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Applying Project Management Techniques to Improve Due Date Performance: The Case of a Papua Power Plant Construction in Indonesia

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Master in Management

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Abstracts

Obstacles can occur on a project causing nonconformance in terms of time and cost. A Power Plant in Indonesia is being constructed and the project was still underway, when a delay was anticipated. In this case, the construction progress was only 13.1% on day-92, while it should have been completed around 26.4% to finish within 184 days.

This thesis purpose is to identify and analyze the delay causes, by applying Critical Path Method (CPM) and Project Evaluation Review Technique (PERT) methods. Data concerning project activities and three estimation times were collected from internal reports and semi-structured interviews, as follows: optimistic, most likely, and pessimistic durations. A project schedule and the critical path were computed by using Microsoft-Excel and Microsoft-Project software to operationalize PERT/CPM methods. These results were analyzed using of s-curve, network diagram and probability calculation, to anticipate the due date achievement level. The delay causes were collected by subsequent interview and treated by the Fishbone Analysis, which enabled the following categorization of failures: labor, machine, material, environment and method. These provided support for managers to take action. Finally, a discussion concerning the traditional methods of Project Management, i.e., Design-Bid-Build, suggests that Building Information Modelling (BIM) could generate better synchronization among stakeholders, by eliminating the major source of delays. Also, the Life Cycle Assessment was found necessary to decrease carbon dioxide emissions, so the building could achieve more sustainable performances. Moreover, integrating BIM, Building Energy Modelling and LC Energy Analysis was suggested to improve project sustainability.

Keywords: Construction Project Management; Schedule; Delay Causes; Building Information Modelling (BIM); Life Cycle Assessment (LCA)

JEL Classification: C51, O22

Sumário

Num projecto, há obstáculos que podem causar não-conformidades, no tempo e custo. No caso em apreço, antecipou-se um atraso numa Central Hidroelétrica em construção. No dia 92, o avanço da construção era de apenas 13,1%, enquanto deveria ter sido concluído 26.4%, para ser possível terminar o projecto em 184 dias.

O objetivo desta dissertação é identificar e analisar as causas de atraso, aplicando o Critical Path Method (CPM) e a Progam Evaluation and Review Technique (PERT). Os dados relativos às atividades do projeto e às estimativas de tempos otimista, mais-provável e pessimista foram recolhidos em relatórios e entrevistas semi-estruturadas. O cronograma e caminho crítico foram calculados através do Microsoft-Excel e Microsoft-Project que operacionalizam os métodos PERT/CPM. Para antecipar o cumprimento da data de entrega prevista, esses resultados foram analisados através da s-curva, diagrama de rede e cálculo de probabilidades. As causas de atraso foram recolhidas por consequentes entrevistas e tratadas pela Análise-de-Espinha-de-Peixe, o que permitiu a categorização das falhas em mão de obra, máquina, material, ambiente e método. Finalmente, uma discussão sobre os métodos tradicionais de gestão de projetos, ou seja, Design-Bid-Build sugere que o Building Information Modelling (BIM) poderia gerar melhor sincronização entre as partes interessadas, para eliminar a principal fonte de atrasos. Além disso, a Avaliação do Ciclo de Vida foi considerada necessária para diminuir as emissões de CO_2, para que o edifício pudesse atingir um desempenho sustentável. Também foi sugerida a integração entre BIM, Building Energy Modeling e LC Energy Analysis para melhorar a sustentabilidade do projeto.

Palavras-chave: Gestão de um Projeto de Construção; Cronograma; Causas de Atraso; *Building Information Modelling* (BIM); Avaliação do Ciclo da Vida (LCA)

Classificação JEL: C51, O22

Acronyms and Abbreviations

AEC – Architecture, Engineering, and Construction

AOA – Activity-on-Arrow

AON – Activity-on-Node

API – Application Platform Interface

APM – Agile Project Management

BIM – Building Information Modelling

BEM – Building Energy Modelling

CPM – Critical Path Method

DBB – Design–bid–build

EF – Earliest Finish

ES – Earliest Start

HVAC – Building's heating, ventilation, and air conditioning

IT – Information Technology

LCA – Life-Cycle Assessment

LCEA – Life-Cycle Energy Analysis

LCI – Life-Cycle Inventory

LCIA – Life-Cycle Impact Assessment

LF – Latest Finish

LS – Latest Start

PERT – Project Evaluation and Review Technique

PMI – Project Management Institute

PMLC – Project Management Life Cycle

TPM – Traditional Project Management

WBS – Work Breakdown Structure

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1. Introduction

1.1 Background Information

Project management is needed in implementing construction projects. This is implemented during the construction project until it has finished. According to Kerzner (2017), project management is a series of activities related to certain goals and a certain period of time or temporary endeavor. Period of time, cost, and performance are three constraints in managing or controlling company resources on a project.

Considering the success measurement, there are four important factors of construction project measured by parameters of time (period), cost, scope, and quality (PMI, 2017). Projects' poor performance often cause time lag and cost overrun (Sears, 2015). The company has additional costs outside of the contract target and cause losses in the construction project when it has delays and low quality (Lewis, 2011). Therefore, it is necessary to pay more attention to delays and the cost of the project that will probably occur in the project.

Missing the deadlines is a global phenomenon, wherein most projects have delays, and this has become a 'classic problem' in every construction project. A delay can be defined as the condition when the time to complete a project is longer than the project owner's contract. Hamzah et al. (2011) defined 'delay' as time overrun or extension of time to complete the project. Delay is a crucial problem in the construction industry, which remains with a low reliable rate of profitability, development, and poor investment in research and education (Yusuf et al., 2015).

There are some aspects of project management that need attention to minimize the delay, such as material management or procurement, stakeholder management, transparency, and integration system. The procurement of material in construction is an important aspect because it usually costs 50% to 60% of project cost (Caldas et al., 2015). In the process of procurement decisions, the construction companies must concentrate on sustainability issues to address the sustainability challenges of supplier performance. Stakeholders also take an important role in maintaining all of the scope and construction management quality, and even their expectations are dynamic depending on the environmental condition (Chowdhury et al., 2020). Therefore, construction companies have to pay attention to the sustainability requirement expected by the stakeholders. Razy et al. (2019) developed a conceptual model of a Cyber-Physical System to solve the problem between standard mass production for the BIM-web libraries and the electronic requirement for personalized natural materials that adhere to the dynamic owner requirement.

Based on the related previous research that recently happened in Indonesia, Agritama (2018) stated that Surabaya, the largest city in East Java Province, experienced quite a high delay in building construction projects. His research concluded that the dominant factors of the delay are mostly due to design changes by the owner and material delivery. Additional costs usually occur in the late project. He considered that the tardiness affecting cost overrun might generate disputes or conflicts, arbitration, employment termination, and litigation (Mukuka et al., 2015). Hassan’s (2016) research in Manado City explained that the impact of project delays would cause losses to the contractor, consultant, and the owner itself. His research described the factor in which the main cause of the delay in completing the Manado Town Square III development project is the lack of material construction. Different results in Widhiawati’s (2009) research mentioned the potential factors that affect the delay of Kotamadya Denpasar Bali construction project consists of seven categories; namely 1) workers, 2) material, 3) equipment, 4) site characteristic, 5) managerial, 6) financial, 7) other factors (e.g., work accident, rainfall intensity, economic conditions); moreover, it is concluded that the worker factor has a dominant level of agreement.

Indonesia has thousands of small islands and five large islands, with the capital being on the island of Java. The existing construction and infrastructure development is still not quite evenly distributed, especially outside Java, such as Kalimantan and Papua. Papua is one of the farthest islands from the capital city of Indonesia, which is Jakarta. Papua is one of the government’s concern regions to improve its electricity capacity. The government’s initiative to increase electricity capacity in Papua is to build a power plant. Power plant is an industrial facility generating energy electricity. Many power plants use one or more generators that turn mechanical energy into electrical energy. Most power plants use one or more generators that convert mechanical energy into electrical energy. So that, the topic of this thesis focuses on the construction of a power plant construction in Papua. The importance of doing this research is because Papua is an area that is difficult to reach due to limited and also remote access or transportation to it. However, the delay becomes unavoidable, and the project manager must know the underlying causes of the delay. Thus, a project schedule analysis using PERT and CPM is important.

1.2 Case Study

Nowadays, one of the national construction companies in Indonesia is building a power plant in Papua. This project's total value is around 17 Billion Rupiah, or the equivalent of 982 thousand Euros. This construction project was due to be ready in a relatively short time, i.e., within six months, starting from September 29, 2020 and planned to finish at the end of March 2021.

Delays were also predicted to occur in the implementation of the power plant construction project in Papua. In fact, this project has not reached the goals in the ongoing progress. Delaying in the completion time in a particular activity would result in delays in subsequent activities. The more activities were postponed being completed in accordance with the original plan, the more time the whole project would require.

In this case, it is crucial to control and evaluate a project, such as the Papua power plant construction project. The project was still ongoing, but the progress delay was far from what was expected or deviated from its target. Instead of being targeted to be completed on day-184, the progress was only around 13 percent on day-92. Therefore, this study focused on project evaluations that have been carried out during the first three months.

There is a relatively far gap between the progress of work and the time used. Estimating the duration should be done by considering all the possibilities that may occur and which part of the activity is critical. The formal procedures and techniques based on network utilization are taking an important role. This is the basis for using the Critical Path Method (CPM). CPM is a project activity model illustrated in a path with activity components or Work Breakdown Structure (WBS). As planning, scheduling, and controlling processes are considered to be the core part of management, the CPM and PERT concepts/techniques can be used to manage the project more efficiently with less cost incurred (Gosku & Catovic, 2012). With these concepts, the project manager will be able to have a clearer plan ahead by scheduling from the start to the end of the construction project.

