CHAPTER II

LITERATURE REVIEW

In this chapter, there will be spreads of the literature studies. The literature review presents a review on the current state of the research on this emerging subject, summarizes the results of primary research to present the fact that a more comprehensive and balanced. The review aimed at literature review on maintenance process was by the previous study that explained the maintenance management. The theoretical basis for supporting the problem-solving in the research also explained in the literature review.

1.1 Review on Previous Research

The development in wind turbine energy technology is not limited to the significant increase in the size of modern units, but also includes the high reliability and availability of the current machines (Abderrazzaq & Hahn, 2006). The fundamental operating feature of the power system is that the electrical energy production and consumption are simultaneous. Therefore, the reliability requirement within the electricity industry is very high (Kumar et al., 2007). If wind turbine which refers to distributed energy resource are not managed effectively, it will increase investment cost and sharply increase system operation cost that affect the absorption of distributed energy resource itself by the system in return (Xia & Liu, 2016).

Maintenance can be defined as all activities necessary to restore equipment or in this case, is machinery and also to keep in a state which it can perform its designated function (D. Jonge, 2017). The maintenance of power system equipment and especially the maintenance of generating units are implicitly related to power system reliability and have a tremendous bearing on the operation of the power system (Kumar et al., 2007). Therefore, it is necessary to assess the plant availability by analysing the actual fault and maintenance records even there are some restriction in deveoping this strategies which can be attributed to the variation in location, resources and other factors that are claimed to be the sole province of the end user of the product (Abderrazzaq & Hahn, 2006). Unfortunately, only few researchers have

discussed the performance and reliability of existing wind turbines. Whereas the majority of works in this field were either very general or just focused on the reliability of a specific part of wind turbine (Abderrazzaq & Hahn, 2006). Another rarely studied issue is the long-term impact of distribution network on the turbine performance and productivity. In contrast, most of the researches are now oriented towards the impact of wind turbines on the networks, and not the opposite (Boulaxis et al., 2001). In general for complex systems, e.g., electric systems, maintenance does not necessarily mean replacing the whole system. It often includes the repair or replacement of a part of the system (Perez-canto & Rubio-romero, 2013).

This research tries to review the literature of maintenance management. Research about maintenance has done by several researchers. Xia & Liu, (2016) mentioned about optimization scheduling maintenance by elaborating the risk management. Due to intense electricity consumption, environmental concerns, and technological development, a great number of renewable distributed resources have been widely installed in the distributed network. The aim of this paper is mainly to analyze optimal scheduling of Virtual Power Plant model to maximize its profit, with due consideration given to the uncertainty of renewable energy output, such as wind power, and to make the energy mix respond to system need. A risk quantization method is introduced to deal with uncertainty. This paper presents a scheduling model, which takes total operation cost, traded electricity cost, unit earnings, supply-demand balancing and other constraints into account, with a risk quantization assessment method embedded into this model. According to the scenarios generated by the uncertainty of wind power output, numerical results for a proposed case are discussed. These results show the expected profit of scheduling is closely associated with different degrees of confidence, which is a great help for the operators when making the tradeoff between risk and profit. From the journal of (Xia & Liu, 2016) the information about distributed network system already explained and it has an important role in the renewable energy resource power plant.

Perez-canto & Rubio-romero (2013) addresses the problem of power plant preventive maintenance scheduling. The main task is to determine the period for which generators of an electric system should be stopped for planned preventive maintenance over a certain time horizon. (Perez-canto & Rubio-romero, 2013) used mathematical model in order to evaluate which generators must stop production to be checked periodically for safety reasons in the

wind farms. From this previous research, the information about the preventive maintenance policy which used scheduling maintenance is expected.

The information about scheduling maintenance to support the research proposed also conducted by the previous research of Samaranayake & Kiridena (2012) which mentioned about the execution of aircraft maintenance planning and scheduling operations under uncertainty involves materials changes, rectification, and re-assembly. It is shown that re-scheduling of materials (spare-parts), resources and operations can be taken care of by simultaneous and dynamic forward planning of materials and operations with the finite loading of resources, using the integrated framework. By way of accounting for a wider range of situations at the planning stage, any unplanned maintenance activities can be effectively dealt with at the execution phase using the forward planning capabilities built into the unitary structure with merged functionalities of the three techniques of CPM, MRP, and PAC. The utility of the proposed approach was demonstrated using a test case where a maintenance project with possible unplanned maintenance tasks and associated activities and resources was briefly discussed. Potential benefits of adopting the proposed framework include on-time project completion, reduced inventory of spare parts and reduced overtime costs.

Moreover, the previous researches on network analysis scheduling using CPM and PERT methods conducted by (Sandyavitri, 2008). It shows that shortening duration conducted with four alternative ways, namely by way of overtime, working alternately, the addition of new labor, and with partial removal of labor from other activities. The method of shortening duration of activities carried on in the critical path based on calculation, obtained an increase in total cost of Rp 65,509,817, - due to the shortening the duration of implementation work of 68 days to 53 days with alternate work (shift).

