I Consultant SDN. SHD is a one stop center (OSC) in Penang which can presume all types of construction tasks including management and can fulfill the client's requirement. The project information is shown in the Figure 1.1.

Title of Project	CADANGAN PINDAAN DAN TAMBAHAN KEPADA KILANG 2 TINGKAT YANG SEDIA ADA YANG MENGANDUNGI: (A) KILANG 2 TINGKAT KILANG YANG SEDIA ADA SERTA (B) TAMBAHAN 4 TINGKAT KILANG BARU KEPADA KILANG 2 TINGKAT SEDIA ADA DI ATAS LOT 15519 DAN 15997 KAWASAN PERINDUSTRIAN BEBAS BAYAN LEPAS FASA 4, MUKIM 12, DAERAH BARAT DAYA, PULAU PINANG.
Site Location	Bayan Lepas, Pulau Pinang.
Consultant Company	M.E.I Consultants Sdn. Bhd.
Contractor Company	M.E.I Project Engineers Sdn. Bhd.
Height of Building	B4 Building: 24.5m
	Canteen : 14.4m
Date of Project Start	1st November 2016
Date of Completion	23rd September 2017

Figure 1.1: Project Information

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The control of project scheduling is a vital part in the process of project construction, especially for those projects which consider project time and budget as targets. Delivering project on-time or not have much to do with earning or losing a profit and/or a return on investment for parties. In actual construction site, there are many uncertainties and risk will cause delay and damages on the progress on the project. The basic input parameters for planning (time, cost and resources for each activity) are not deterministic and are affected by various sources of uncertainty. Moreover, there is a relationship between these uncertainty sources and project parameters; this causality is ignored in current state-of-the-art project planning techniques (such as simulation techniques) in order to forecast the completion duration of the project. In this paper we present an approach, using Monte Carlo Simulation (MCS) modelling, which addresses both uncertainty and the potential risk which cause the delay in duration and the most probable completion duration for the project.

There are constraints in every construction project. However, the source of the constraints often neglected and facing difficulties and damages when overcoming the effects of the constraints during the construction period. The construction working environment involves multi-party participation. Needs and constraints in a multi-party working situation bring complications in project management. These can further develop into conflicts and disputes, which bring cost consequences, direct and indirect, to clients and contractors (Yates and Hardcastle, 2002). The project team members have to meet client's needs on one hand and to overcome constraints on the other hand. With the limited literature for the constraints in the construction working environment, it is important to identify the potential constraints in the construction project, which will help to decrease the unnecessary wastage and loss of both money and time because of inadequate planning. Controlling the constraints is thus a pre-condition for high performance of the project. There are five categories of constraints in construction project, they are: economic constraints, legal constraints, environmental constraints, technical constraints, and social constraints (Lau and Kong, 2006). But, only economic constraints which is also known as resource constraint is discussed and further analyzed in this paper.

Therefore, precise estimation of the project completion duration have to compensate necessary loss directly and indirectly with limited resource during the project period. Project execution is often impacted by the uncertainties and thus may delay the committed project deadline. Delay not only taints the reputation of project manager, but in some cases, the project owner may claim liquidation damages from project performer. High penalty costs and loss of revenue would be ensued. (Jen and Chen, 2009). This paper studies the appropriate ways to optimize both aspects using managing tools.

2.2 Definition of Critical Path Method (CPM) scheduling

Critical Path Method (CPM) scheduling has been used since the 1950s, when it is implemented on government projects in order to determine the best trade-off between cost and time. By developing schedule and analyzing the work to be accomplished with the aid of a flowchart or network diagram, the detailed relationships among the activities could be carefully evaluated. The network showed the predecessor and successors to each activity. This way if an activity was changed, behind, or ahead of schedule, the following activities' dates were automatically adjusted based upon the relationships among the activities (Newitt, 2011). Currently, CPM schedules are used on large construction projects and they are required in most public contracts. CPM identifies those chains of activities (the critical paths) in the project that control how the project will take. He commonly referred to as the *Precedence technique* which defines the activities as boxes (node in the network), which are connected together (their relationships identified) by lines (Hinze, 2011). *Precedence Diagramming Method* (PDM) is further defined by four types of logical relationships. The terms *dependencies* and *precedence relationship* also are used to describe these relationships (Heldman, 2015). The four dependencies, or logical relationships, are as follows:

1. Finish-to-start (FS) The finish-to-start relationship is the most frequently used relationship. This relationship says that the predecessor-or *from* activity-must finish before the successor-or to activity-can sart. In PDM diagrams, this is the most often used logical relationship.
2. Start-to-Finish (SF) The start-to-finish relationship says that the predecessor activity must start before the successor activity can finish. This logical relationship is seldom used.
3. Finish-to-finish (FF) The finish-to-finish relationship says that the predecessor activity must finish before the successor activity finishes.
4. Start-to-start (SS) The start-to-start relationship says that the predecessor activity must start before the successive activity can start.