Based on the explanation above, the Papua Power Plant Construction Project is required CPM and PERT implementation in monitoring and controlling the project schedule. With these methods, the relationship between each activity and the entire project will supposedly be clearer. Moreover, it can organize realistic scheduling and timing of power plant construction project activities in Papua. Therefore, this business project case study aims to deeply discuss the issues emerging in the Papua Power Plant Construction Project, such as project schedule, procurement, and stakeholder management. The results attained from the discussion will then be proposed as a solution to cope with the identified problem.

1.3 Problem Formulation

This business project concerns the project management of a power plant construction that could not reach its goals as in the targeted plan. It is expected that the delay of some particular activities will require more costs and time. The problem formulation of this business project case study are as follows:

1. The complexity and dynamics of the project time are expected to cause cost and scope deviations to the original plan.

   The company has to investigate particular activities that may cause the project delay, which consists of deviations and their impact. It means that the company should analyze the deviation and its impact on the completion of the actual project within the expected targets.
2. The company should analyze probabilities to complete the project in the target time.

   There could be several factors that cause delays in the execution of the plan. The company needs to be able to identify them and predict all occurred deviations from the original plan. There is a possibility that the project will be finished late, so it is necessary to reduce work time by increasing resources.
3. The company should know all problems that happened in the project and should take action to correct the mismatch between the original plan and the actual plan.

   Responding to the current delay, the company should consider taking additional actions based on the supporting factors that could ensure the company moving forward by resolving the problems causing the progress delay. Therefore, adequate project management tools should be selected and used to ensure that the project performance is acceptable. This means that due dates are achieved, that the cost is within acceptable figures, and that no heavy contractual penalties are due to be paid for poor performance.

1.4 Research Question

This section will show the research questions based on the case study and on the previous business formulation. In order to provide guidance to the investigation of the problem of the business project, four research questions were defined, as follows:

1. What activities are included in CPM, and how do they relate to each other?
2. What is the probability that the project will be completed in less than the target time?

3. Why did the progress delay happen in the power plant construction plant project?
4. How can the company resolve the progress delay and accelerate the project so it will be completed on the target plan?

1.5 Research Objectives

A research objective is what we need in order to think ahead and plan the possible methodology that is required; furthermore, each research objective should be achievable in the set timeline (Ming-Khoo, 2005). The purpose of this study is to find out, analyze, and eliminate the factors that cause progress delay within the Power Plant Construction Project in Papua. To achieve this purpose, there are objectives that need to be set accordingly. Firstly, the progress of the project will be analyzed in order to know how far the project has been done. Secondly, the timeline and duration of the project will be analyzed, where the schedule of the project will be calculated. This business problem aims to provide consideration for the scheduling and organizing perspective of the project activities. So, this business case will identify the causes of delays that occurred during the project as the consideration of what kind of action to resolve the problem. And then, it generates the solution in order to accelerate the project so it will be completed in time.

By the end, the problem in the project will be discussed further regarding management aspects such as procurement and stakeholder management. Procurement is responsible for planning and taking actions accordingly and so in carrying out the project from 29 September 2020 until 31 March 2021. In addition, stakeholder management will be discussed in this research since it is related to the integration and transparency of the management and implementation of the whole built asset. So, to have a better management system in the company project will be discussed.

1.6 Methodology

A Methodology is established to follow and structure the business solving process in order to achieve the previously identified goals (vide section 1.5). This chapter illustrates the direction and methods of this study to address the identified research questions.

As mentioned in the background, this business construction project has been started on 29 September 2020 and should be completed by the end of March 2021. In order to answer the proposed research questions (vide section 1.4), this research will explore theories or literature review to support this study such as project management in general, construction project, work breakdown structure, network activities, CPM, and PERT.

Firstly, this research will collect data concerning activities and times from a monthly report of the project. The key respondent is a construction project manager with seven years of working experience in the company. In-depth interviews were used to gather data and describe what tasks were carried out during the project. After the data is collected, the data of activities and schedules are sorted to remove unwanted, incomplete, or confidential data (data treatment). The clean data will be confirmed by the construction project manager to ensure the accuracy of the data. Then the data will be processed using the CPM and PERT methods implemented in Microsoft Excel and Microsoft Project. These two methods will help to evaluate the schedule and duration of each activity. The S-Curve is also needed to compare the actual work progress against the plan. The results of the methods will be analyzed based on the outputs which are the activity network diagram (describing the project workflow from start to finish), earliest start, latest start, earliest finish, and latest finish schedules and also the probability of the project being completed on time. After that, the researcher will conduct an in-depth interview with the construction project manager to find out the causes of the delay and how to overcome the problems. This study will conclude with recommendations for resolving the project's issues. So, the contributions of this research are essentially to the practitioner.

1.7 Business Project Case Study Report Structure

Chapter 1: Introduction

This chapter contains general information about the problem discussed, along with the company and the project analyzed as the case study for this report. From here, the chapter provides problem formulations, along with the research questions and research objectives. After defining the objectives and questions, this chapter then briefly explains the methodology that will be used in achieving the research's objectives and answering the research's questions. In addition, it also shows the structure of this report.

Chapter 2: Literature Review

The literature review chapter is conducted to acquire the theoretical aspects guided by research questions. It contains theories related to projects in general and in construction project management. Work Breakdown Structure, and network explanation will be included. It also contains theories regarding the methods such as CPM, PERT, and the Fishbone Analysis.

Chapter 3: Methodology

This chapter contains information about the methodology used in this study. It explains how to do data collection, how the data is processed and how to analyze the results. It highlights the methods that will be used to answer the research questions and achieve the research goal.

Chapter 4: Case Study

This chapter will start by showing the conceptual stages of project management and the data collection. Data are processed into the results using the above mentioned techniques, frameworks and software. Result analysis will use the critical path, s-curve and PERT. This chapter also identifies the causes of the project delay through a fishbone mapping technique.

Chapter 5: Discussions of The Result

This section consists of two parts. The first one will elaborate the strategy to tackle causes of delay in the project. The second part is about discussion for a better project management system which will provide some inputs for long-term business strategy within AEC domain.

Chapter 6: Conclusions

This chapter contains the answers to the research questions which are elaborated from the analysis and discussion of the case study results. Moreover, the project objectives are also addressed. Furthermore, it provides a few notes on the contribution and limitation of this study, and it also makes suggestions for future studies.

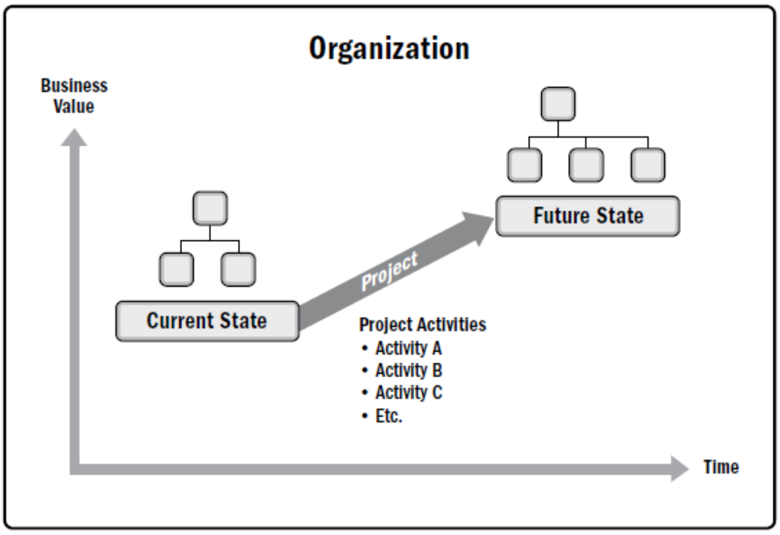
2. Literature Review

2.1 Project Management

A project is a temporary effort to build a specific product, service, or outcome. (PMI, 2017). One project consists of several tasks that need to be done by resulting deliverables. The goal of the project is defined as the objective or result toward which work is to be directed, and then the vital position, purpose, result, and product to be obtained of service performance (PMI, 2017). Another characteristic of a project is a temporary work, which means it has a specific beginning and end. ‘Temporary’ is not necessarily mean that a project has a short duration, but the objectives will meet the project. The result can be distinctive or repetitive and must be achieved within a certain period. (Kerzner, 2017).

Project management has developed from a management knowledge restrained to some functional areas to have a project management system that influences all of the functional units of the company (Kerzner, 2017). Project management is being mandatory for the survival of many firms. Lately, it has been developing into a process of a business rather than merely a project management process.

Figure 2. 1 Organizational State transition via a Project (PMI 2017)



According to Figure 2.1, the project brings the business value at a certain state to the future state that is supposedly better value in an organization. PMI (2017) defines ‘business value’ as the net quantifiable or measurable benefit obtained from the business effort or endeavor. The benefits can be tangible, intangible, or both. Tangible benefit, i.e., money, assets, equity, tools, and market shares. Intangible benefit, i.e., knowledge, experience, reliability, public trust or reputation, and others.

Although Traditional Project Management (TPM) is well established, as the world around us revolved, there are several things that needs to be developed and adjusted in the approach of managing projects. The fast-paced companies are interested more in a shorter time-to-market demand with a cost-cutting tendency, although this increases the pressure on innovations to keep rolling. Therefore, there has been several tools and techniques such as CPM (Critical Path Method) and PERT (Program Evaluation and Review Technology) being developed to support the TPM approach. In the meantime, the modern project management also being developed back at 2001 when Agile Manifesto was being proposed (Erickson et al., 2015). Currently, Agile Project Management (APM) has become the new and interesting project management approach among scientists and practitioners as it covers a wider range of activities in the organization, more flexible and cooperative with the client's needs as its orientation (Spalek, 2016). Also, APM encourages companies to work closely with the client in order to tailor the product to his or her needs.

Project Management Life Cycle (PMLC)

There are five phase processes in the traditional Project Management Life Cycle (PMLC), which are:

1. **Initiation**

   Initiation is the first phase of project management. Initiating a project is led by the organizational leaders in response to several factors, and begin to act on the organization. According to PMI (2017), these factors are categorized into four fundamental categories, as follow:

   - Meet regulatory, law, and social compulsion,
   - Meet the stakeholders' need objective,
   - Carry out or change business strategies or technological strategies,
   - Create, fix the product, services, or processes.