Research about maintenance also conducted by Elmabrouk & Aljiebali (2012) which provides a framework for crashing total maintenance project time at the least total cost by using Linear Programming (LP) technique which assisted by CPM (critical path method) and PERT (Project Evaluation Review Technic) for maintenance project manager to carry out their responsibilities. To determine the extent of crashing project time of the project after crashed this paper present the development a CPM based on crash time of the activities that will provide the minimum time beyond which the project cannot be crashed. The events on

the critical path have zero slack, dummy activity has no duration and the total duration for the completion of the project is 110 days based on the critical path. After crashing, the project completion became 105 days with the total cost for crashing $ 3500,000. The findings from this research to support the research proposed are CPM method are available in order to analyze the project completion crash time. Moreover, the comparison between previous research and the research proposed can be seen in Table 2.1:

Table 2.1. Review on Previous Research

Author and Research Year	**Research Title**	**Research Findings**	**Research Method**
Xia & Liu, (2016)	Optimal Scheduling of Virtual Power Plant with Risk Management.	Network system already explained it has an important role in the renewable energy resource power plant	Risk Management, Maintenance Scheduling
Perez-canto & Rubio-romero (2013)	A model for the preventive maintenance scheduling of power plants including wind farms.	Used mathematical model in order to evaluate which generators must stop production to be checked periodically for safety reasons in the wind farms.	Mathematical Model, Preventive Maintenance Scheduling
Samaranaya ke & Kiridena (2012)	Aircraft maintenance planning and scheduling: an integrated framework.	Unplanned maintenance activities can be effectively dealt with at the execution phase using the forward planning capabilities built into the unitary structure with merged functionalities of the three techniques of CPM, MRP, and PAC.	CPM, MRP, and PAC.

Author and Research Year	Research Title	Research Findings	Research Method
Sandyavitri (2008)	The Change Impact Control Design Against Time and Cost of Construction Works.	Obtained an increase in total cost of Rp 65,509,817,00 due to the shortening the duration of implementation work of 68 days to 53 days	PERT, CPM
Elmabrouk & Aljiebali (2012)	Crashing Project Activities Using Linear Programming Technique	The events on the critical path have zero slack, dummy activity has no duration and the total duration for the completion of the project is 110 days based on the critical path. After crashing, the project completion became 105 days with the total cost for crashing $ 3500,000.	CPM, PERT, Linear Programming

From the maintenance previous research, the research gap, each of previous research can be analyzed in order to fulfill the research purposed. Table 2.1 explains the objective focused on each previous research and the previous research by comparing the previous research with the research purposed. There are scheduling maintenance objective and network system analysis project. From the checklist, the researcher tried to fill the gap of research in preventive maintenance problems, scheduling maintenance process objectives, and network system analysis as shown in Table 2.1.

From the Table 2.1, it will explain the comparison between previous research with the research purpose. Research about operation and maintenance process has a different focus objective. For the research of preventive maintenance scheduling was observed by Xia & Liu

(2016); Perez-canto & Rubio-romero (2013) and Samaranayake & Kiridena (2012). While Sandyavitri (2008) and Elmabrouk & Aljiebali (2012) focused on network analysis system of the maintenance process. Therefore, the research proposed tried to collaborate the research gap between analysis maintenance scheduling process and network analysis of maintenance process.

1.2 Maintenance Management

Maintenance management has traditionally been a reverse engineering activity, where the decision process has been highly correlated with the technical and mechanical education of the maintenance staff and their own practical experience. Even if accumulated technical experience is essential, it should not be the only basis for maintenance related decisions (Rausand & Høyland, 2004). Maintenance decisions have to take into account a large number of decision criteria that may sometimes be contradictory. To choose the "best" maintenance task at the "best" possible time is a complex task that does not depend only on the current state of the item, but also on future factors like the consequences of this choice for the long term exploitation of the item. Shin & Jun (2015) defined that maintenance is all technical and managerial actions taken during usage period to maintain or restore the required functionality of a product or an asset. Maintenance aims to reduce the degradation of the operational of an asset in order to keep the performance working properly. Maintenance consists of sustaining and improving availability which can turn the effect of productivity (Alrabghi & Tiwari, 2015).

The importance of maintenance also explained by (Mobley, 2008) which stated that the primary reason for establishing a maintenance engineering function is to provide focus on asset reliability, maintainability, and life-cycle cost for the entire facility. Maintainability is the probability that a failed item will be restored to operational effectiveness within a given period of time when the repair action is performed in accordance with prescribed procedures. This can be paraphrased as 'The probability of repair in a given time. Although maintenance can increase machine reliability in the long term, the machine or equipment should be stopped in order for the maintenance tasks to be safely performed, which may interrupt the system throughput in the short term (Ni et al., 2015). Considering the safety and benefits maintenance loss parameters such as downtime losses and minimal repair cost should be analyzed comprehensively to investigate the influence of different maintenance strategies (Hu & Zhang, 2014).