The *critical path* (CP) is generally the longest full path on the project. Any project activity with float time that equals zero is considered a critical task (Heldman, 2015). Forward pass is the calculations start at the beginning of the project and move to the end of the project, of from left to right. If two arrows back into an activity, the largest number is chosen. Backward pass is the calculations start at the end of the project and move to the beginning of the project, or from right to left. If two arrows back into an activity, the lowest number is chosen (Newitt, 2011). *Float time* is also called *slack time*, and you'll see these terms used interchangeably. There are two types of float: total float and free float. *Total Float* (TF) is the amount of time you can delay the earliest start of a task without delaying the ending of the project. *Free Float* (FF) is the amount of time you can delay the start of a task without delaying the earliest start of a successor task (Heldman, 2015).

2.3 Analysis Network Diagram

Network technique best known as Program Evaluation and Review Technique (PERT) and CPM came about in the 1950s. The network diagram of PERT and CPM technologies provide a powerful measurement of time and work packages relationship than either the bar chart or the milestone chart. The network diagram, basic to PERT and CPM techniques, providing a more dynamic interrelated pictures of the events and activities and interrelationships relative to the project. The main value of the network technique is its ability to track time and cost considerations of the project. While PERT and CPM are excellent system for keeping track of all activities on a project, the planning value of network technique is considered to be as important as the control of the project work packages during the project execution. (Lewis, 1993)

2.4 Monte Carlo Simulation (MCS) Used in Project Management

Monte Carlo methods (or Monte Carlo experiments) are a broad class of computational algorithms that rely on repeated random sampling to obtain numerical results; typically one runs simulations many times over to obtain the distribution of an unknown probabilistic entity. The name comes from the resemblance of the technique to the act of playing and recording results in a real gambling casino. They are often used in physical and mathematical problems and are most useful when it is difficult or impossible to obtain a closedform expression, or infeasible to apply a deterministic algorithm. Monte Carlo methods are mainly used in three distinct problem classes: optimization, numerical integration and generation of draws from a probability distribution (Acebes et al, 2014). In time management, Monte Carlo simulation may be applied to project schedules to quantify the confidence the project manager should have in the target project completion date or total project duration. A three-point estimate is often used to simplify this practice, where the expert supplies the most-likely, worst-case, and best-case durations for each task or group of tasks. The project manager can then fit these three estimates to a duration probability distribution, such as a normal, Beta, or triangular distribution, for the task. Once the simulation is complete, the project manager is able to report the probability of completing the project on any particular date, which allows him / her to set a schedule reserve for the project (Kwak and Ingall, 2007). Using Monte Carlo Simulation Method, executing this step repeatedly, an arbitrarily large number of realizations of project completion time may be generated allowing inference of its uncertainty (Van Dorp and Duffey, 1999). Simulation is a process of replicating the real world based on a set of assumptions and conceived models of reality. As the purpose of a simulation model is to duplicate reality, it is an effective tool for evaluating the effects of different designs on a system's performance (Wang et al, 2003). Monte Carlo simulation is a numerical procedure to reproduce random variables that preserves the specified distributional properties (Carmel et al, 2009). In Monte Carlo simulation the system response of interest is repeatedly measured under various system parameter sets generated from the known or assumed probabilistic laws. It offers a practical approach to the uncertainty analysis because the random behavior of the system response can be probabilistically duplicated (Zhu et al, 2002). On the basis of calculating the accumulative probability distribution data of duration for each activity in a certain project, Monte Carlo method was used to simulate the duration for each activity and the overall project to acurately determine the completion probability of the project under considering of the changeability and randomness of duration for each activity (Wang and Huang, 2009). In time management, Monte Carlo simulation may be applied to project schedules to quantify the confi dence the project manager should have in the target project completion date or total project duration. Project manager and subject matter experts assigns a probability distribution function of duration to each task or group of tasks in the project network to get better estimates. A three-point estimate is often used to simplify this practice, where the expert supplies the most-likely, worst-case, and best-case durations for each task or group of tasks (Kwak and Ingall, 2007). In the Monte Carlo Simulation process, the critical path will be stabilized when simulation times N is large enough, so that the probability distribution of a certain project's activity duration is obtained on which the probability of project completion duration in the stipulation time (Chen et al, 2009).