   The initiation phase's output is the collection of information about the project that they would start to run.

2. **Planning process**

   In the second phase of PMLC, the project managers will have some information regarding the project, and the most important is the Project Charter (Stern, 2020). The project charter is the summary and review document of the initiation phase in which it contains the overall project, but it does not necessarily have the direction. In the planning phase, the organization develops the activities of the project and how the activities will be controlled in the whole project. Each step of activities requires information about the resource, timeline, cost, and constraints in the field project.

3. **Executing**

   In the project, execution is to perform the planning design to meet the project requirement. This is more in-depth engineering work to implement the project. This activity uses resources such as foreman, equipment, material, facilities, and time. In the field, changes may happen to the scope and prevalent in the pilots (Stern, 2020). Changes in scope can disrupt the time and cost baseline. If the changes need to be implemented, the project manager needs to be aware of the potential risk and problems that may occur in the project.

4. **Monitoring and controlling**

   The monitoring and controlling phase is performed during the executing project. The purpose of monitoring the progress is to provide data capture procedures, which is to measure the pace of progress the objectives (Rad, 2002). The monitoring and controlling in the areas of schedule, cost, quality, and scope. The project needs to be assessed the performance periodically by tracking, reviewing, and reporting the current progress and recognizing the current state is on time or late. It is an important phase because the project manager has to determine whether it needs to take preventive action.

5. **Closing**

   The closing phase is the last stage of project management in which the project manager reviews all project work and ensures it works until reaching a deal in the project contract. This phase of activity is important for administrative closure. In this phase, a project manager has to confirm all deliverables accepted by customers, such as the accounting report. It also needs to deal with the excess of material, reassigning the personnel, and pay them. Moreover, it is to reallocate the project facilities, equipment, and other resources (PMI, 2017). Project managers have to manage their employees' knowledge and share it to identify the lessons learned in the project.

2.2 Construction Project

According to Walker (2015), construction project management is the planning, coordination, and control of a construction project from the conception phase until the completion phase. It needs to deliberately identify the objectives of the client regarding utility, function, quality, time, and cost. In construction management, it concerns the relationship between resources (materials, equipment, funds, and workers) and integrating, monitoring, and controlling all the stakeholders to the project and the output. Furthermore, evaluation and alternative selection to meet the satisfaction of the client with the project outcome.

In the construction process, there are a few fundamental characteristics in common with other projects. The process has a starting to a finishing point, which is well known to use the Project Management Life Cycle (PMLC). The construction project is started by knowing the environment condition, creating motivation, and the opportunity to construct to achieve the goal.

2.2.1 Operating System and Managing System

The role of construction project management is to guarantee that the project works in line with the client's objective. According to Howell (2011), the term "operating system" is a brief description of the way work is managed.

There are two kinds of operating systems for project management, traditional and modern (new flow). Howell (2011) argued that "a new flow-based operating system was poised to replace the activity-centered operating system of traditional project management and that a coherent organizational and contractual approach would evolve." The use of technological systems is one way in a new flow. Meanwhile, the project management team able to rethink the design process and deliverables.

According to Lyons (2017), construction requires a unifying process. The construction operation system is something that the industry should be looking to develop. To build a future project, construction needs to connect people and technology (i.e., think, device-agnostic) and software (e.g., operating system) in managing a project. A construction operating system is a term for the central, cloud-based software that connects each point solution, device, and user throughout the overall construction business from bidding to closeout. The way it works is using the Open Application Platform Interface or "Open API". The construction operating system will integrate data from all of these applications into a single unified system that will provide actual, clear, organized, and trendy data. (Jobsite, 2017).

There are several benefits to using the Open API operating system. According to Helsinki et al. (2016), one of the benefits can be described for urban construction, where cities can greatly benefit from using harmonized open APIs. For example, they can build their own operating processes in cities and achieve cost savings. In their statement argued, cities can take advantage of the insights that companies, developer communities and individual developers can offer, if possible, to involve targeted users of an open API in the design and development phases at an early stage.

2.2.2 Building Information Modeling

Building Information Modeling (BIM) reenacts the construction project in a virtual environment. The benefit of a simulation is that it takes place on a computer with the use of a software program (Kymmell, 2008). BIM is a process of generating and managing data for a building during its life cycle, that merges the next generation of Information Technologies (IT) with Computer-Aided Design (CAD) to build a real-time and dynamic building modeling software to increase productivity in building design and construction. The purpose of applying the BIM process in the Architecture, Engineering, and Construction (AEC) field aims to develop a process of life-cycle information. The life-cycle information is about physical characteristics and functions in a design that can be useful and continued to the facility management, and can even help further design decisions, whether for renovation or demolition (Vanlande et al., 2008).

Building geometry, spatial relationships, geographical information, as well as consideration of the quantity and quality of building components are part of the BIM production process. BIM can be used to illustrate the whole building life cycle, including the construction process and facility operations, as it is easy to extract the quantity and quality of material, so it will help to divide, differentiate and describe the scope of work. The system, installation, and sequence of the circuit can be displayed on a scale relative to any facility or facility group. BIM can be used to make progress with model drawings of the actual parts used to construct a building. This way, BIM requires construction projects to change the traditional Architecture stages, where most of it depends on paper-based modes of communication, which are used by most architects and engineers. These accidental errors in paper documents would cause unanticipated additional costs, delays, and eventual lawsuits between various parties in the construction project team (Eastman et al., 2011). The use of 2D visualizations and instructions in a 3D world will require multiple translations, which may create oversights and undetected errors until it is too late to address them effectively. As construction is almost always site-specific and rarely performed by the exact same project team, these will complicate the planning and preparations for a project and create major challenges for the project team in finishing a project (Kymmell, 2008).

BIM can be characterized by many technologies and software packages that can be used by BIM, such as CAD data and object, and parametric building modeling, along with the data exchange and sharing models where there is centralized control of ownership and a master copy of data. Commonly, other features that can characterize BIM is the main feature that can store, share, and exchange data within the system, as it is data-rich and comprehensive, also cover unimplemented information domains. Implementing a BIM system will also cover several life-cycle phases of the AEC project, where BIM supports 4D analysis so activities from the project schedule can be simulated and studied real-time and dynamically (Vanlande et al., 2008).

2.3 Work Breakdown Structure

Work Breakdown Structure (WBS) provides a common reference for every project element and shows the project's specific tasks (Rad, 2002). WBS describes the work sequence in more detail and explains the level of work from the general to a specific form. It is to integrate the project plans, time (period), resources, and quality that become manageable, and detail components. The WBS is used to generate work schedules and estimating the duration of each activity of the primary tasks. The WBS is deliverable-oriented, so the WBS is to highlight a logical order of the products, the parts, and modules.

The WBS is a hierarchical breakdown of the total scope of work that the project team must do to achieve project objectives and produce the required results (PMI, 2017). According to Heizer (2017), each descending WBS level represents a more detailed definition of project work. The typical WBS decreases in size from top to bottom and is indented as follows:

Level:

1. Project
2. Primary tasks in the project
3. The sub-tasks in the primary tasks
4. Activities or deliverables in the sub-tasks

The hierarchical level is different for each project and depends on how big the project is. However, the WBS lowest level should represent the deliverable and detail activities, so it is becoming measurable to know the progress of the project.

2.4 Network

The network is relationships among work parts depicted or visualized in a network diagram. A network diagram is to identify which of the project activities start earlier or later. There are two approaches to draw the project network diagram. These approaches can be called notation. These notations are AOA (Activity-on-Arrow) and AON (Activity-on-Node). According to Heizer (2017) AON convention, nodes designate activities. AOA arrows represent activities where is the beginning and finishing times of an activity called "events". AON node diagram represents activities.

Figure 2.3 depicts the example of AOA notation. A diagram is usually identified as an event by number in the nodes. Event "1" is the initial condition of the project before it starts. The diagram shows that it starts with task A and task B, which means those two activities do not have any predecessors. Event "2" and "3" are the condition after doing task A and task B. Task C and task D have only one predecessor, namely, task A and task B, respectively. The completion of the project or event "4" will be reached after Task C and Task D have finished.

Figure 2. 2 Activity-on-Arrow Notation

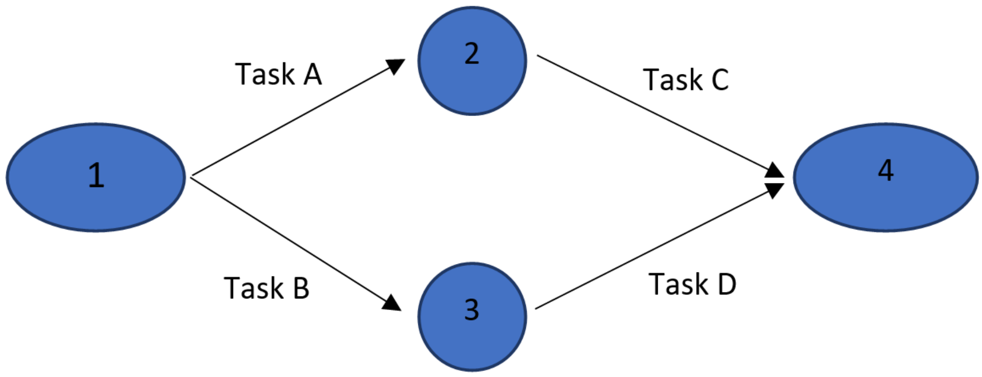
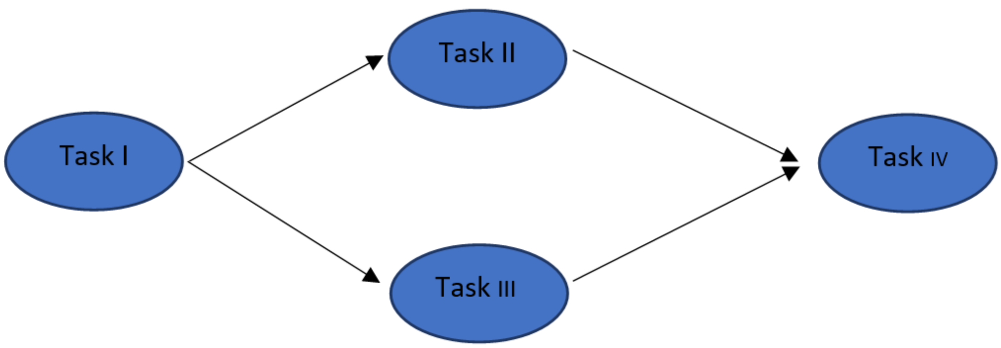


Figure 2.3 depicts the example of AON notation. Nodes represent project activities, and arrows describe relationships between activities. This example starts with one task, which is Task I. Task I is followed by Task II and Task III. Task IV will be started after Task II and Task III are finished. The overall project completion will be achieved after Task IV is done.

