Application of Critical Path Method (CPM) and S-Curve on Scheduling Deep Water Well Pump Construction Project in Sorong, West Papua

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Abstract

The difficulty of clean water in Indonesia, especially areas far from the city, resulted in a shortage of drinking water supply for the surrounding communities. CV Ulu Ulu Utomo company engaged in the trade and installation of deep water well pumps for irrigation and industry in the work of the project so far has not used the method of scheduling the project in planning the time and cost required, so there is still a delay in work time and additional costs. Therefore, this study aims to determine the form of network diagram, analyze the optimal time, and estimated total cost of deep well pump construction project in Sorong, West Papua using Critical Path Method (CPM). This research is a type of descriptive and accurate research that systematically describes project activities and data sources obtained from interviews, observations, and documentation. The results of research with Critical Path Method (CPM) showed a network diagram on a series of project activities that are on a critical path is the A1-A2-C2-C4-D2-E2 trajectory with a normal time of project completion for 102 days and a cost of IDR 79.353.000 while the project completion time is accelerated to 91 days over 6 hours at a cost of IDR 82.593.890.

Keywords
CPM, Crash Time, Project Management, and S-Curve.

1. Introduction

The construction of clean water supply facilities and infrastructure in this decade is increasing. One of the basic necessities of living things is water, which is needed for drinking, household needs, and irrigation. But nowadays in certain areas often the water needed is difficult to obtain because of the low rainfall of one area, the discharge of small rivers, the absence of landfills, and far from other water sources. This is what happens in Sorong region, West Papua, which relies on surface water for daily needs is still very lacking, especially for irrigation that requires more water. One alternative is to use groundwater. In everyday life, the use of groundwater used by residents, namely wells dug, but currently the well dug is no longer able to work optimally. Currently, the government provides facilities regarding the manufacture of deep well pumps, so the Ministry of Energy and Mineral Resources made a clean water procurement program carried out by drilling groundwater or by the manufacture of deep well pumps that have been started since the beginning of 2005-2018 calculated to have been built as many as 2,288 units of drill wells with clean water discharge with a capacity of 144.4 million m^3 / year that can help 6.6 million people in difficult areas of clean water in 34 provinces and 312 districts (Hastuti, 2019). This is characterized by the increasing activity of deep well pump installation projects.

Projects are not only or not always concerning physical work, not always in the form of construction projects as far as having a series of interconnected activities, but there are also clear restrictions on the implementation of activities starting and ending in producing a deliverable product with specifications, quality cost limits and scope that have been determined (Pastiarsa, 2015). By Jaroslaw Konior & Szóstak (2020) a project can be said to be successful or failed depending on the planning and scheduling of the project that has been created and the project can be managed effectively or efficiently. Projects that can be completed at a cost amount that is not more than the predetermined budget then the project can be said to be a good project, in addition it can also be completed on time in accordance with the scheduling that has been set and produce product activities that meet the specifications and criteria required.

In general, the construction of a project has a deadline, which means that before or exactly the time limit that has been set before the project must be completed. Scheduling by Atin & Lubis (2019) is the planning of project activities outlined in a work schedule that describes the sequence in the process of work on an activity accompanied by the time of comment and end of work in an activity. This scheduling is useful as a guideline for each work unit of activity against time constraints in starting and ending a task.

CV Ulu Ulu Utomo is a company engaged in the trade and construction of deep well pump for irrigation and industry. CV Ulu Ulu Utomo in working on his project, so far the method of scheduling the project used in making planning the time and cost required for the project work is still not appropriate, so there are still delays in work time and additional costs. However, the company must be able to complete the project according to the agreement in the predetermined contract. The following are the target and realization of the project, and the budget of costs and the realization of project costs carried out by CV Ulu Ulu Utomo over the last 1 year:

Table 1. Target dan Realization of CV Ulu-Ulu Utomo Project

Project Name	Completion Target	Realization of Settlement	Delay
Bangka Belitung	3 months	3 months	-
Sorong, West Papua	3 months	3 month 12 days	12 days
Palangkaraya	4 months	4 months	-
Padang	3 months	3 months	-
Tulung Agung	4 months	4 months	-
Kolaka, North Sulawesi	4 months	3 months 27 days	-

Sources : CV Ulu Ulu Utomo (2019)

Based on Table 1, it can be known that 6 projects have been run by CV Ulu Ulu Utomo for the last 1 year with the average completion of the project takes 4 months. However, unlike the project in Sorong, West Papua, there was a delay in completion for 12 days which was originally targeted for completion of 3 months but was completed within 3 months and 12 days.