2.5 Economics Constraints

The economic constraints mainly happened with budget limit and allocation of the money. Due to the budget limit, the adopted construction system may not be the best option for achieving the project goal and quality. It will affect the proceeding of the project. As for the allocation of money to be used in the project, if the money is not effectively allocated, it will affect the progress of the project. The effect on the project is the product quality and performance of the project. In summary, if economic constraints for the project could not be managed well, the product/performance/function/quality of the project will be affected (Lau and Kong, 2006).

2.6 Qualitative Risk Analysis

The Qualitative Risk Analysis process involves determining what impact the identified risks will have on the project on the project objectives and the probability they will occur (Heldman, 2015). The Qualitative Risk Analysis process also considers risk tolerance levels, especially as they relate to the project constraints (Financial, Time, Design and Quality) and the time frames of the potential risk event (Gould, 2003). The general risks that occurs on any project can be classified into four major areas:

1. Financial. The project will cost more than the money that has been allocated to it, or it will cost more than the product itself is worth.
2. Time. The project will not be completed within the planned time. Worse, it will be completed so late that it has an adverse effect on other parts of the owner's work.
3. Design. The project will no perform the function for which it was intended or, more commonly, will perform the function in a degraded manner.
4. Quality. The project will have poor-quality materials or workmanship, or the work will be incomplete in some way.

Risk Probability and Impact Matrix is an overall risk rating for each of the project's identified risks. The combination of probability and impact results in a classification usually expressed as high, medium, or low (Heldman, 2015). High risks are considered a red condition, medium risks are considered a yellow condition, and low risks are considered a green condition, this ranking known as ordinal scale as the values are ordered by rank from high to low (PMBOK, 2017)

2.7 Primavera P6

Primavera P6 Professional Project Management enables project driven organizations to intelligently manage their programs and projects—from small and simple to large and complex. Primavera solutions can help to make better portfolio management decisions by providing end-to-end, real-time visibility into all relevant information. Users can determine whether they have sufficient resources and team members with the right skills to accomplish the work. Primavera solutions help users to evaluate the risks and rewards associated with projects and programs. Getting the project management, collaboration, and control capabilities required to manage change and successfully deliver projects on time, within budget, and with the intended quality and design.

Users can interoperate with ease across the enterprise with Primavera's flexible integration capabilities (Oracles,n.d, 2014). It empowers project managers and team members to work together and reduce risk thorugh (Oracles,n.d, 2014):

1. Flexible planning and scheduling analysis to stay on target, including critical path scheduling, baseline, Grantt charts, trade logic and analysis in event of changes.
2. Advanced reporting and analysis for key performance metrics, project dashboards and look ahead reports.
3. Strong accountability management practices to track action items and responsibilities.
4. Better resource management to effectively plan labor, equipment, materials and keep everyone billable.
5. Integrated cost management to help forecast profit, conduct earned value analysis, compare estimates and integrate with accounting.

Customizable contingency management to help identify, plan and mitigate risk, track issues and set automatic alerts.

2.8 Work Breakdown Structure (WBS)

When projects are simple, consisting of few defined activities, it might be possible to grasp the total construction effort with little difficulty. Unfortunately, most projects for normal schedule are prepared with dozens or even hundreds of activities. When a project consists of numerous of activity, it often suggest to organize the activities in some way to make it possible to communicate the schedule information to others and to maintain an understanding of the various aspects of the project (Hinze, 2011). The work breakdown structure is a convenient way to group activities into a work packages. Work packages includes all of the works performed to complete a particular facility component. There are possibly many level of the work breakdown structure.

2.9 Monitoring and Controlling

A proper planning and control through scheduling, monitoring and evaluation have been found to be among the necessary elements, which contribute to the success of new products and research and development projects (Dvir et al, 2003). Unfortunately, for a complex project management proper planning cannot ensure the effectiveness of managing the project, we need to monitoring and controlling the scheduling, resources or etc have add that these planning and control tools focus on measuring specific performance aspect of the system, such as task completion, cost and schedule, which may be important to some stakeholders but are unable to show if the system is maturing adequately over the development life cycle (Magnaye et al, 2014).