Figure 2. 3 Activity-on-Node Notation



2.5 Critical Path Method (CPM)

The project activity is identified by disclosing all of the series activity in the form of a continuous path of a project from beginning to ending. It seems a chain of activities, in term "path". However, the projects may have parallel activities at a particular time, so the diagram network on the bridge shows that "path" appears between the beginning and ending. These paths do not represent alternative options over the network, instead, each of these paths has to be traveled during the actual process (Sears, 2015).

The critical is the minimum time to complete the overall project, which is the largest possible routes through the network. All of the paths must be traversed to finish all of the activities, so the longest duration of one of these paths is the length of time necessary to finish the activities as in the agreement of the established project logic (Sears, 2015).

The CPM (Critical Path Method) is a way of using an arrow diagram to determine the critical path. According to Lewis (2011), the critical path has no latitude when the project has been scheduled to the end point because a critical path is the longest among paths in the project. The shorter path than the critical path is called float or slack. The float or slack is the path that provides to have a delay in a certain duration does not cause a delay in the overall project because there will be unexpected events and or inaccurate estimation.

According to Heizer (2017), the CPM is also known as the network method that shows a series of component activities. This method was developed to control many activities in complex dependencies and enable the project manager to see clearly the relationship between activities. It is needed to calculate the two distinct starting and ending times for every activity in the project in order to find the critical path. There are some terms as follows:

- **Earliest Start (ES)**: the earliest time to start the activity when all predecessors have been done.
- **Earliest Finish (EF)**: the earliest time that finishes an activity.
- **Latest Start (LS)**: the latest time to start an activity without making any delay to the overall project.
- **Latest Finish (LF)**: the latest time an activity has to be finished but does not delay the completion of the whole project.

There are two kinds of approaches to get the ES, EF, LS, and LF in one network which are forward and backward pass. By doing forward or backward pass calculations, the slack value of one activity can be identified. Slack or Float is the delay without slowing down the completion of the project or past the schedule constraint (Dionisio, 2018). The Slack value can be determined by finding the difference between the LS value and the ES value. Furthermore, an activity with a zero slack or float value knows as critical activity (Heizer, 2017).

Taner et al. (2020) mentioned the benefit of CPM is to estimate the time to complete the project. In line with the statement, Elsosan's (2015) research classified the advantages of CPM in controlling the time and cost of a construction project. Several other advantages in using CPM mentioned by Ashushrma (2020) are 1). It is effective in new project management, 2). It can strengthen a team perception if it is applied properly, 3). It provides a demonstration of dependencies, which helps in the scheduling of individual activities, 4). It helps in optimization by determining the project duration, 5). It helps in determining the slack time. 6). It helps the project manager in identifying the most critical elements of the project. 7). It gives a fair and concise procedure of documenting of project, etc. As a result, CPM is an explicit and clear approach to illustration project plans, schedules, time, and cost performance is developed (Ashushrma, 2020).

2.6 Project Evaluation and Review Technique (PERT)

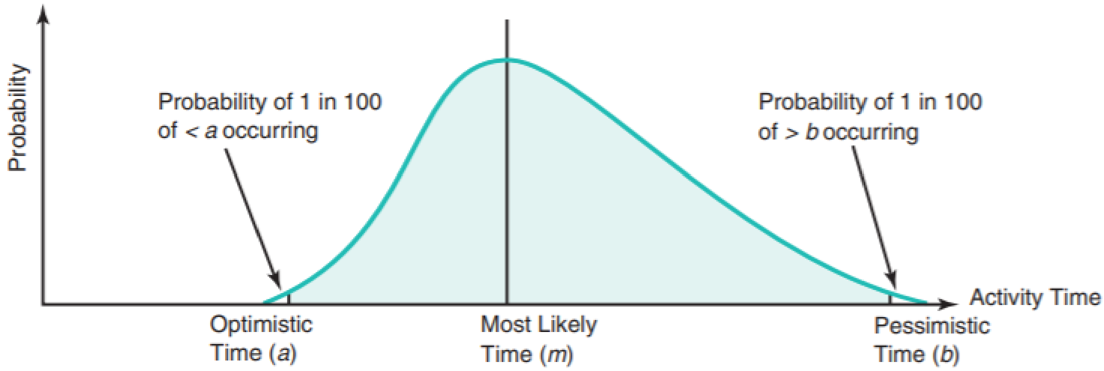
The difference between PERT and CPM is that PERT calculates task duration and estimates the probabilities of work completion. Meanwhile, the CPM is estimated task duration without considering the probabilities (Lewis, 2011). PERT is a technique to simplify the scheduling and planning of a complex and big project. The CPM estimates the time of project activity with a deterministic approach by one estimation that reflects certainty, while PERT is used to deal with a situation with a high degree of uncertainty in the activity period.

PERT is concerned with the required time to complete each task. It is focused on the minimum required time to the end of all activities in a project. Furthermore, considered an uncertain schedule on a project though unknowing the details and durations (Howard, 2009). This method aims to reduce the delays and interruptions as much as possible and coordinate the various parts of work. This technique allows the project to control and manage orderly because the schedule and the job budget have been determined.

PERT's goal is to achieve a certain level, which is important in completing project activities. PERT is a sophisticated method of project planning, control, and development based on the portrayal of network activities (Howard, 2009). According to Heizer (2017), PERT is used to an approach that assumes activity durations, depends on many factors and variations, hence it is better to estimate the range by using three points estimates, are as follows:

- Optimistic duration time (a) is the optimist scenario, which means the fastest time to finish the activity by assuming all required resources are available and assuming everything works well, have no delay, and no issue.
- Pessimistic duration time (b) is the worst scenario for the activity based on analysis so that the duration will be the longest time.
- The most likely time (m) is the estimation based on the duration of the activity analysis by assuming the resources have been assigned, realistic expectations of the activity duration, and possible interruptions.

Figure 2. 4 Beta probability distribution with the three estimation times (Heizer, 2017)



Those three estimation times will be considered as parameters that attempt to measure the uncertainty, i.e., standard deviation and variance. Thus, this method has a specific way of dealing with various forms of calculation.

PERT assumes the time activity development to be distributed as Beta distributions and the consequential development time to be a usual distribution (Ramesh, 2019). The reason is that it is more accurate to determine the weighted average than to add three parameters and then divide by three (Cyinthia, 2018). It most likely the duration (time) has a higher chance to occur than the optimistic and pessimistic duration. The beta distribution is used to consider the three parameters (a, b, and m). The beta distribution weights of three parameters are to find the expected activity of time (t), which is shown as follows:

$$t = \frac{(a + 4m + b)}{6} \tag{1.1}$$

To know the variance (v) or dispersion of completion time of activity, it is the 1/6 of the range of distribution between the optimistic (a) and pessimistic (b) time duration. The range of time indicates the degree of uncertainty associated with the process of estimating activity durations. So that the variance (v) can be calculated using the following equation:

$$v = \frac{(b-a)^2}{6} \tag{1.2}$$

The variance shows the distribution time duration of every activity in the project. In the PERT, it uses the variance of activities in the critical path. It is because those activities are mainly affecting the overall project completion time (Heizer, 2017). To compute the project variance (v_p), it sums the variance of the critical activities:

$$\sigma_p^2 = v_p = \Sigma \text{ (activity on critical path variances)} \tag{1.3}$$

By having the project variance, it is able to have the project standard deviation (σ_p) as follows:

$$\sigma_p = \sqrt{v_p} \tag{1.4}$$

It is assumed that the total project completion duration follows the normal probability distribution. The standard deviation will be used to calculate the probability of the project completion at the time by finding the *Z* value, as follows:

$$Z = \text{(Due date – Completion expected date)}/\ \sigma_p \tag{1.5}$$

The *Z* value is the standard deviation the target date lies from the expected date or distribution weight (t). Z value enables to calculate the probability that occurs in the normal distribution. Therefore, it shows the probability of the project completion time in pursuit of the target date.

PERT is useful in understanding the performance of the work throughout the course of the project and oriented in project scheduling techniques (Arjun, 2020). Habibi et al. (2018) classifying two main benefits of PERT as follows: a). Estimating project time and cost, and b). Approximate the estimated results to real values. According to Prodyogi (2017), the benefits of PERT are mentioned in 5 (five) points, which are: 1). What-if Analysis Tool, 2). Ability in Coordination, 3). Visibility on Critical Paths, 4). Planning for a Big Project, and 5). Activity Analysis. PERT diagrams are used to observe critical information such as the order of activities in the project, the effect and priority, the effects of problems affecting the functioning between activities (Saker, 2015: Taner et al., 2020).

2.7 Cause and Effect Analysis

A single cause and effect diagram often called a “Fishbone” diagram or Ishikawa diagram can help in brainstorming or inspiring to identify possible causes of a problem and in sorting ideas into beneficial categories, which is a visual way to notice cause and effect. It is a more organized and/or structured approach than some other tools on hand for brainstorming causes of a problem, such as the “Five Whys tool” (Kane et al., 2020).