Table 2. Budget and Project Cost Realization CV Ulu Ulu Utomo

Project Name	Budget Costs (IDR)	Cost Realization (IDR)
Bangka Belitung	368.040.000	368.040.000
Sorong, West Papua	1.108.006.000	1.121.006.000
Palangkaraya	612.570.000	612.570.000
Padang	458.040.000	458.040.000
Tulung Agung	650.040.000	650.040.000
Kolaka, North Sulawesi	378.090.000	375.090.000

Sources : CV Ulu Ulu Utomo (2019)

In addition, it is also seen in Table 2 shows from several projects that have been implemented CV Ulu Ulu Utomo most of the projects are completed in accordance with the budget of the cost that has been set back. But in the project in Sorong, West Papua the cost of the project has increased by IDR 13.000.000, from the original cost budget of IDR 1.108.006.000 increased to IDR 1.121.006.000. This is due to external factors such as shipments of goods from abroad and weather factors that affect the number of future shipping costs. one of several projects undertaken by CV Ulu Ulu Utomo in Sorong, West Papua, is a deep well pump construction project.

Therefore, in addition to the estimated work time, another thing that needs to be planned carefully is the cost. Cost optimization is carried out to minimize the risks that occur and still get maximum results with optimal costs. Critical Path Method (CPM) is one of the right methods to help solve the problem of deep well pump construction project in Sorong, West Papua faced by CV Ulu Ulu Utomo. By Badruzzaman et al. (2020) Critical Path Method (CPM) is the basis for planning and controlling work schedules based on the work network. Network analysis on this CPM is used to optimize the total cost of the project by accelerating or reducing the duration required to complete the project in question (Lermen et al., 2016). While the S Curve shows the ability of the project based on activities, the total percentage of time and weight of work of all project activities can be used as a reference in determining the completion of the project part, the cost of project implementation, as well as the arrival of materials, tools and work for certain tasks (Wibowo & Rozy, 2020).

From the explanation above, this study aims to determine the network diagram, analyze the optimal time and estimated total cost on the deep well pump construction project in Sorong, West Papua by using the Critical Path Method (CPM).

2. Literature Review

2.1 Project Management

By Robbins & Coulter (2012) management includes coordinating and supervising one's work so that its activities can run effectively and efficiently, which implements four main functions namely planning, coordinating, leading, and controlling. While project management in the arts and sciences for planning, organizing, monitoring and controlling all aspects of the project to achieve project goals and targets safely in accordance with the agreed schedule, budget, and performance criteria (Radujković & Sjekavica, 2017). By Al-Hajj & Zraunig (2018) in project management practices try to be able to complete projects efficiently to minimize costs and be able to achieve external goals related to customer needs. The main task of project management is to plan and control the project schedule (Zareei, 2018). By Berjis et al. (2020) project planning is used to develop work plans taking into account various aspects of each activity and to predict project status during the project life cycle. Project planning is divided into several stages, namely activity planning, an order of activities, resource allocation, scheduling, and project floatation. The success of project management will affect the success of the project, because the success of a project depends on the success of the project management and the success of the final product produced. A project is said to be successful or unsuccessful depending on whether or not the project meets the standards of time, cost, and quality on the project (Gomes & Romão, 2016).

2.2 Critical Path Method (CPM)

Critical Path Method (CPM) is a project planning technique to support and serve as an alternative Gantt Chart developed in the late 1950s by scientists working at Du Pont Company and UNIVAC Division of Remington Rand working together to develop CPM while working on a du Pont chemical plant maintenance project, and after more than five decades of CPM engineering was praised and accepted throughout the developed world (Aliyu, 2012). According to Anyanwu (2013) CPM provides more "Micro" information than "Macro" information that provides more specifications to validate the progress of a project. In addition, the main advantages of CPM are being able to identify critical and non-critical activities to assist in the transfer of construction resources when necessary, especially in the event of delays in critical activities. Some terms and calculations used in the CPM method according to Tamrakar (2013) are:

a. Forward Pass
   - Earliest Start Time (ES) is the earliest time to start an activity.
     ES = EF highest of predecessor activities
   - Earliest Finish Time (EF) is the earliest time to complete the activity and the earliest start time plus activity time.
     $EF = ES + t$

b. Backward Pass
   - Latest Start Time (LS) is the last time at the start of the activity without delaying the critical path time.
     $LS = LF - t$
   - Latest Finish Time (LF) is the last time to complete an activity without delaying critical path time.
     LF = Lowest LS of predecessor activities