Maintenance strategies involve both repairing failed systems (corrective maintenance), preventing breakdowns (preventive maintenance), and opportunistic maintenance. Figure 2.1 will explain the different of maintenance strategies:

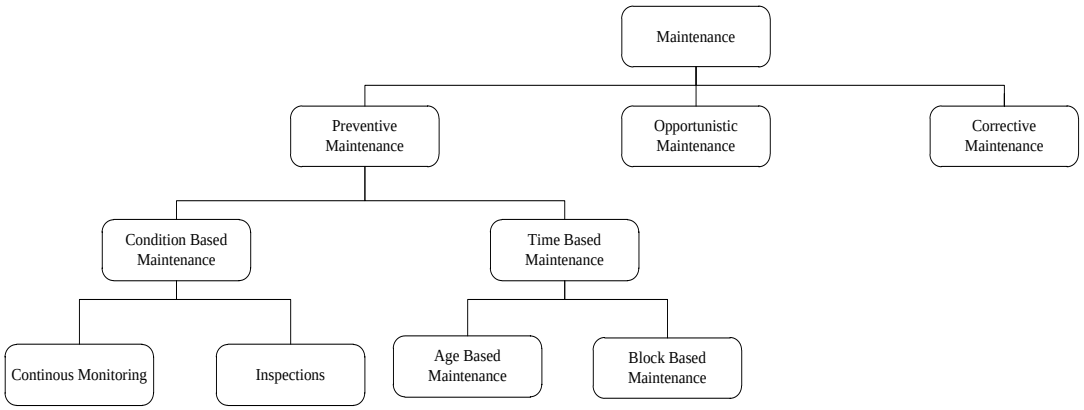

Figure 2.1 Schematic Overview Maintenance Policies

Source: D. Jonge (2017)

The practice of the maintenance are adopting different kind of policies. If the equipment fails, then it can be maintained by Corrective Maintenance policy (Cavalcante & Lopes, 2015). Wang et al., (2014) mentioned that corrective maintenance is a maintenance task performed to identify and rectify the cause failures for a failed system. The study about corrective maintenance also has done by Adolfsson (2011) which found that one of disadvantage for the developer if conduct the corrective maintenance is unplanned machine stops in every minute that caused a large cost. It makes the corrective maintenance is a vital process to maintain the correcting machine failures. To improve availability by decrease the unscheduled failures in order to increase system reliability and safety there are maintained by Preventive Maintenance (Cavalcante & Lopes, 2015). The decision rule is to determine when the actions of minimal repairs and the maintenance must be performed (Azadeh et al., 2015).

Preventive maintenance is determined based on the time the, parts of the installation has been operational and is scheduled up front. Corrective maintenance jobs arise from faults and are assigned a certain priority by the originator of the work request. This priority determines the sequence of work planning, the highest priority jobs are first in line to be planned and scheduled. High priority corrective orders are scheduled before low priority preventive orders. The priority is based on the criticality of the equipment and on the type of work that has to be performed and can be determined with an organization specific ranking index or risk matrix (Simões, Lda, & Gomes, 2011). Preventive maintenance is generally preferred since breakdowns occur at unexpected moments and can have severe consequences. Two types of preventive maintenance can be distinguished by predetermined maintenance or well known as time-based maintenance (TBM) and condition-based maintenance (CBM)

(Jonge et al., 2015). Condition-based maintenance (CBM) is one of the knowledge which studied about the maintenance program that recommends maintenance actions (decisions) based on the information collected through condition monitoring process. In (CBM), the lifetime (age) of the equipment is monitored through its operating condition, which can be measured based on various monitoring parameters (Ahmad & Kamaruddin, 2012). Although the Condition Based Maintenance (CBM) is an applicable policy to improve equipment reliability and efficiency. By the characteristics of CBM which can estimate remaining useful life of the equipment, it is an effective strategy which can be compared to other maintenance strategies (Azadeh et al., 2015). Condition-based maintenance (CBM) is the practice of diagnosing the condition of an expensive long-life asset by condition monitoring and following with an appropriate maintenance action. By inspecting an asset, it may be possible to obtain a better understanding of the condition of the item and thus intervene with an appropriate maintenance action prior to failure (Ye et al., 2015). Condition-based maintenance (CBM) also can be implemented in order to analyze the real availability condition.

In the case of wind turbine generator, Mabel et al., (2011) stated the 'availability' of a wind turbine refers to the percentage of time it is in a position or state for generating power. Servicing, inspection, component failures and accidents, such as lightning strikes reduce the availability of wind turbine. The availability of each wind turbine in a may differ depending on the net period of time for which it is functional with regard to power generation. While (Abderrazzaq & Hahn, 2006) state the availability of wind turbine is not easy to guarantee by the manufacturer alone, even if he has the right maintenance tools. This can be attributed to the variation in location, resources and other factors that are claimed to be the sole province of the end user of the product. Time-based maintenance (TBM), also known as periodically based maintenance a traditional maintenance technique. The decision of (TBM) determined based on failure time analyses. In other words, the aging (expected lifetime) of some equipment is estimated based on failure time data or used based data (Ahmad & Kamaruddin, 2012).

2.2.1 Maintenance Scheduling

Scheduling of maintenance basically considering the person who in charge to do the job and when the job should be started or done. Different type of schedules are made suiting the

respective job plans and different techniques for making or following the schedules. Analysis of maintenance scheduling also can be elaborated by the project of scheduling. The project schedule includes at least planned start and expected finish dates for each activity. The project schedule remains preliminary until resource assignments have been confirmed. According to Project Management Institute (2013), project schedule may be presented in summary form (the master schedule) or in detail. Although it can be presented in tabular form, it is more often presented graphically, using one or more of the following formats:

a. Project network diagram with date information added (shown in Figure 2.2). These charts usually show both the project logic and the project's critical path activities. It is a graph (flow chart) depicting the sequence in which a project's terminal elements are to be completed by showing terminal elements and their dependencies. It is always drawn from left to right to reflect project chronology. An example of project network diagram with dates is shown in Figure 2.2.