There are six (6) steps on the procedure of Fishbone diagram (ASQ, 2021), as follows:

1. Agree on a problem statement (effect). Writing on the center-right of the flipchart or whiteboard, then drawing a box around it, and making a horizontal arrow running to it.
2. Inspire the major/main categories of causes of the problem.
3. Write the categories of causes as branches from the main arrow.
4. Thinking of all the possible causes of the problem. Into questions “Why does this happen?”. Then, the facilitator writes it as a branch from the proper category. Causes can be written in several sites/places (if they relate to several categories).
5. Then do the repetition, within asking “Why does this happen?” related at each cause, next, by writing sub-causes branching off the causes. Continue to ask “Why?” and generate deeper levels of causes. Layers of branches indicate causal relationships.
6. When the group runs out of ideas, keep attention within space/places on the chart where ideas are slight.

2.8 Literature Review Summary

Project management is being mandatory for the survival of many firms. In business terms, project management never runs normally, meaning that several obstacles such as delays that can occur on a project, can significantly affect costs. A mismatch between planning and implementation mostly can cause a delay that would lead to greater loss for the company. To analyze the main factors causing delays, it is necessary to have some special reviews in the project management approach. This is because project management has been developing into a process of a business rather than merely a project management process. In utilizing Project Management approach, although Traditional Project Management (TPM) is well established, the birth of Agile Project Management (APM) stole the spotlight in the eye of scientists and practitioners. The new approach is more agile, meaning it’s more flexible and cooperative with the client’s needs as its orientation (Spalek, 2016). The Project Management Life Cycle

(PMLC) is also being explained with 5 phases of processes that include initiation, planning, executing, monitoring and controlling, and closing process (vide section 2.1).

Afterward, the construction project that takes the role as the case study of this report is being explained, in which its management describes planning, coordination, and control of a construction project from the conception phase until the completion phase, covering Project Management Life Cycle. This aims to determine the relationship between resources (materials, equipment, funds, and workers) and to integrate, monitor, and control all the stakeholders to the project and the output. Moreover, a construction operating system is a cloud-based software that links each point solution, device, and user in the entire construction business from bidding to closeout. Building Information Modeling (BIM) is also explained as a process of generating and managing data for a building during its life cycle, that merges the next generation of Information Technologies (IT) with Computer-Aided Design (CAD) to build a real-time and dynamic building modeling software to increase productivity in building design and construction. BIM changes the traditional paper-based communications and designs that could cause unanticipated additional costs, delays, or even lawsuits between various parties in the construction project team. As a solution to solving delay considerations, BIM is useful as a powerful tool for reducing delays.

Afterward, it is necessary to have a Work Breakdown Structure (WBS) to describe the work sequence in more detail and explain the work level from the general to a specific form. It is to integrate the project plans, time, resources, and quality that become manageable and detailed components (vide section 2.3). The network diagram illustrates the sequence of activities and connections among activities in the project. A network diagram identifies which project activity starts earlier or later (vide section 2.4).

Delays that occur in a construction project can be analyzed through several methods such as CPM and PERT to control the time and cost of a construction project, where CPM is able to provide companies information to make critical and important decisions, using the critical "path" network diagram. Critical activity can be identified by finding where the amount of slack time is 0. The slack time can be calculated by the difference between the latest start and earliest start schedules or the latest finish and earliest finish schedules. In contrast, PERT calculates task duration and estimates the probability of work completion. The probability of completion of the project can be calculated by considering three estimated times and target time (vide section 2.6).

Lastly, the cause and effect analysis is a method that can help in brainstorming or inspiring to identify possible causes of a problem and in sorting ideas into beneficial categories, which is a visual way to map cause and effect. It is a more organized and structured approach than some other tools on hand for brainstorming causes of a problem (Kane et al., 2020). There are six steps in doing Fishbone diagram procedures. These steps include deciding on a problem statement, gathering information for the key categories of problem causes, writing down the categories, searching for any potential causes, drilling down to the root cause, and paying attention to any ideas that come up (vide section 2.7).

3. Methodology

3.1 Introduction

The methodology of this study is to identify and explain how the study is conducted. This section will describe the data collection process and the methods and approaches used to address the research questions.

3.2 Methodological General Issues

A research business project is a systematic analysis and investigation of a project to identify facts. This research business project tries to find problems in a construction project in a remote area. This case study focuses on a power plant construction project in Papua by a state-owned company.

This study can also be a business project case study because it will try to solve the project problems. A business project case study is a planning and decision tool that forecasts the potential outcomes after taking certain actions to solve the issues. In this business case, the writing structure must consider the introduction, literature review, methodology, discussion, conclusion, and recommendations (Schmidt, 2009). It is expected that at the end of this report, the company will receive recommendations on which strategy it should implement to address the project's cause of delay.

Yin (2009) claims that it is possible to classify the case study typology into three major groups: exploratory, descriptive, and explanatory. This business project uses an exploratory method to clarify the understanding of a particular phenomenon or problem that may not be clear, aiming to make it more explicit (Saunders et al., 2007). In this case, an exploratory single case study will be used. This study uses a quantitative approach to process the data of schedule and a qualitative approach to analyze collected data from in-depth interviews.

3.3 Data Processing

It is called data processing when data is obtained and converted into usable information. Data processing is typically performed by a software engineer or data scientist. It is essential to be done accurately so the output will not be damaged or adversely impacted. Data processing takes raw data and transforms it into a more readable format (charts, papers, and others) so that computers can translate it and workers in a company can use it. In this case study, data processing is divided into five stages, which are data collection, data preparation, data input, processing, and result analysis.

3.3.1 Data Collection

To obtain the data needed in this study, data collection can be divided into two types of data, which are primary data and secondary data. The data that has been obtained will be used as the main basis for answering the problem formulation in this study related to the causes of delay and the solution.

Primary data is original data in the field that is taken directly from the interviewee with semi-structured questions. An in-depth interview is an interaction between an interviewer and a single participant discussing issues or problems in the construction of the power plant. In-depth interview results in oral narration and descriptive. An in-depth interview is a process of question and answer between interviewer and interviewee to obtain information for one purpose. This interview is good for a business project study, which using internal resources. This interview was done with the interview guide presented. The interview guide presented purpose and introduction, so the respondents able to understand why the interview needs to be done, open-ended questions, chosen because the open-ended question is more effective to reveal respondents' thinking and conclusion, to get any suggestion and recommendation from respondents. The interview topics, questions, and the collected data will be structured in tables and can be seen in Appendix 1 (Table 8.1).

Furthermore, this stage also collects some data regarding the work activity, which is the scope of work of each method and the estimated time such as fastest time (optimistic duration time) and the longest time (pessimistic duration time), the causes of delay, and the solution resolves the causes. The respondent is important because they are the key to data information related in all company activities (from planning, implementation to monitoring). The respondent of this research is a Construction Project Manager with seven years working experience in the company. He is responsible for planning, controlling, and leading construction projects. The interview was conducted from October 2020 until December 2020 with six meetings by voice call (WhatsApp call) or video call (such as Zoom). The topic was varied related to the construction performance in the project. Moreover, activities data is obtained from the weekly report from the company. However, some of the content cannot be revealed in this thesis due to the company's confidentiality. In this study, the project report includes all activities or construction work, from preparatory work to commissioning and remote monitoring systems. The information shown from the report is regarding detailed activities, the schedule, and others related to this research. Moreover, the data obtained for this project report are schedules, activities, and work progress in percent. The primary data can be seen in Appendix 2.

Secondary data is a type of data that is not obtained from the primary source. There are literature and books as references and tools of analysis. In addition, data will also be obtained through journals, articles, and official websites as references that connect the issues discussed in the study.

3.3.2 Data Preparation

Data preparation is the process of removing unnecessary, incomplete, incorrect, and secret data from a database. This stage is referred to as pre-processing because it involves organizing and sorting data before input data. In this case, the researcher will clean up data that does not have cost data and schedule, and then the cleaned data will be confirmed to the construction project team to ensure accuracy.

3.3.3 Data Input

Input data is the stage where the clean data will be entered into the Microsoft Project software. In this stage, the data that is entered into the Microsoft Project are deliverables, sub-tasks, primary tasks, start time, finish time, duration, and predecessors. These data are also entered into Microsoft Excel, which will be added with other information such as the cost percentage for each activity, three-time estimates, weekly planned and actual complete percentage.

3.3.4 Processing

Processing is the fourth stage in which the data entered into the software in the previous step is processed for interpretation. This phase consists of S-Curve, CPM, and PERT processing.

3.3.4.1 S-Curve

This research project using the s-curve analysis to portray the progress over time. The time interval can be expressed in weeks or months. The s-curve analysis will design the cumulative work based on costs. This analysis will also elaborate on aspects that may conclude along with the project. A bill of quantity and monthly report are required for this work. There are several steps in making the S Curve execution timeframe using Microsoft Excel. The first thing that needs to be done is to input each of these work items' schedule (completion time). Then calculate the ratio between each work item's cost to the total cost so it will be the percentage of each activity; After that, add up the percentage of the distributed activities cumulatively for each unit of time from the start until the end of project; then input the monthly or weekly cumulative progress at the bottom of the table. After that, input a line diagram showing the monthly or weekly cumulative progress for each period, then the s-curve is obtained. The same step to draw the s-curve for planned work progress to compare with actual work progress to track how the project performs and the deviation between the plan curve and the realization curve.

3.3.4.2 Critical Path Method

There are two methods that have been widely used for approaching project scheduling, namely the Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT). These methods may help project managers to evaluate times on activities, calculate activities flow and duration towards the project. According to Kramer & Jenkins (2006) statement, this emphasizes that any critical activity that is delayed (or has additional time to the activity duration) can trigger a corresponding delay in the completion date. CPM assumes previous experience with similar projects from relationships of resources and job times.