2.3 S-Curve

The S curve is a graphical representation that describes the relationship between the time the project is executed (the horizontal axis) and the total cost value (vertical axis) of the project progress cumulatively from start to finish (Wang et al., 2016). The S curve becomes a very helpful and necessary tool for project planning, monitoring, and control and the evaluation of the cumulative progress of the project as a whole from start to finish during the implementation stage (Cristóbal, 2017) (Jarosław Konior & Szóstak, 2020) (Chao & Chen, 2015). According to Chao & Chien (2010) owners and contractors typically use the S Curve for project planning and control because the S Curve can be referred to estimate cash flow to make financial arrangements before the project is implemented and set targets for evaluation of overall progress during the project. S curve maker in a project, the first thing to do according to Pastiarsa (2015) is:

a. Calculates the percentage of the weight of each activity or activity.
b. Then the schedule (planned start date and end date) of each WBS component is depicted in the Bar Chart. The formula for calculating the percentage of activity weights by Pastiarsa (2015) as follows:

   Percentage of activity weighting = $\frac{\textit{Cost per charge budget plan}}{\textit{Total project budget cost plan}}$ x 100%

3. Methods

3.1 Variable Operational Definition

An operational definition is a clue as to a measured variable. To facilitate the analysis process, each variable is operationally defined. The operational definition of this research variable is Activity or Activity Type, Activity Order, Activity Time, Project Cost, and Project Completion Time Interval.

3.2 Data Type

This study uses 2 types of data, namely as follows:

a. Primary Data, is a data source that provides data directly to data collectors data (Sugiyono, 2013). To obtain primary data, there are several ways that can be done, namely as follows:
   1. Interview, the process of collecting data is done through a direct interview with CV Ulu-Ulu Utomo company related to the same research object.
   2. Observation, data collection is done through direct observation in the field related to objects and research activities
b. Secondary Data, is an indirect source of data but obtained through other people and documents (Sugiyono, 2013).

3.3 Data source

In this research data collection was conducted at CV Ulu-Ulu Utomo which is located at Fortune Business & Industrial Park, B 28, Jalan Tambak Sawah No. 6-12 Sidoarjo, East Java, Indonesia. The data collection was obtained from the project operations and this research only focused on the deep well pump construction project in Sorong, West Papua. Data collection began on January 28, 2019, until the data was sufficient.

3.4 Analysis Method

This research analysis technique is used with Critical Path Method (CPM) analysis and assisted using QM for Windows program. The resolution steps according to Pastiarsa (2015) is:

1. Data Collection Time and Activities. The first stage is carried out by describing the activities included in the project accompanied by the necessary data sourced from the company.
2. Determination of The Relationship Between Activities. The determination of the relationship of one activity and the activity of another is based on the sequence of work processes such as what activities as a precursor as well as what activities will precede.
3. Building Network Diagrams. Network diagrams are organized to determine the project schedule based on the network between activities so that all activities that make up the network diagram can describe the entire project.
4. Calculation of Earliest Start (ES), Earliest Finish (EF), Latest Start (LS), Latest Finish (LF), and Slack values of Each Activity. The process of determining ES in the network diagram is by calculating and determining ES from event number 1 to maximum number, ES event number 1 has a value equal to 0, then with one of the formulas that have been described based on the number of activities and dummy to related events can be used in calculating ES event number 2,3,4 and so on.
5. Determination of Critical Path. Critical path are determined based on critical trajectories with the longest duration of work between all tracks.
6. Determining Accelerated Activities. Namely, activities that are on a critical path, especially in the main activities.
7. Slope Value Calculation, slope value can be calculated by using formula (Pastiarsa, 2015):

   Cost Slope = $\frac{\textit{Expedited cost} - \textit{slowed down}}{\textit{normal time} - \textit{time accelerated}}$

8. Calculate the Time And Cost of Project Completion. Calculate the time or duration when the project completion acceleration is carried out as well as the total costs that must be incurred by the company after the acceleration of the duration of project completion.
9. Arranging the S Curve, as for the stages in the preparation of the S curve according to Pastiarsa (2015) i.e. identify work and activity list, determine activity time, allocate average/linear cost (percentage) for each job, calculate daily cost weighting through a summation of daily cost needs, make the S curve in accordance with the previously calculated weight (Scale 0% - 100%).
10. Conclusion and Suggestion.

4. Data Collection

4.1 Data on Activity Type, Order of Activity, Normal Time, Predecessors, and Cost per Activity

Table 3. Types of Activities, Order of Activities, Normal Time, Predecessors, and Cost per Activity Deep Well Pump Construction Project in Sorong, West Papua