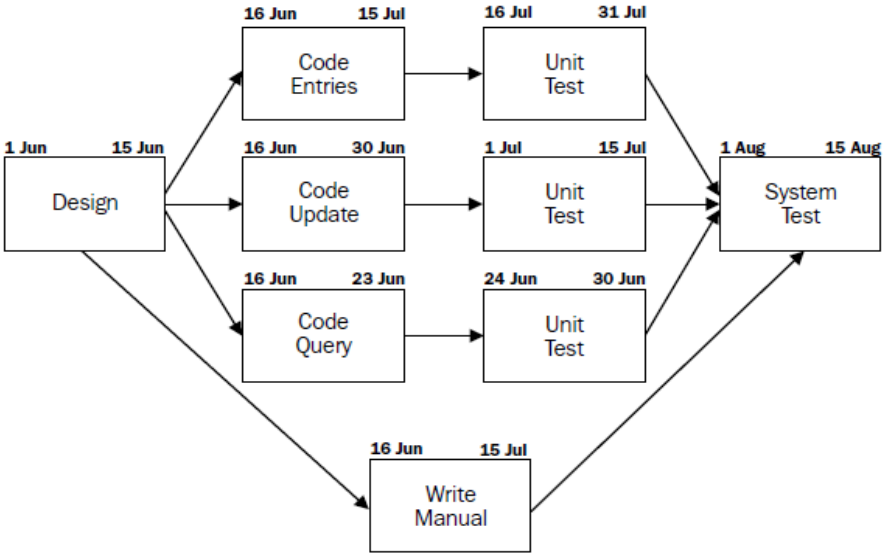

Figure 2.2 Project Network Diagram with Dates

Source: Project Management Institute (2013)

There are many other acceptable ways to display date information on a project network diagram. From the figure above shows start and finish dates without time-of-day information. In the context of project planning, a network diagram is a sequence of steps (activities), commonly represented by blocks, that are linked together in the logical sequence they need to be carried out.

b. Bar charts, also called *Gantt Charts* (shown in Figure 2.4), show activity start and end dates, as well as expected duration, and sometimes show dependencies. They are relatively easy to read and are frequently used in management presentations. Although now regarded as a common charting technique, Gantt charts were considered revolutionary when first introduced. This chart is also used in information technology to represent data that have been collected. The example of a bar chart (Gantt chart) can be seen in Figure 2.3.

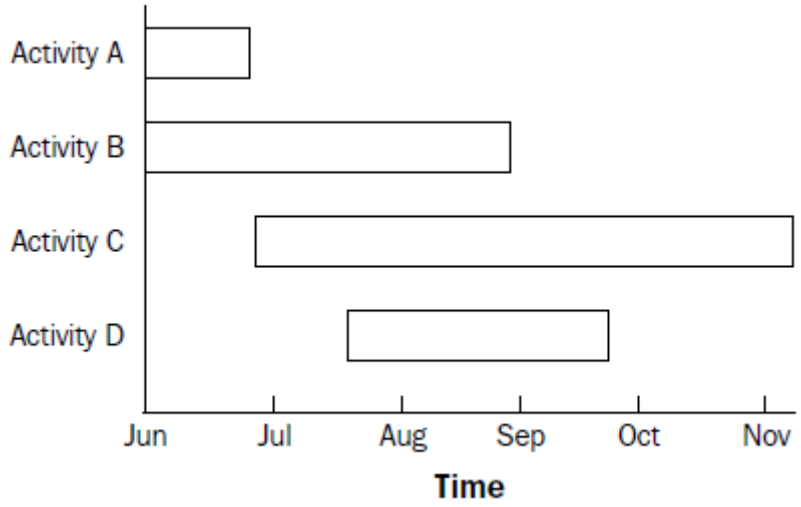

Figure 2.3 The Example of Bar Chart (Gantt Chart)

Source: Project Management Institute (2013)

There are many other acceptable ways to display project information on a bar chart. Gantt charts illustrate the start and finish dates of the terminal elements and summary elements of a project (Maylor, 2001). Terminal elements and summary elements comprise the work breakdown structure of the project. Modern Gantt charts also show the dependency (precedence network) relationships between activities.