In this part, this study used CPM to answer the first Research Question to discover which activities are included in the critical path and how they relate to each other. In this case study, the schedule has been established. The planned duration with a certain degree of certainty is determined to ensure the timely completion of each activity, and therefore, the project completion. The Work Breakdown Structure has been well-constructed based on its dependencies, the level of the project phases, and the deliverables. So, the first step to do the CPM method is to collect all activities, the schedule, predecessors, and duration to be input in the Microsoft Project and ensure the hierarchy of each activity. The Microsoft Project will help to determine the Earliest Start, Latest Start, Earliest Finish, and Late Finish. And then, the Float or Slack time will be known by calculating the difference between the latest start and earliest start time of an activity or the difference between the latest and the earliest finishing time of activity. If the slack activity is zero (0), then it is categorized as a critical path activity. Microsoft Project also helps to describe the network from initial activity to last activity. The network diagram is redrawn following the AON (Activity-On-Node) standard for critical activities using Microsoft Visio to provide better visualization.

3.3.4.3 Program Evaluation and Review Technique

On the other hand, Program Evaluation and Review Technique (PERT) is used to generate probabilities from calculating aspects as realistic durations that have been considered in terms of resources and field conditions. PERT considered the probability, and the uncertainty includes optimist and pessimist duration in its analysis. It may also expect activities that have the potential for causing the delay. Thus, the project manager may know the possibility of the delay earlier. PERT method will be useful to answer Research Question number two, which is to determine the probability of completion of the project. The PERT method is carried out through Microsoft Excel for data input such as the three duration (i.e., optimistic, pessimistic, and most likely) and target duration in order to get the expected time duration, the variance, and its standard deviation. Hence, the probability will be obtained by calculating using the formula (1.5). The probability reflects the uncertainty of the estimated duration in the project construction activities schedule.

3.3.5 Results Analysis

In this stage, the output of the process will be the network diagram, the s-curve, the probability to be on time. From the output, the researcher will analyze the output to find the cause of the delay by using Fishbone analysis. Fishbone analysis, also known as the Ishikawa diagram or Cause-Effect Diagram, is the method used to help troubleshoot within project activities by analyzing cause and effect in the construction project in a fishbone diagram. Fishbone analysis will answer Research Question number 3, which covers the reason the delay happened in the power plant construction project. This method will be helpful in the brainstorming process and identify possible causes of a problem, and sorting causes into categories. Cause-and-effect diagrams are used to identify problem factors that have a significant effect on company performance. Fishbone analysis is carried out by discussing with the project manager. The first step to analyzing a fishbone is to determine the problem statement or effect. Then ask about issues that occur during the project carried out in the field. The topics being discussed are human resources, material, machine, method, and environmental issues. These problem categories can be added if needed.

After finding the causes of delay, the researcher will identify the solutions to solve the causes of delay in the project. The recommendation will be discussed based on the problems and needs in the field. Another recommendation will be generated for long-term business strategies in which it can be a modern tool for better project performance in the future based on the literature study.

4. Case Study

4.1 Introduction

This business project is a case study conducted on a construction project handled by this company which focuses on implementing its time management. The projects that will be discussed below are still under construction projects at the time of the project research. The activity to be studied concerns a construction work project to build a power plant in Papua. The data taken is from contracting companies which are one of the state-owned enterprises in Indonesia.

4.2 Core Conceptual Stages of Project Management

In a power plant project, there are five primary stages from the initiation process until project closure. The main work of this project requires a total of 6 months. These are the following stages:

1. **Project Initiation**

   It began with the government wishing to increase electricity power in the Papua region. Capable stakeholders are needed to build the power plant in the area. Therefore, stakeholders in this project are the government, user company, contractors, and suppliers. The construction company is a contractor who is responsible for executing construction from the start until the power plant can operate to generate electricity. The construction company has project managers responsible for project implementation, supervision, and regular project progress reports provided to the stakeholders. In this process, they collected data related to equipment, tools, and material needs. It also provided information about field conditions to the owners, contractors, and engineer teams involved in this project.

2. **Project Planning**

   It involved making plans and work sequences during the project. Project planning was to identify the duration of the activities and the lag time, float time, and critical paths in the power plant construction project work schedule. The project planning phase considered the possible obstacles that might affect construction project work. This project is targeted to start in October 2020 until completion in March 2021. This project must be completed on time, which corresponds to the target of the government and companies' plans. The contractor team planned the project with around 400 construction workers to finish on schedule. Moreover, project planning was about the building design process and calculating each product supplied before conducting an open tender.

3. **Project Execution**

It was started after the planning process had been agreed upon by the related parties or stakeholders. The execution started with coordinating all project stakeholders, which began with a meeting and briefing to the construction workers by the field coordinator. Stakeholders such as the government and companies came to the project field as an agreement that the project starts. At this stage, the construction company has selected the vendor or supplier and the supplying material and product specifications scheme. Every implementation process applies a Covid-19 prevention protocol as well as the work safety procedures to every worker present in the field. The implementation process has four main jobs, namely preparatory work, civil works, mechanical and electrical work, and other work. The work that makes the biggest contribution to the fieldwork is civil works, namely buildings work for electrical equipment in the implementation stage.

In the project execution, communication is the key factor for a successful project. Communication in the project is essential because it aims to pursue the daily objectives. Effective communication improves employee motivation and productivity as well as a positive environment. Every work process must be transparent to various roles in the field. By having good communication and coordination, the obstacles that occur in the field can be solved quickly to satisfy every stakeholder. If there is a change in the scope of work, the coordinator ensures that it is conveyed to the project manager.

4. **Project Monitoring and Controlling**

This stage ensures that all the planned schedule, cost, and quality are being adequately implemented on the project. Monitoring of the project is to check the progress of every activity. In this case, it uses some tools such as drones and other devices to help the contractor. Project managers are responsible for monitoring and controlling the entire project and ensuring to reach the key milestones. Project managers also examine the supplier performance. The project manager makes a daily report which contains the percentage of work accomplishments such as construction contract volume and calculation of actual progress percentage against the planned. A daily report shows the barriers, challenges, and obstacles faced during the project. Meetings with stakeholders such as the project sponsor are held weekly by conducting teleconferences or face-to-face meetings. The reporting is mainly done by sending email and through a cloud system that connects with each stakeholder. Monthly meetings are also held by each stakeholder face-to-face who reports monthly progress, attaching S-Curve to visualize work progress and costs incurred during the project. In addition, it also discusses whether there will be changes from the initial plan that was set.

5. **Project Closure**

Project closure will represent the completed project. The construction company will hand over the final report on the entire project from the project managers to the project sponsor and other stakeholders. Since the project is still halfway through, so the project closure activities have not started yet. This closing process will be carried out if each division has completed its project and provided reports and then received approval from the project sponsor and parties involved during the process. To get the approval, the construction results will be audited and inspected to ensure safety and quality. In the closure process, the construction company will identify and retrieve the excess equipment and excess material. They also ensure to demobilize the contractor's project workforce and restore the site conditions.

4.3 Data Collection and Treatment

The planning process results in the list of activities carried out during the implementation or construction process. The construction activities are divided into several groups of activities. The project consists of 4 primary tasks with five sub-tasks in the second primary tasks and three sub-tasks in the third primary tasks. There are 111 deliverables or activities included in the power plant construction project from the all-sub tasks.

The following describes the four primary tasks as follows:

1. Preparatory work

Preparatory work is work that consists of mobilization and demobilization. Mobilization is an activity to get resources into the project site, while demobilization activity is to return project equipment according to the tender document's specifications. Based on the agreement between the project sponsor and the construction company, this activity is considered complete. This activity also includes equipment procurement as stated in planning documents such as hoes, drills, land transportation equipment such as trailers or trucks, water transportation equipment (pontoon), and others. Before mobilization, the contractor must notify and ask the project manager to approve the excavator's type and capacity utilization. Materials procurement is also included in the preparatory work. In addition, mobilization activities include bringing in staff and work personnel according to work needs, creating a base camp for workers' needs, including electricity from small electric generators with diesel fuel and toilets. In this activity, all risks that might occur are the responsibility of the contractor. Type of machines and field workers may turn over in the middle of the project as well as the hand tools, and other types of tools will be returned (demobilized) within a specific time depending on the schedule and contract.

2. Civil works

   Civil works focus on building construction, starting from excavation and foundation until the entire power plant building is ready for use. The civil works aim to facilitate and host the power plant's electric generation equipment. Civil works are the most dominant work in the power plant construction project, with 85% of the total project cost. The civil works include building a dam and intake, settling tank, tailrace, pipe penstock and anchor block or saddle, and powerhouse. In the subtask of dam and intake, there are 3 groups of activities, which are intake channel building works, concrete and install works, and open intake channel works. In the settling tank subtask, there are 4 groups of activities, which are settling tank, plastering, and finishing, roof and sluice drain, and reinforced concrete works. The tailrace subtask consists of 2 groups of activities: the earthwork and open channel work. The pipe penstock and anchor block subtask include earthwork, rebar concrete, plumbing activities group. The powerhouse's subtask has 7 groups of activities, namely earthworks, installation works, reinforced concrete works, frame and door works, painting and drainage works, roof and cover work, and utility installation works. The civil work limitation is to finish the physical building until it is ready to be used for electrical installations at the next step of the work.

3. Mechanical and electrical works

   Mechanical and electrical work aim to install electrical things with certain specifications stated in the Bill of Quantities document. It consists of 2 subtasks, namely mechanical works and electrical installation works. Mechanical works include turbine, speed increaser, generator, electronic flow, powerhouse wiring, hoist crane manual, digital load control and ballast, generator set, ME toolkit, and transformer. The electrical installation works consist of activities such as installing single and double switches, sockets, lights, lightning protectors, panel mounting, and lighting panel installation.