No	Activity Description	Activity Code	Date	Normal Time (days)	Predecessors	Normal Cost (IDR)
A	**Initial Field Preparation and Orientation**					
1	Mobilization and Demobilization of Personnel	A1	08/11/18 – 17/11/18	10	-	6.600.000
2	Mobilization and Demobilization Equipment	A2	18/11/18 – 01/12/18	14	A1	7.950.000
3	Administration and Coordination	A3	02/12/18 – 12/12/18	11	A2	2.340.000
4	Data Collection	A4	02/12/18 – 17/12/18	16	A2	1.110.000
5	Preparation of Methodology and Work Plan	A5	05/01/19 – 23/01/19	19	B1	1.200.000
B	**Survey and Investigation Work**					
1	Geological Survey/Soil Mechanics	B1	18/12/18 – 04/01/19	18	A4	6.200.000
2	Environmental/SocioEconomic Survey	B2	24/01/19 – 08/02/19	16	A5	7.500.000
C	**Installation Work**					
1	Water PumpIng Place Making	C1	13/12/18 – 26/12/18	14	A3	18.100.000
2	Installation of Tools and Machines	C2	02/12/18 – 27/12/18	26	A2	6.200.000
3	Panel and Pipe Installation	C3	02/12/18 – 18/12/18	17	A2	6.500.000
4	Soft Starter Installation	C4	28/12/18 – 10/01/19	14	C2	4.000.000
D	**Testing Jobs**					
1	Test Commissioning	D1	19/12/18 – 30/12/18	12	C3	7.000.000
2	Test Run Genset	D2	11/01/19 – 28/01/19	18	C4	4.000.000
E	**Final Stage**					
1	Water Discharge Machine Test	E1	31/12/18 – 16/01/19	17	D1	235.000
2	Rechecking	E2	29/01/19 – 17/02/19	20	D2, E1	418.000
	Total					**79.353.000**

Sources : CV Ulu Ulu Utomo (2019)

Based on Table 3, it can be determined that in the work of deep well pump construction project in Sorong, West Papua 15 types of work must be completed, details of the job description and work code can be seen in the second and third column, in the fourth column is a detail of the work date of each activity that shows the start and end date of the work. From the details of the work date obtained the amount of duration needed to complete each work contained in the fifth column, there it appears that the duration of the maximum completion is 26 days on the work of Installation of Tools and Machines (C2) and the shortest duration is 10 days on the work of Mobilization and Demobilization of Personnel (A1). While in the sixth column is a predecessor to know other activities that must be done before starting an activity, the description of activities in the deep will pump construction project namely Mobilization and Demobilization of Personnel (A1) is the initial work that must be done that no work precedes it, Mobilization and Demobilization Equipment (A2) are carried out when Mobilization and Demobilization of Personnel (A1) has been completed. Administration and Coordination (A3), Data Collection (A4), Installation of Tools and Machines (C2), Panel and Pipe Installation (C3), these four jobs can be done simultaneously after Mobilization and Demobilization Equipment (A2) is completed. Geological Survey/Soil Mechanics (B1) is carried out when Data Collection (A4) has been completed. Preparation of Methodology and Work Plan (A5) is worked after Geological Survey/Soil Mechanics (B1), Environmental/SocioEconomic Survey (B2) after the Preparation of Methodology and Work Plan (A5), Construction of Water PumpIng Place Making (C1) is carried out after Administration and Coordination (A3), Soft Starter Installation (C4) done after Installation of Tools and Machines (C2), Test Commissioning (D1) done after Panel and Pipe Installation (C3), Genset Test Run (D2) done after Soft Stater Installation (C4), Water Discharge Machine Test (E1) done after Test Commissioning (D1). and the last Rechecking (E2) can be done if the Test Run Genset (D2) and Water Discharge Machine Test (E1) has been completed. In the last column, the sixth is a breakdown of the normal costs incurred for per job with a total cost of IDR 79.353.000, the smallest cost seen in the Water Discharge Machine Test (E1) is IDR 235.000 and the largest cost on the Manufacture of Water PumpIng Place Making (C1) for IDR 18.100.000.

4.2 Penentuan Toleransi Waktu dan Biaya

By referring to the results of the research, the company provides tolerance to the cost and time of project acceleration by 10% (Ir. Sumardi, Construction Management).

5. Results and Discussion

5.1 Results

A. Critical Path Method (CPM)

1. Data Collection of Project Activities and Time

Data collection of activities and processing times is based on data on the order of activities and normal time in the deep well pump development project in Sorong, West Papua which can be seen in Table 3.

2. Establishing Relationships Between Activities

This data is data on the relationship of project activities with other project activities arranged based on the predecessor, where the predecessor activities must be completed first before starting the next activity. Details of the predecessor can be seen also in Table 3.