2.2.2 Project Management

Project management is considerable economic importance and dramatic growth has occurred in project work across different sectors, industries and countries (Turner et al., 2010). The relationship of Project Management to Other Management Disciplines are shown in Figure 2.4:

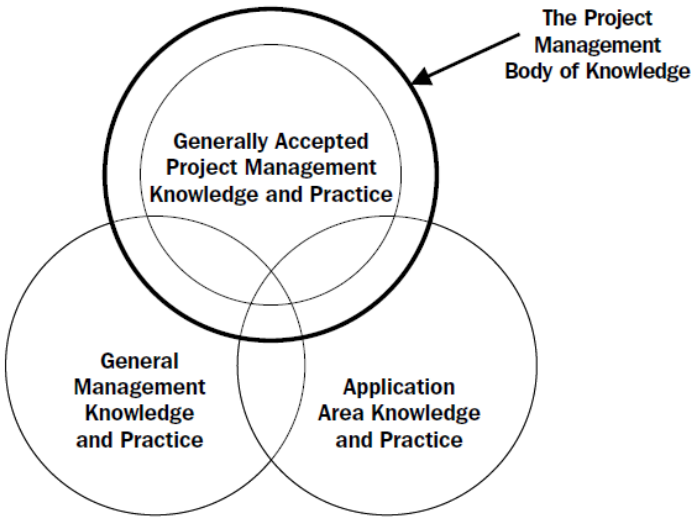

Figure 2.4 Relationship of Project Management to Other Management Disciplines

Source: Project Management Institute, 2013

Much of the knowledge needed to manage projects is unique to project management. The overlaps shown are not proportional. In the other hand, Horine (2009) defined project management as the application of a body of knowledge, skills, tools and techniques to project activities to meet project requirements. Project working is the fulfillment of a task under the constants of time pressure, so time is an extremely important measure for project efficiency. Because of all these challenges in executing projects, it is important to have a project plan. Project management scope is shown in Figure 2.5:

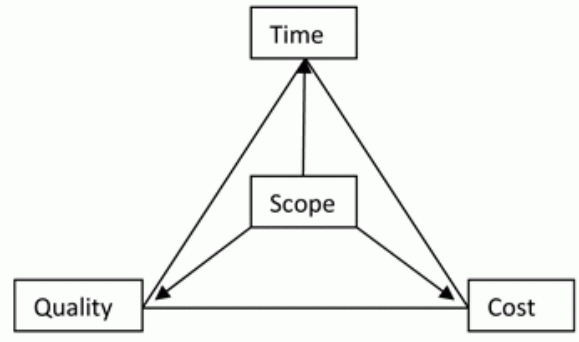

Figure 2.5 Project Management Scope

Source: Project Management Institute, 2013

The main purpose of using a project management framework is to increase organizational value (Dalcher, 2012). The organization can benefit from using project management framework by increasing the effectiveness of human effort in the organization while increasing the efficiency of these efforts. Therefore, project success is measured by its

efficiency in the short term and its effectiveness in achieving the expected results in the medium and the long term (Jugdev et al., 2001; Müller and Jugdev, 2012). Therefore, the value of the project can be understood in so far as it satisfies customer needs, aligns the project output with the organization's strategy and gives a return on investment (Thomas and Mullaly, 2008).

2.2.3 Critical Path Method (CPM)

A project plan, in the beginning, is a simple planning tool, however, while working on the project it will become one of the most important control instrument and after ending the project it is a measurement of whether the project plans and what different approaches to project plans are used in practice. According to Taha (2008) Critical Path Method is are network-based methods designed to assist in the planning, scheduling, and control of projects. A project is defined as a collection of interrelated activities with each activity consuming time and resources. CPM (Critical Path Method) is the one of network scheduling technique which approach to estimate project duration. CPM is deterministic and uses fix time estimates for each activity. CPM has its advantages and disadvantages. Some of the CPM advantages are as follows:

1. It is an effective tool for monitoring project progress.
2. It helps improve project understanding and communication among involved personnel.
3. It highlights activities important to complete the project on time. These activities must be completed on time to accomplish the entire project on predicted time.
4. It shows interrelationships in workflow and is useful in determining labor and resources needs in advance.
5. It is an effective tool for controlling costs and can easily be computerized.
6. It helps to avoid duplications and omissions and to determine project duration systematically.

Critical Path Method also commonly used method among others systems that using networking system. By using Critical Path Method, the amount of time required for completing several stages in the project can be determined with certainty. Moreover, Critical

Path Method also able to determine the resources used and time required in order to complete a certain project. Critical Path Method is a project management which emphasizes on the budget calculation as the main object to analyzed (Siswanto, 2007). Critical Path Method can be classified as a networking analysis that aimed to optimize the project budgeting by reducing or accelerating the time required to complete a certain project.

According to Handoko (1999), in the process of identifying the critical path, there are some terms or understanding that need to be learned:

a. Early Start

Early Start or ES is the earliest time that activity can start. An activity near the end of a path or much later will only start if all the previous activities in the path also started early. If any one of the previous activities slips then it will push this activity out.

b. Early Finish-EF

Early Finish or EF is the earliest time that activity can finish. It is the date that an activity can finish if all previous activities started early and none of the activities slipped.

If project manager and the team know about the early start and early finish dates of all the activities(tasks) then they will know how much freedom they have to move the start dates without causing any problem to the project.

c. Late Start-LS

Late Start or LS is the latest time an activity can start. If an activity is on the path which is much shorter compare to the critical path, then it can start much late without any delay to the project. But these delay cause problem if other activities on the path slip.

d. Late Finish-LF

Late Finish or LF is the latest time that an activity can finish. If an activity is on a shorter path and all of the other activities on the same path start as well as finish early, then it can finish very late without causing the project to be late.

Knowing late start and late finish will help you see how much it can be played around on the schedule. An activity having large LS and LF means there are more options available.