4. Other works

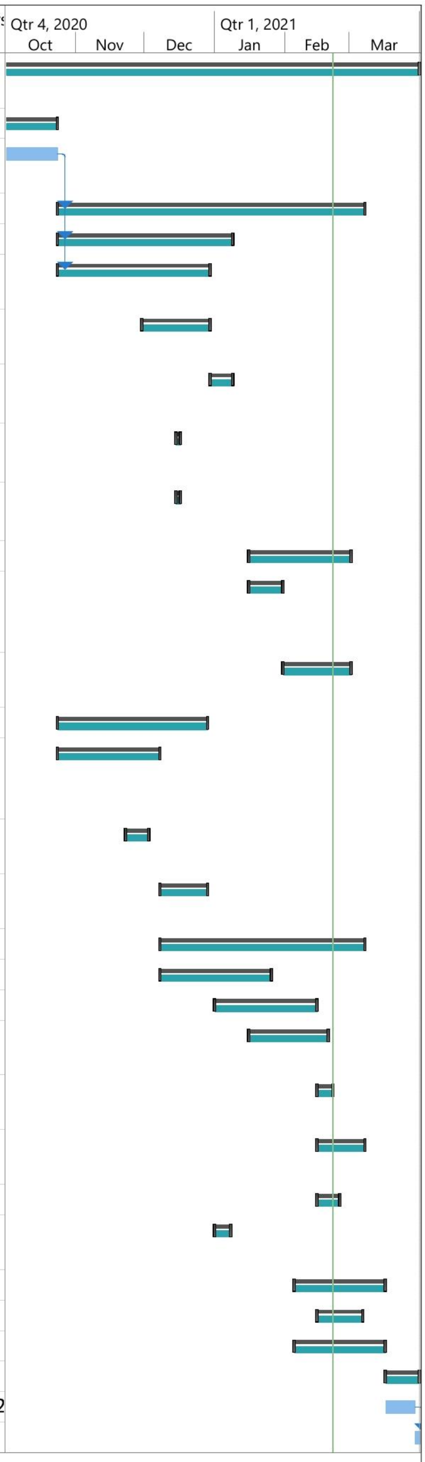
Other works are a set of activities that include training, commissioning tests, and SLO (Operation Eligibility Certificate) as well as remote monitoring systems. Commissioning is to provide the electrical and facilities able to operate according to the operational requirements or standard. This work is carried out when civil and electrical works have been completed.

4.4 Data Processing

The four primary tasks above are divided into activities or deliverables, as shown in figure 4.1. These activities are defined with the WBS (Work Breakdown Structure) as the activity code. The code is in the numeric form that was made by the Microsoft Project. Figure 4.1 shows all activities and its detail. It shows every activity with its duration (in days), schedule (start and finish), as well as the Gantt Chart on the right side of the image. The plan and actual percentage are based on the plan and actual situation in September. This diagram can help the project team to recognize the project’s progress in a simpler and easier way to read.

Figure 4. 1 Summary of Project Activities (please check Figure 8.1 in Appendix 2 for the detail)

ID	WBS	Task Name	Duration	Start	Finish	Predecessors
1	**1**	**POWER PLANT CONSTRUCTION**	**184 days**	**Tue 9/29/20**	**Wed 3/31/21**	
2	**1.1**	**PREPARATORY WC**	**25 days**	**Tue 9/29/20**	**Fri 10/23/20**	
3	1.1.1	Mobilization demobilization	25 days	Tue 9/29/20	Fri 10/23/20	
4	**1.2**	**CIVIL WORK**	**135 days**	**Sat 10/24/20**	**Sun 3/7/21**	**3**
5	**1.2.1**	**DAM& Intake**	**77 days**	**Sat 10/24/20**	**Fri 1/8/21**	**3**
6	**1.2.1.1**	**Intake channel**	**67 days**	**Sat 10/24/20**	**Tue 12/29/20**	**3**
12	**1.2.1.2**	**Work of concrete +**	**30 days**	**Mon 11/30/20**	**Tue 12/29/20**	**9**
16	**1.2.1.3**	**Open Intake Channel**	**10 days**	**Wed 12/30/20**	**Fri 1/8/21**	**13**
19	**1.2.2**	**Settling Tank Building**	**2 days**	**Tue 12/15/20**	**Wed 12/16/20**	
20	**1.2.2.1**	**Roof work, Sluice Drain**	**2 days**	**Tue 12/15/20**	**Wed 12/16/20**	
23	**1.2.3**	**Tailrace**	**45 days**	**Sat 1/16/21**	**Mon 3/1/21**	
24	**1.2.3.1**	**Earthwork / Foundation / Concrete**	**15 days**	**Sat 1/16/21**	**Sat 1/30/21**	
26	**1.2.3.2**	**Open Channel**	**30 days**	**Sun 1/31/21**	**Mon 3/1/21**	
29	**1.2.4**	**Pipe Penstock (4**	**66 days**	**Sat 10/24/20**	**Mon 12/28/2**	
30	**1.2.4.1**	**Earthwork / Concrete Block**	**45 days**	**Sat 10/24/20**	**Mon 12/7/20**	
37	**1.2.4.2**	**Reinforced Concrete**	**10 days**	**Mon 11/23/20**	**Wed 12/2/20**	
41	**1.2.4.3**	**Plumbing Work +**	**21 days**	**Tue 12/8/20**	**Mon 12/28/20**	
50	**1.2.5**	**Powerhouse**	**90 days**	**Tue 12/8/20**	**Sun 3/7/21**	
51	**1.2.5.1**	**Earthworks**	**49 days**	**Tue 12/8/20**	**Mon 1/25/21**	
57	**1.2.5.2**	**Masonry Wor**	**45 days**	**Fri 1/1/21**	**Sun 2/14/21**	
62	**1.2.5.3**	**Reinforced Concrete**	**35 days**	**Sat 1/16/21**	**Fri 2/19/21**	
84	**1.2.5.4**	**Frame and Door Work**	**7 days**	**Mon 2/15/21**	**Sun 2/21/21**	
95	**1.2.5.5**	**Painting work +**	**21 days**	**Mon 2/15/21**	**Sun 3/7/21**	
100	**1.2.5.6**	**Roof + Cover**	**10 days**	**Mon 2/15/21**	**Wed 2/24/21**	
106	**1.2.5.7**	**Utility / Installation**	**7 days**	**Fri 1/1/21**	**Thu 1/7/21**	
115	**1.3**	**MECHANICAL AND**	**40 days**	**Fri 2/5/21**	**Tue 3/16/21**	
116	**1.3.1**	**Mechanical**	**20 days**	**Mon 2/15/21**	**Sat 3/6/21**	
127	**1.3.2**	**Electrical install**	**40 days**	**Fri 2/5/21**	**Tue 3/16/21**	
137	**1.4**	**OTHER WORKS**	**15 days**	**Wed 3/17/21**	**Wed 3/31/21**	
138	1.4.1	Training, Commi	13 days	Wed 3/17/21	Mon 3/29/21	136,135,12
139	1.4.2	Remote Monito	2 days	Tue 3/30/21	Wed 3/31/21	138



4.5 Result Analysis

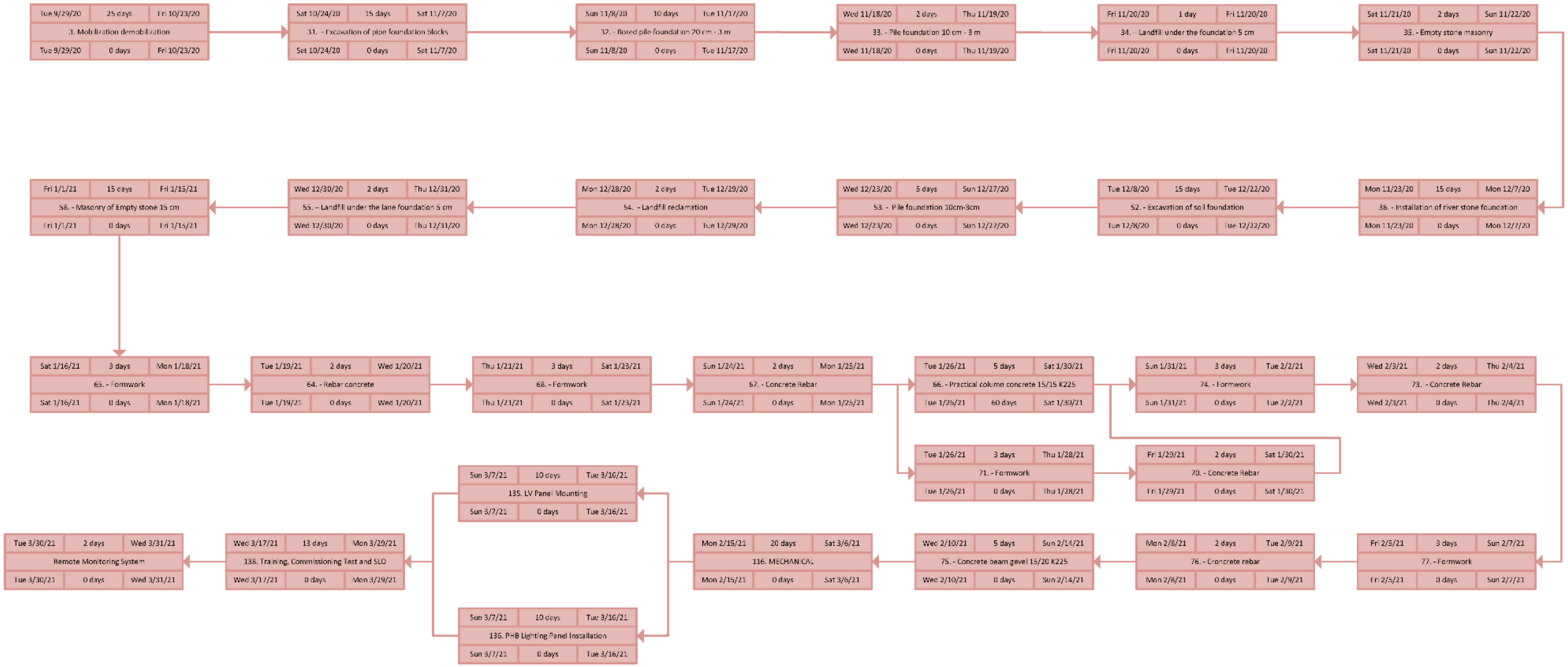
4.5.1 Analysis of Critical Path and S-Curve

The total duration and resource planning is made by the construction company, which wins the proposal's bid to control the construction project. The schedule and resource planning has been agreed upon by the project owner and the construction company. It was based on the discussion and judgment of experts from construction companies. With the elaboration of time duration and schedule for each activity, Microsoft Project enables to find out which activities are included in the critical path.