3. Building Network Diagram

Based on the relationship between activities and expected time (Estimated Age), it can be compiled a network diagram describing a series of activities of deep well pump construction projects in Sorong, West Papua. Normal network diagrams can be seen in Figure 1 below:

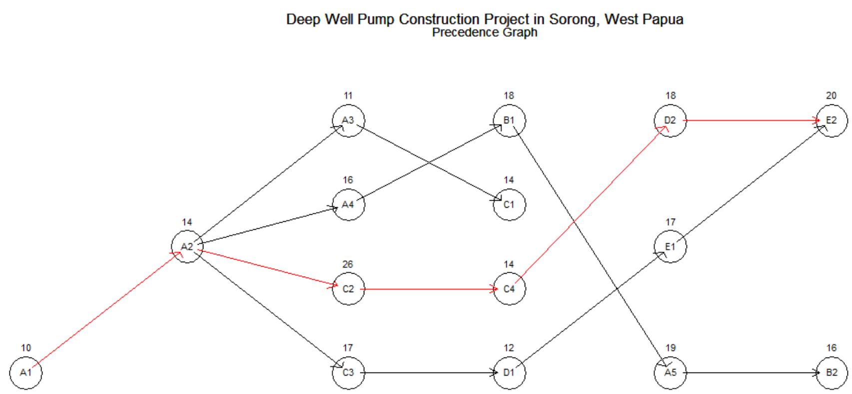

Figure 1. Network Diagram (Normal Time) of Deep Well Pump Construction Project in Sorong, West Papua

Based on Figure 1, it appears that A1 activities duration of 10 days, A2 duration of 14 days, C2 duration of 26 days, C4 duration of 14 days, D2 duration of 18 days, and E2 duration of 20 days are on a red line trajectory which is a critical trajectory indicating if the activities on the track are critical activities.

4. Count Earliest Start (ES), Earliest Finish (EF), Latest Start (LS), Latest Finish (LF), and Slack Per Activity

Table 4. Calculation Result of ES, EF, LS, LF, and Slack

Activity Code	Early Start (ES)	Early Finish (EF)	Late Start (LS)	Late Finish (LF)	Slack
A1	0	10	0	10	0
A2	10	24	10	24	0
A3	24	35	77	88	53

A4	24	40	33	49	9
A5	58	77	67	86	9
B1	40	58	49	67	9
B2	77	93	86	102	9
C1	35	49	88	102	53
C2	24	50	24	50	0
C3	24	41	36	53	12
C4	50	64	50	64	0
D1	41	53	53	65	12
D2	64	82	64	82	0
E1	53	70	65	82	12
E2	82	102	82	102	0

Sources : Data Processing (2019)

Table 4 shows the calculation results of Earliest Start (ES), Earliest Finish (EF), Latest Start (LS), Latest Finish (LF), and Slack which aims to determine the start and end time of an activity, to find out the relationship between its activities, and to determine the critical path by looking at activities that have a slack value of 0. Activity codes that have slack 0 values are A1, A2, C2, C4, and E2 which means that all five activities are on a critical path.

5. Determining Critical Paths

Critical path determination can be done by looking at the longest path of its implementation time compared to all other existing path. Where activities that are on the critical path have a high sensitivity to delays, then in the implementation of the track project is required strict supervision. Based on the network diagram that has been made in Figure 1 and Slack calculation in Table 4, it obtained critical path with activities that are in a critical path, namely Mobilization and Demobilization of Personnel (A1), Mobilization and Demobilization Equipment (A2), Installation of Tools and Machines (C2), Soft Starter Installation (C4), Test Run Genset (D2), and Rechecking (E2).

From the critical trajectory can be known the working age of the project with a normal time of 102 days. The total duration of project life is calculated by summing up the length of work duration that is on a critical trajectory. The results of the calculation of the total duration at the critical trajectory of normal time = 10 + 14 + 26 + 14 + 18 + 20 = 102.

6. Determine Accelerated Activities

Activities in the project carried out acceleration is activities that are on a critical path, because activities that are in this critical path become the main focus and prioritized so as not to experience delays. With acceleration and cost increase of 10% (Ir. Sumardi, Construction Management).

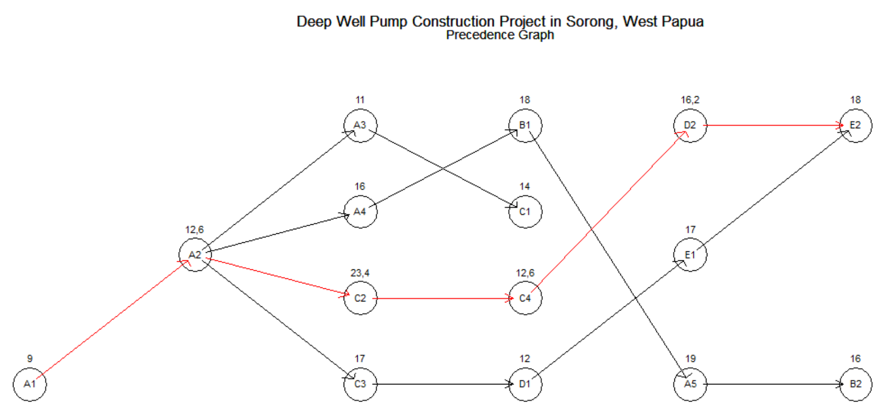

Figure 2. Network Diagram (Acceleration Time) of Deep Well Pump Construction Project in Sorong, West Papua