The network approach to planning and scheduling consists of a method for describing the activities and events required to achieve a defined objective (the network of nodes and arrows) and a procedure for calculating the chain of activities and events (the critical path) which fix the minimum completion date for the objective (Davis, 1963).

A network is a graphical representation of the project activities and their relationships. A project network is a set of arrows and nodes. Before drawing the network, it is necessary to ensure that the project has a unified starting and ending point. The need for this start activity arises when there is more than one activity in the project that has no predecessors and the end activity is needed when there is more than one activity that has no successors. There are two ways that are commonly used to draw a network diagram, Activity on Node and Activity on Arrow, it is shown in Figure 2.6.

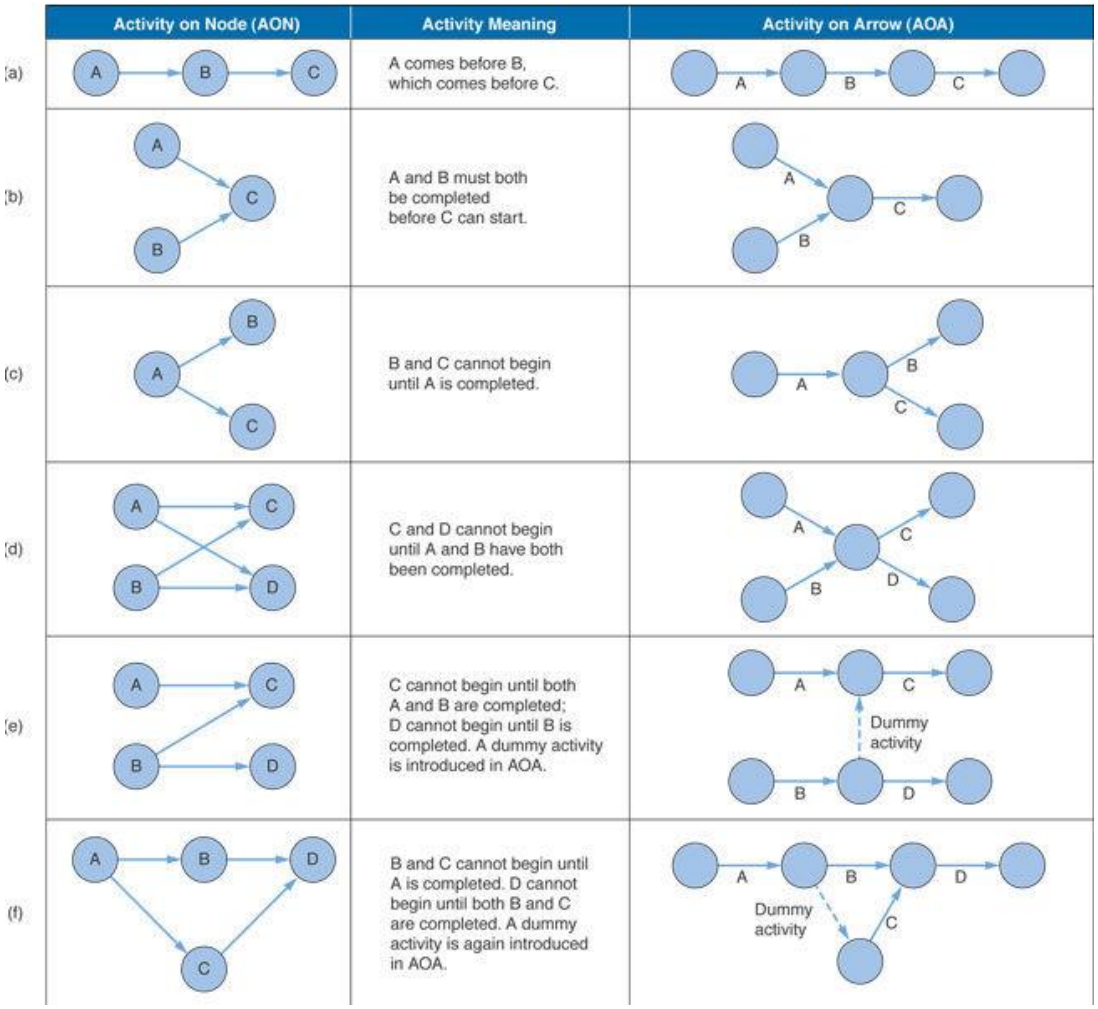

Figure 2.6 Comparison between AON and AOA

Source: Principles of Operations Management, 2004

There are many kinds of network diagram, but the classic ones are AON and AOA diagrams.

a. Activity On Arrow (AOA) diagram

AOA diagram is drawn using circles as the nodes, with nodes represents the beginning and ending points of the arrows or tasks. Arrows act as activities or tasks in AOA diagram. Even though AOA is a good approach to drawing a network diagram, it has its own drawbacks too. The following are the drawbacks of AOA network diagram conventions identified by Taylor (2008):

- The AOA network diagram can only show Finish to start relationships. It is not possible to show lead or lag time except by adding or subtracting time. This makes project tracking difficult.
- There are instances where "dummy activities" can occur in AOA diagram. (dummy activities are activities which do not have duration but simply there to show dependency of one task on another task)
- AOA networks are not supported by many software tools, thus it is not widely used.

b. Activity On Node (AON) diagram

AON network diagram is where circles are used to represent an activity, with arrows linking them together to show the sequence in which they are performed. The following are the advantages of AON network diagram identified by Taylor (2008):

- AON does not have dummy activities as the arrow represents only dependencies.
- AON can accommodate any types of relationship (Finish to Start, Finish to Finish, Start to Start, Start to finish, Lead and Lag)
- AON is wide as it is supported by almost all the project management software tools

Network planning can be defined as a method or technique that has a big role in supporting the process of planning, scheduling, and controlling a certain project. The basic principle or fundament of Network Planning lies on the project management and different activities coordination. According to Turner (2010), When there are several activities that need to be done, the network planning can be used in order to make sure that all the aspects included in the project can be finished properly in term of the quality and the punctuality of the deadline.