CHAPTER 3

METHODOLOGY

3.1 Introduction

The flow chart in Figure 3.1 is designed to illustrate the entire procedures and activities in this project. In this project, the construction master schedule is obtained, so as to reschedule the required data by using Primavera P6 and Microsoft Excel as manual calculation. The 2 most important data are schedule of the project and the Bill of Quantities of the ongoing project. After, obtain the schedule of the project, determine the risk level of the activities qualitatively base on the Risk Matrix. Then assign the expected optimistic, most probable and pessimistic duration of the activities based on the risk level in the Risk Matrix. During planning stage, few approaches are proceed on the same time in order to validate the accuracy of the results. The approaches are using Primavera P6 to identify the critical path of the project, manual calculating the critical path of the project using conventional Critical Path Method and using Monte Carlo Simulation method to identify the critical path of the project. Then, the results from the approaches are compared and validated with actual project progress for accuracy checking. Finally, the simulated completion duration and the cost of the project will be optimised to achieve a most probable completion duration with minimum cost. Thus, it can be used as a guideline for monitoring and controlling purposes in construction management.

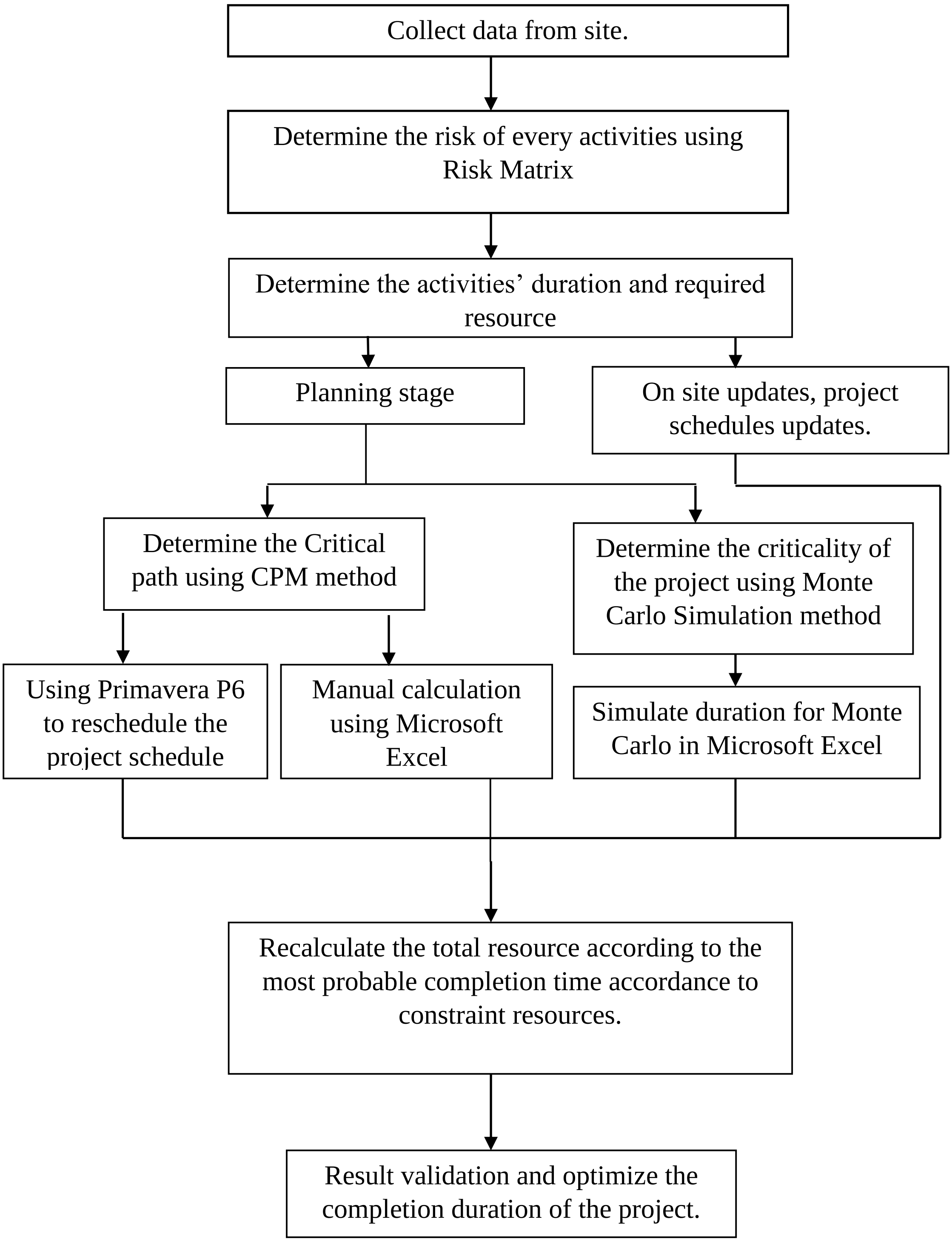

Figure 3.1: Flow Chart

3.2 Data Collection

The Master Schedule provided by consultant need to be analysed. The project schedule was prepared by the contractor required to be checked for the duration and the flow of work that are involved in the construction. The AMBU projects (AMBU B4 Building and AMBU canteen) are to be monitored by the consultant to ensure that the work in according to schedule. The Project Manager is required to be updated by the Contractor about work progress so that the schedule can be analysed to prevent problems on the site, such as delay that can affect the schedule and overall cost of the whole project.

3.3 Data Analysis

3.3.1 Qualitative Risk Analysis

The first step is to categorise the activities into difference degree of risk level using the Risk Matrix based on their Impact Rating and Probability Rating which are shown in the Figure 3.1. Then the activities' expected durations which are optimistic duration, most probable duration and pessimistic duration are determined based on their risk level respectively (Ganame and Chaudhari, 2015).

Risk Matrix						
PROBABILITY	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
	IMPACT					

Figure 3.2: Risk Matrix

3.3.2 Critical Path Method Manual Calculation