Figure 2 is a network diagram of the construction of deep well pump in Sorong, West Papua after the acceleration of duration in activities that are on the critical path, namely Mobilization and Demobilization of Personnel (A1), Mobilization and Demobilization Equipment (A2), Installation of Tools and Machines (C2), Soft Starter Installation (C4), Test Run Genset (D2), and Rechecking (E2). So there is a change in the life of the project work on the critical path after the acceleration of the project is to 91 days more than 6 hours. The result of calculation of total duration at the critical path of acceleration time = 9 + 12,6 + 23,4 + 12,6 + 16,2 + 18 = 91,8.

7. Slope Value Calculation

The increase in costs caused by the first cost slope can be done by calculating the cost of activities or the work of the influence of acceleration by using the formula as follows:

Acceleration Cost = $\frac{\text{normal time}}{\text{accelerated time}}\ x\ normal\ cost$

A1. Mobilization and Demobilization of Personnel
Normal Time = 10 days
1 day = 8 hours
Crash Time (10%) = 10% x 10 = 1 day
Accelerated = 1 day = 10 – 1 = 9 days
Crash Time Cost $= \frac{10}{9}\, x\ IDR\ 6.600.000$ = IDR 7.333.333

For subsequent calculations can be done in the same way. Recapitulation of time values and acceleration costs can be seen in Table 5.

Table 5. Recapitulation of Time and Cost of Acceleration of Deep Well Pump Construction Project in Sorong, West Papua

No	Activity Description	Predecessors	Normal Time (days)	Normal Cost (IDR)	Crash Time (days)	Crash Cost (IDR)
A	**Initial Field Preparation and Orientation**					
1	Mobilization and Demobilization of Personnel	-	10	6.600.000	9	7.333.333
2	Mobilization and Demobilization Equipment	A1	14	7.950.000	12,6	8.833.333
3	Administration and Coordination	A2	11	2.340.000	11	2.340.000
4	Data Collection	A2	16	1.110.000	16	1.110.000
5	Preparation of Methodology and Work Plan	B1	19	1.200.000	19	1.200.000
B	**Survey and Investigation Work**					
1	Geological Survey/Soil Mechanics	A4	18	6.200.000	18	6.200.000
2	Environmental/SocioEconomic Survey	A5	16	7.500.000	16	7.500.000
C	**Installation Work**					
1	Water PumpIng Place Making	A3	14	18.100.000	14	18.100.000
2	Installation of Tools and Machines	A2	26	6.200.000	23,4	6.888.889
3	Panel and Pipe Installation	A2	17	6.500.000	17	6.500.000
4	Soft Starter Installation	C2	14	4.000.000	12,6	4.444.445
D	**Testing Jobs**					
1	Test Commissioning	C3	12	7.000.000	12	7.000.000
2	Test Run Genset	C4	18	4.000.000	16,2	4.444.445
E	**Final Stage**					
1	Water Discharge Machine Test	D1	17	235.000	17	235.000
2	Rechecking	D2, E1	20	418.000	18	464.445
	Total Critical Path Duration/Total Cost		**102**	**79.353.000**	**91,8**	**82.593.890**

Sources : Data Processing (2019)

From Table 5 it can be known that the time required to complete the deep well pump construction project in Sorong, West Papua after the acceleration of the project is 91,8 days or 91 days over 6 hours with a total cost of IDR 82.593.890 from the original duration of 102 days and the total cost of IDR79.353.000.

After the cost of project acceleration is known, it can then determine the additional cost caused by the acceleration (cost slope) using the formula:

Cost Slope $= \frac{\text{accelerated cost}-\text{normal cost}}{normal\ time - time\ accelerated}$

$= \frac{\text{Rp } 7.333.333 - \text{Rp } 6.600.000}{10-9}$ = IDR 733.333 per day

For subsequent calculations can be done in the same way. Recapitulation of cost slope values can be seen in Table 6.

Table 6. Cost Slope Recapitulation

No	Activity Description	Acceleration Time (days)	Cost Slope (IDR)	Crash Cost (IDR)
A	**Initial Field Preparation and Orientation**			
1	Mobilization and Demobilization of Personnel	1	733.333	733.333
2	Mobilization and Demobilization Equipment	1,4	630.952	883.333
C	**Installation Work**			
2	Installation of Tools and Machines	2,6	264.957	688.888
4	Soft Starter Installation	1,4	317.461	444.445
D	**Testing Jobs**			
2	Test Run Genset	1,8	246.914	444.445
E	**Final Stage**			
2	Rechecking	2	23.223	46.446
	Total Cost			**3.240.890**

Sources : Data Processing (2019)

Based on Table 6, it can be noted that the cost slope shows changes in the additional costs that must be spent per day for each work carried out by acceleration, namely work that is on a critical path with a total additional cost of IDR 3.240.890 from the total normal cost.