In the other word, Network planning also can be defined as a dependency relationship among several work components that illustrated by a form of the network diagram. From the definition above, it can be underlined that network planning will show which activities from

the several activities in the project that need to be done first. After determining the first activity that should be done, this process can be used as a base for doing the followed activities after that. Several activities required other activities to be done first. Therefore, network planning has a crucial role in the project management.

Network planning is an illustration of phenomenon and activities that will happen in the future, assembled chronologically. According to Wang (2012), the activities illustrated in the network planning have a connection or relation with each other. Network planning also used as a method for answer a question about how to manage a certain project properly.

2.2.4 Critical Path

The critical path is a path where there are several activities listed according to the most time-consuming activities, from the beginning of the network until in the end of a network (Levin and Kirkpatrick, 1977). According to Ervianto (2002), to determine the Critical Path Analysis, the Forward Analysis and Backward Analysis can be used. In the Critical Path Method, if there is one or more activities place on the critical path delay, the time required to complete the entire project will be delayed as much as the delayed times happen.

According to Giovanni (1997), critical path method assumes that activity times are not subject to uncertainty and bases the identification of project criticality on the slack time allowed for each activity completion. The attention of planners is mostly devoted to zero total slack time activities, that it to those activities belonging to so called as “critical path”. Hence most critical paths are also those ones having the lowest occurrence probability. By finding the critical path, the researcher can managers to prioritize activities for the effective management of project completion and to shorten the planned critical path of a project by pruning critical path activities or crashing on critical path activity (crash duration). By crashing on the activity, the activity itself will obtain the greatest amount of compression for the least incremental cost.

"Crash duration" is a term referring to the shortest possible time for which an activity can be scheduled. It is achieved by shifting more resources towards the completion of that activity, resulting in decreased time spent and often a reduced quality of work, as the premium is set on speed (Hendrickson, 2008). Crash duration is typically modeled as a linear

relationship between cost and activity duration; however, in many cases, a convex function or a step function is more applicable.

2.2.5 Program Evaluation and Review Technique (PERT)

There are several terminology that define the term of PERT. According to Malcolm et al., (1959), PERT is a management planning and control tool for defining and integrating what must be done to finish complex jobs in time to meet a deadline. It is a system for diagnosing and anticipating the integrated influence of time, resources and technical performance on the outlook for achieving significant end objectives. The PERT system measures and uses time as a common denominator to reflect resource applications and technical performance for research and development projects.

The original Program Evaluation and Review Technique (PERT) (Malcolm, et al., 1959) is an activity-on-arrow network with one start and one finish event, which represent the beginning and the end of a project. To accomplish the project, certain activities must be carried out according to a given pre-defined sequence. This logic is depicted by a directed, acyclic graph in which the vertices of the graph represent the events, while the arrows represent the tasks to be performed. An event occurs when all preceding activities have been completed; only then can the succeeding tasks start. In this way, the event is used for expressing logical dependencies between activities (Miklos, 2014). The example of PERT Duration Calculation for Single Activity is shown in Figure 2.5.