The first approach is to manually calculate the schedule to determine the critical path of the project ABMU B4 Building and AMBU Canteen. The project schedule is recalculated in 2 ways which are forward pass and backward pass (Newitt, 2005).

Algorithm of Forward pass calculates at the beginning of the project and move to the end of the project, from left to right to obtain the earliest finish time of every activities.

$$EF_{ij} = ES_{ij} + t_{ij} \tag{3.1}$$

Proceed to next node using j as next node, then compute the earliest occurrence for next node using equation (3.2)

$$ES_j = max\{EF_i\} = max\{ES_i + t_{ij}\} \tag{3.2}$$

Algorithm of Backward pass calculates at the end of the project and move to the beginning of the project, or from right to left of the schedule to obtain the latest finish time of the activities.

$$LS_{ij} = LF_{ij} - t_{ij} \tag{3.3}$$

Proceed backward pass to the node in the sequence that decrease j by 1, then compute the latest occurrence for the next node i (i<j) using the equation (3.4)

$$LS_i = min\{LF_j\} = min\{LF_j + t_{ij}\} \tag{3.4}$$

The criticality of the activity is determined by the following condition:

$$TF_i = LF_j - EF_i \tag{3.5}$$

$$TF_i = 0 \tag{3.6}$$

The TF indicates the activity has zero free time to before proceeding the successive.

3.3.3 Monte Carlo Simulation Method for Schedule Analysis

The second approach is Monte Carlo Simulation Method. It generates random results with numerous trials. The simulation has average 1000 to 10000 trails to generate a normal distribution curve, but in this project 5000 trials is used in this simulation model. Standard Normal Distribution Table is a table that shows probability that a standard normal random variable Z is less than a number z:

$$\Phi(z) = \Pr(Z < z) \tag{3.3}$$

A standard normal random variable Z is a random variable with mean equals to zero and standard deviation equals to 1.

$$If\ Z\ is\ N(0,1)\ and\ Y\ is\ N(\mu, \sigma^2), then\ Y = \sigma Z + \mu \tag{3.4}$$

According to the equation, the Z value can be generated randomly using Microsoft Excel (Winston, 2014). The mean and standard deviation value of the expected durations which are optimistic, most probable and pessimistic duration can be calculated by this following equation (Hiller et al, 2008),

$$\mu = \frac{a + 4m + b}{6} \tag{3.5}$$

$$\sigma^2 = \frac{(b - a)^2}{36} \tag{3.6}$$

$$a = optismistc\ duration; m = mostprobable\ duration; b = pessimisitc\ duration$$

Using Microsoft Excel to enter the function NORM.INV(RAN( ), Mu, Sigma), to generate random values. Then the values are recorded and tabulated. The random data is then averaged to obtain the most probable completion duration.