B. Making S Curve Normal and Accelerated

After obtaining the results of its acceleration and increase in cost, then create an S curve to see the progress of a project. the following is a manual calculation of the normal S curve of each type of work by using a formula:

Weight (%) = $\frac{Cost\ per\ work\ item}{Total\ cost\ of\ all\ jobs}\ x\ 100\%$

As for the weight calculated per day can be done by dividing the % of the cost of work weight by the duration of work/activities.

A1. Mobilization and Demobilization of Personnel

Total cost per activity = Rp 6.600.000
Total cost of all activities = Rp 79.353.000
Total duration per activity = 10 days

Weight (%) = $\frac{Rp\ 6.600.000}{Rp\ 79.353.000}\ x\ 100\%$
= 8,32 %

As for the distribution of weights each day, namely:

Weight (%) = 8,32 % : 10
= 0,832%

The results of the next calculation can be done with the same formula, after obtaining the results of the normal S curve, it can be done a normal calculation for the S curve acceleration of each type of work with the acceleration time taken 10% of the normal duration with consideration to avoid the occurrence of delays in the critical path. The calculations for the accelerated S curve are as follows:

A1. Mobilization and Demobilization of Personnel

Total cost per activity = IDR 7.333.333
Total cost of all activities = IDR 82.593.890
Total duration per activity = 9 days

Weight (%) = $\frac{Rp\ 7.333.333}{Rp\ 82.593.890}\ x\ 100\%$
= 8,88 %

As for the distribution of weights each day, namely:

Weight (%)= 8,88 % : 9
= 0,987 %

The results of the next calculation can be done with the same formula. Based on the planning and weight count results, if using the analysis of the S curve can be seen in Figure 3.

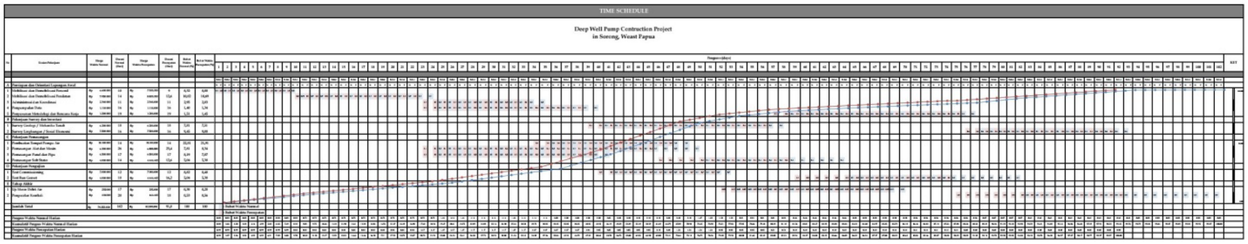

Figure 3. Curve-S Deep Well Pump Construction Project in Sorong, West Papua

From Figure 3, the comparison of deep well pump construction schedule in Sorong, West Papua between the workmanship with normal time and acceleration time is seen no noticeable difference and looks narrow except at the end of the project there is a fairly noticeable difference from the total duration of the project with normal time of 102 days and acceleration time of 91 days over 6 hours.

C. Comparison of Optimum Time and Cost with Real Conditions

From the results of the analysis using the CPM method the acceleration time resulted in a more optimum time and cost compared to the normal CPM time. See more details on the comparison in Table 7.

Table 7. Optimum Time and Cost Comparison with Critical Path Method (CPM)

Description	Critical Path Method (CPM)	
	Normal Time	Accelerated Time
Completion Time	102 days	91 days over 6 hours
Project Completion Costs	IDR 79.353.000	IDR 82.593.890

Sources : Data Processing, 2019

From Table 7 it can be concluded that with the acceleration carried out on the work that is on the critical path of the completion time of the deep well pump construction project in Sorong, West Papua is faster than the previous normal time of 91 days more than 6 hours and from the costs incurred, the cost of completion of the accelerated project is greater than the normal time cost of IDR 82.593.890.