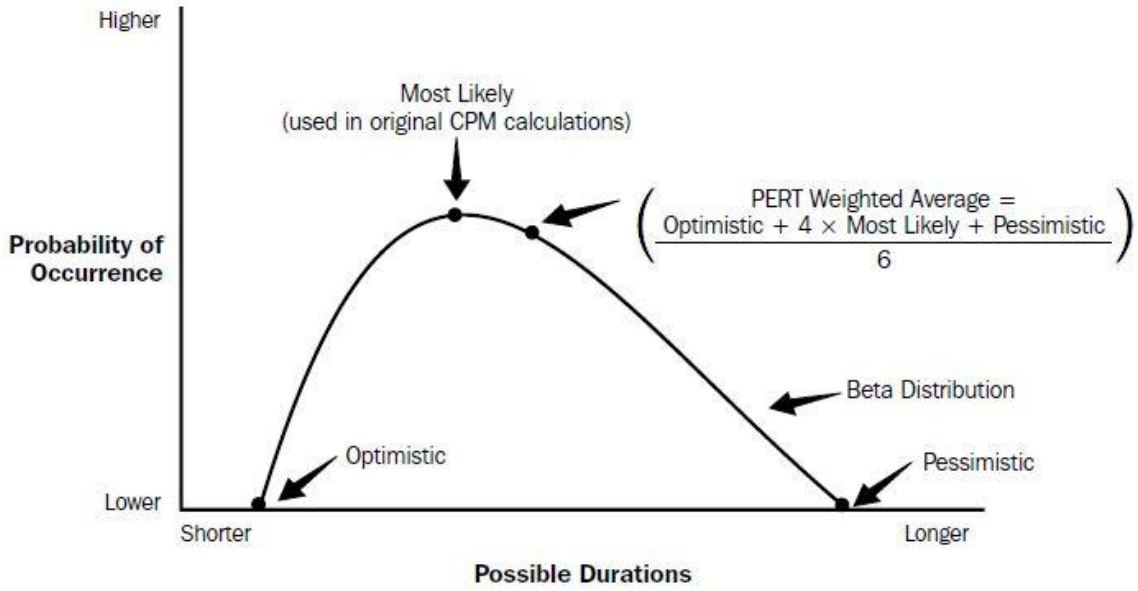

Figure 2.7 PERT Duration Calculation for Single Activity

Source: Project Management Institute, (2013)

PERT technique is a traditional, well-known approach to the expert of project management. It uses a weighted average duration estimate to calculate activity duration. Although there are surface differences, PERT differs from CPM primarily in that it uses the distribution's mean (expected value) instead of the most likely estimate originally used in CPM. According to Heizer and Render (2005), opportunity distribution is used in PERT based on the three time setimation for each activities, such as optimistic time, pesimistic time and realistic time.

PERT method has a goal to reduce any delay time, disruption of production, and also coordinating every activity's component comprehensively in order to complete the project as fast as possible. This technique will able to create a well controled and well organized activities, due to the schedule and budget of a certain activities already determined first befor being done. Levin and Kirkpatrick (1972) explained that an optimistic time is a time estimation which has a very small possibility to be achieved. The feasibility of an opstimistic time only happen once in a hundred. In the other hand, pesimistic time is a time estimation which has a very small possibility to be realized. The feasibility of the pesimistic time also happen once in a hundred. Meanwhile, the realistic time is the most possible time estimation based on the calculation of the estimator. The estimation for opstimistic time usually denote

as a letter “a”, the pesimistic time denoted as letter “b” and the realistic time denoted as a letter “m”.

In addition to the above, the programs on which PERT/CPM has proved most useful tend to be complex, have a high degree of uncertainty and/or have a high rate of interdependency among the various activities and events in the network. The primary benefits from using PERT/CPM rather than previously existing methods appear to result from the explicit recognition in planning of the interrelationships in the network and the computational procedure, based on the network, which allows for systematic analysis of alternative resource allocation both before and during the program (Davis, 1963).

2.2.5 Cost Estimation Analysis

To calculate the cost estimation analysis, the researcher needs to see from the aspect in cost estimating and cost budgeting. These processes interact with each other and with the processes in the other knowledge areas as well. Each process may involve effort from one or more individuals, based on the needs of the project. It is primarily concerned with the cost of the resources needed to complete projects activities. However, optimization analysis should also consider the effect of project decision on the cost of using the project’s product.

Cost estimating involves developing an approximation (estimate) of the costs of the resource needed to complete project activities. According to Project Management Institute (2013), the cost must be estimated for all resources that will be charged to the project. This includes, but is not limited to, labor, materials, supplies, and special categories such as an inflation allowance or cost reserve. It may benefit from being refined during the course of the project to reflect the additional detail available. In some application areas, there are guidelines for when such refinements should be made and what degree of accuracy is expected. For cost budgeting, involves allocation the overall cost estimates for individual activities or work packages to establish a cost baseline for measuring project performance. Reality may dictate that estimates are done after budgetary approval is provided, but estimates should be done prior to budget request wherever possible.

The cost baseline is a time-phased budget that will be used to measure and monitor cost performance on the project. It is developed by summing estimated cost by period and is usually displayed in the form of an S-curve. Many projects, especially larger ones, may have multiple cost baselines to measure different aspects of cost performance. For example, a spending plan or cash-flow forecast is a cost baseline for measure disbursements. In Figure 2.7 shows illustrative cost baseline display.

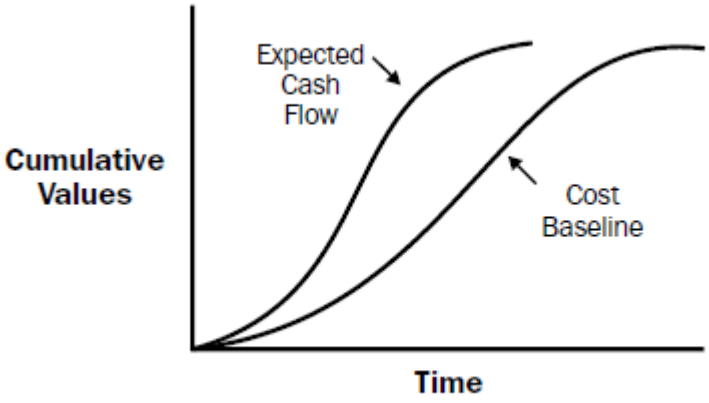

Figure. 2.8 Illustrative Cost Baseline Display

Source: Project Management Institute, (2013)

In the development of the project, the variable cost is a very important role in construction management, where the costs should be controlled as much as possible in the allotted time. Control time emphasize on the cost factor because there is a close relationship between the project completion time with the costs of the relevant project or supporting activity.