3.3.4 Using Software Primavera P6

The third approach is using software Primavera P6 to analyze the schedule Project AMBU B4 BUILDING and AMBU CANTEEN. The provided schedule is Microsoft Manager format, therefore the schedule period need to be reschedule using the software by entering the starting date of the activities and the duration of the activities to complete. The software able to schedule the activities to obtain the longest path of the project which is the critical path for the project itself.

3.3.5 Monte Carlo Simulation for Cost Analysis

The cost of every activities in the project is obtained from the Bill of Quantities of the Project AMBU. The first step is to simplify the cost of every activities, then multiple the cost per day with the duration of the activities (Klanšek and Pšunder, 2010)

$$C_T = \sum_{i \in I} C_i(D_i) + C_I(D_L) + P(D_L) - B(D_E) \tag{3.7}$$

The total cost of the project is C_T where as $P(D_L)$ and $C_i(D_i)$ are Penalty-duration function and Direct cost duration function respectively. In this project AMBU, the value $B(D_E)$ is assumed to be zero due to no bonus is allocated if project is completed before expected completion duration. Whereas, the value $C_I(D_L)$is included into the direct-cost of the project as the labor cost is paid by every 10% of the material cost in every activities based on the contractor. Then, the total project cost is obtained from the simulation which has generated 5000 trials to find the average cost of the project, maximum cost of the project and the minimum cost of the project.

3.3.6 Optimization of Total Project Cost and the Project Complete Duration

After obtaining the average total cost of the project and the most probable completion duration of the project, the average cost is divided by the average cost per day in the entire project in order to obtain the complete duration of the project based on the average total coast of the project. Then the time based on cost is divided with the most probable completion duration so as to be optimized. Since it is a converging constraint optimization, the both the result can be reduced to a correlation approach 1.

3.3.7 Validation and comparison of Simulated data and Actual Data

The actual site progress is obtained from the contractor which is used to compare with the simulated data using Monte Carlo Simulation Method. The delay percentage is compared between the actual schedule progress and the simulated schedule progress in order to identify the differences of the percentages of delays. The comparison can be provided as a guide for the Project Manager to forecast the upcoming schedule progress.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discusses about the analysis of the result and discussion on the scheduling using Primevera P6 and Microsoft Excel 2013 (Manual Calculation). A site visit was made to the project in Bayan Lepas, Penang to collect more data from the construction site. All collected data is analyzed using Critical Path Method, S-Curve, and Monte Carlo simulation method.

4.2 Result of Qualitative Risk Analysis

The activities risk level are determined by using Risk Matrix. Thus, the result is used to determine the expected durations which are optimistic duration, most probable duration and pessimistic duration. The risk level of each activity is qualified by tcertain range of risk which are risk level from 1to 5 indicates the activity is in low risk, risk level from range of 6 to 12 indicates the activity is in Medium Risk and risk level from range of 13 to 25 is considered high risk activity. The risk level of the activities are shown in the following Table 4.1 and Table 4.2.

Table 4.1: Activities of AMBU CANTEEN Risk Level

No.	Activity	Scale	Risk Level
123	Setting out for pile points	10	MEDIUM
124	Piling work for column piles (1 machine)	20	HIGH
125	Pile cap & Stamp	9	MEDIUM
126	Ground Beam	9	MEDIUM
127	Ground Floor Slab (level 1)	9	MEDIUM
129	Level 1 column & Level 2 Beam & Slab	9	MEDIUM
130	Level 2 column & Level 3 Beam & Slab	9	MEDIUM
131	Level 3 column & Roof Beam	9	MEDIUM
132	Roof trusses & Roof Covering & Water Tight	9	MEDIUM
134	Brick wall	9	MEDIUM
135	Plastering	6	MEDIUM
136	Tiling	9	MEDIUM
137	Ceiling	9	MEDIUM
138	Kitchen Equipment	9	MEDIUM
139	Painting	9	MEDIUM
144	Installation of Ceiling Cassetes Units	9	MEDIUM
145	Ceiling Coordination and Finishes	9	MEDIUM
146	Test and Comisioning	5	LOW
149	Installation of Trunking/ Conduit Works	15	HIGH
150	Installation of DBs & Sub Main Cabling	15	HIGH
151	Lighting & Power Fixture Installation	15	HIGH
152	Test and Commissioning	5	LOW