5.2 Discussion

Analysis of scheduling deep well pump construction projects in Sorong, West Papua by CV Ulu Ulu Utomo based on schedule data and analysis using Critical Path Method (CPM) obtained information that from the network diagram that has been compiled describing a series of activities of deep well pump construction projects in Sorong, West Papua, it can be determined critical path. According to Agyei (2015) a critical path is the path with the longest set of activities and the slack value in the activity is equal to 0. So the jobs that are in this critical path are the A1 (Mobilization and Demobilization of Personnel), A2 (Mobilization and Demobilization Equipment), C2 (Installation of Tools and Machines), C4 (Soft Starter Installation), D2 (Test Run Genset), and E2 (Rechecking) because it has the longest project completion duration compared to other path. Therefore, the work that is on this critical path must be prioritized and can be completed in time so as not to experience delays. Because according to Aliyu (2012) if the work that is on the critical path is delayed, it will cause delays also in the completion of the work as a whole on the project. This means that from all activities in the deep well pump construction project in Sorong, West Papua, activities that are within the critical path must be accelerated so that the project does not experience delays. Because if the acceleration of duration is carried out in all activities including activities that are not on the critical path will only add to the cost while the accelerated time will remain (Syahrizal, 2014).

Total completion time of deep well pump construction project in Sorong, West Papua's critical path with a normal time of 102 days and the total cost of the project amounted to IDR 79.353.000 while the project completion time was accelerated (crash time) to 91 days over 6 hours (10 days faster 2 hours than the normal duration) for IDR 82.593.890 (an increase in costs of IDR 3.240.890). This means that when certain conditions the owner wants a deep well pump construction project in Sorong, West Papua is carried out the acceleration of duration, then there will be a cost increase of IDR 3.240.890 from the normal cost of IDR 79.353.000 to IDR 82.593.890 so that the acceleration cost is greater than the previous normal cost. It is as described by Bishnoi (2018) that completing an activity in a shorter time, will require more resources and will lead to increased costs incurred to carry out accelerated activities in the project.

Thus, if the project owner wants to accelerate the project time of CV Ulu Ulu Utomo company, it is better to use the accelerated CPM method because with this acceleration the project owner can optimize the duration and cost so that the project can run quickly and precisely. This research supports research conducted by Adebowale & Oluboyede (2011) with the CPM method the completion time can be reduced by 37 days with an additional cost of N830,000.00 ($5,355.00), so it can be concluded that if a project is accelerated it will be accompanied by an increase in costs.

The S-curve becomes a necessary tool for project planning and control and for the evaluation of overall progress during the implementation stage (Cristóbal, 2017). According to Cheng et al. (2011) the S-curve can be used for several purposes, one of which is as a target used to evaluate the actual progress of the project and to monitor whether the project is on schedule. Based on the scheduling analysis of deep well pump construction projects in Sorong West Papua by CV Ulu Ulu Utomo on the S curve it can be seen that the project activities can not be completed according to the initial target schedule of completion of 3 months or approximately 90 days. However, the realization of the deep well pump construction project in Sorong West Papua by CV Ulu Ulu Utomo was completed within 102 days. From the calculation of the S curve obtained the result of weighing exactly 100% in normal conditions 102 working days, while if done accelerated weighting results 100% can be completed in 91 days more than 6 hours. So that by using the S-curve can be known if the deep well pump construction project is accelerated, then the project does not experience delays and the completion time is faster 10 days 2 hours than 102 days normal completion time and thus the deep well pump construction project will experience an increase in costs. This is supported by the results of research Sabariah et al. (2012) which explains the effectiveness of the use of S-Curve scheduling methods in the work of construction projects related to decision making related to time and cost, project time control, project cost control, project scheduling, strategies to reduce project delays, as well as project performance, their use is relatively high and better than other network planning methods.

6. Conclusion

Sourced from the results of research and discussion above, it can be concluded in the construction of deep well pump in Sorong, West Papua by CV Ulu Ulu Utomo using Critical Path Method (CPM) that the network diagram in the series of deep well pump construction project activities in Sorong, West Papua which is located on a critical path is the A1 (Mobilization and Demobilization of Personnel), A2 (Mobilization and Demobilization Equipment), C2 (Installation of Tools and Machines), C4 (Soft Stater Installation), D2 (Test Run Genset), and E2 (Rechecking) with the total completion time of the normal time project for 102 days and the total cost of the project is IDR 79.353.000 while the project completion time is accelerated (crash time) to 91 days over 6 hours at a cost of IDR 82.593.890. With the acceleration of this duration the deep well pump construction project in Sorong, West Papua, the completion time is 10 days and 2 hours faster than the normal duration and has increased the cost by IDR 3.240.890.

In the preparation of network so that the determination of critical path can be optimal, is necessary CPM analysis so that it can be made comparisons in its calculations and get more accurate results. The next researcher should try other methods of scheduling projects such as bar chart, PDM, and continued with the acceleration of duration such as Crashing Method, Trade-Off, Labor Allocation, for better research results.

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