The critical path diagram in Figure 4.2 is obtained from the results of the process from Microsoft Project (Table 8.2 in Appendix 4), which is then redrawn using Microsoft Visio so that the network diagram follows the Activity-on-Node (AON) notation. In the AON network diagram, the nodes for each activity show the fastest start time, slowest start time, fastest end time, slowest finish time, and slack for each activity. Critical activities are shown in red with a red arrow. There are 28 activities and a subtask that are in the critical path, and 4 of them are parallel with other activities. These parallel activities are on the critical path because they have the same schedule and duration. In short, the critical path in the project completion process is starting with mobilization/demobilization followed by several activities in the pipe penstock sub-task. The powerhouse sub-tasks carried out in Civil Works, followed by mechanical and electrical work, and finally working on commissioning and remote monitoring systems.

The complete sequence of the critical path, namely: 1.1.1 Mobilization demobilization, 1.2.4.1.1 excavation of pipe foundation blocks, 1.2.4.1.2 bored pile foundation, 1.2.4.1.3 pile foundation, 1.2.4.1.4 landfill under the foundation, 1.2.4.1.5 empty stone masonry, 1.2.4.1.6 installation of river stone foundation, 1.2.5.1.1 excavation of soil foundation, 1.2.5.1.2 Pile foundation, 1.2.5.1.3 land reclamation, 1.2.5.1.4 landfill under the lane foundation, 1.2.5.2.1 Masonry of empty stone, 1.2.5.3.3 formwork, 1.2.5.3.4 rebar concrete, 1.2.5.3.6 formwork, 1.2.5.3.5 concrete rebar, 1.2.5.3.4 practical column concrete and 1.2.5.3.9 formwork + 1.2.5.3.8 concrete rebar, 1.2.5.3.12 formwork, 1.2.5.3.11 concrete rebar, 1.2.5.3.15 formwork, 1.2.5.3.14 concrete rebar, 1.2.5.3.13 concrete beam gavel, 1.3.1 Mechanical installation, 1.3.2.8 LV Panel mounting + 1.3.2.9 PHB lighting panel installation, 1.4.1 Training, commissioning test, and 1.4.2 Remote monitoring system. The remote monitoring system is a survey and inspection through observation to detect problems with the final result. If the remote monitoring system is finished, then all the tasks of power plant construction are complete.

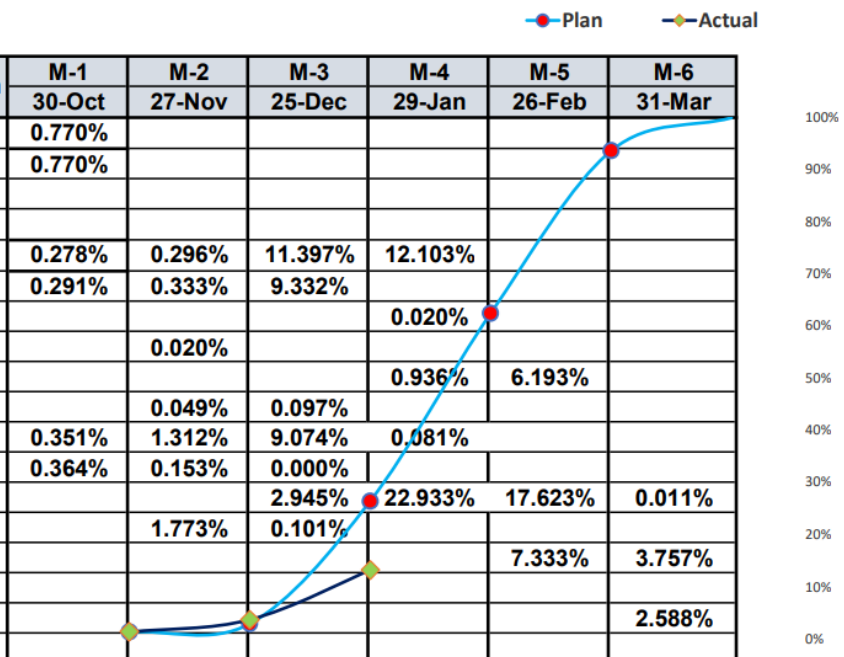
Figure 4. 2 Critical Path (please check Figure 8.3 in Appendix 5 for the detail)



The s-curve helps to graphically visualize the line showing the comparison between the plan and actual progress over time (horizontal axis). From these two pieces of information, it is possible to analyze the difference between the progress of the actual project realization and the project plan. The shape of the s-curve can be seen in Figure 4.3. From existing data, it is known that there is a difference between the planned duration of time against the actual time after the project has been running for 3 months. In its implementation, the power plant construction project experiences a gap between the progress that has been carried out and the expected planning for 3 months. The progress is 13% at the end of September, while project planning is expected to be completed by 26% by that time. From the S-curve, the delay is dominated by construction activities of the dam & intake and pipe penstock. The S-Curve shows the dam & intake activities only had progressed by 9,832% in September, while planning is expected to increase by 11,752%. In the construction of pipe penstock, it is planned to have progressed by 8,870%, while actual work has only progressed by 0.001%. As can be seen from the Gantt chart, the two activities found were during soil excavation. The gap between planning and actual work occurs because the soil is very hard during the excavation, and there are large stones. The size of the rock significantly inhibits progress because soil excavation is a critical path activity.

Soil excavation is an activity that must be carried out at the early stages of constructing the dam & intake and pipe penstock task. The project managers did not estimate that the rock was bigger than expected and the results of soil investigation data analysis. Soil investigation is one of a geotechnical investigation by conducting exploration to obtain surface and subsurface data. Subsurface exploration carried out in the pre-activity project includes drilling samples pre-activity before starting the construction project. The results of subsurface exploration data analysis in the dam and intake task area showed that there are rocks under the ground, but in fact, the stones found during excavation are much larger, so it takes longer to lift the stones. Therefore, the project manager procured a second excavator to carry out a parallel excavation between the dam & intake task and the pipe penstock task. The second excavator allowed the pipe penstock work to begin even though the excavation of the dam and the intake task had not been 100% done. However, it was only able to complete 0.001% out of 8.87% of the overall target in September.

Figure 4. 3 S-Curve (please check Figure 8.2 in Appendix 3 for the detail)



No.	Uraian	Keterangan	%	Rp-Ra	Start	Finish	Duration	M-1 30-Oct	M-2 27-Nov	M-3 25-Dec	M-4 29-Jan	M-5 26-Feb	M-6 31-Mar
1	Preparatory Work	*FINISH*	0.77%	Rp	29-Sep	23-Oct	25	0.770%					
			0.77%	Ra				0.770%					
2	Civil Work	*Continue*	85.55%	Rp	24-Oct	7-Mar	135						
			12.51%	Ra									
2.1	Dam & Intake	*Continue*	24.07%	Rp	24-Oct	8-Jan	77	0.278%	0.296%	11.397%	12.103%		
			9.96%	Ra	24-Oct			0.291%	0.333%	9.332%			
2.2	Dettling Tank	*FINISH*	0.02%	Rp	15-Dec	16-Dec	2				0.020%		
			0.02%	Ra	14-Nov	20-Nov	7		0.020%				
2.3	Tailrace	*Contiinue*	7.13%	Rp	16-Jan	1-Mar	45				0.936%	6.193%	
			0.15%	Ra	14-Nov				0.049%	0.097%			
2.4	Pipe Penstock	*Continue*	10.82%	Rp	24-Oct	28-Dec	66	0.351%	1.312%	9.074%	0.081%		
			0.52%	Ra	24-Oct			0.364%	0.153%	0.000%			
2.5	Powerhouse	*Continue*	43.51%	Rp	8-Dec	7-Mar	90			2.945%	22.933%	17.623%	0.011%
			1.87%	Ra	31-Oct				1.773%	0.101%			
3	Mechanical and Electrical Works		11.09%	Rp	5-Feb	16-Mar	40					7.333%	3.757%
			0.00%	Ra									
4	Other works		2.59%	Rp	17-Mar	31-Mar	15						2.588%
			0.00%	Ra									
	TOTAL			Rp				1.399%	1.608%	23.416%	36.072%	31.149%	6.356%
	CUMMULATIVE PLAN							1.399%	3.007%	26.423%	62.495%	93.644%	100.000%
	TOTAL			Ra				1.426%	2.327%	9.530%			
	CUMMULATIVE ACTUAL							1.426%	3.753%	13.283%			

On the other hand, there are other activities that progress faster than the initial plan. It is building settling tanks work. This activity's actual work was completed in November, while the work was planned for completion in December 2020. There are also activities that worked faster, such as tailraces, powerhouse building, pile foundation, gabions, and bore pile foundation. Even though those activities are post-excavation activities, those activities could be started without waiting for the excavation work to be 100% complete if the part of the areas involved in those activities has been excavated. Therefore, the action is the solution to cover the progress gap between the total actual work and the plan caused by the slow excavation process. So, the construction team carried out other activities that did not involve the excavation area.

4.5.2 Analysis of PERT

PERT diagram helps to build milestones for the project. The construction company should use the method to recognize any potential consequences or obstacles the project may face during each milestone. This ensures that the project manager can address them easily and help the project keep on track. Microsoft Project and Microsoft Excel software were used to analyze the duration of project activities using the PERT method. The construction team works every day, and they start at 08.00 to 12.00 and continue from 13.00 to 17.00. The PERT method considers the following durations: optimistic duration (a), pessimistic duration (b), and most likely duration (m). Each duration is an estimated duration considering the constraints that arise and based on the project manager's experience. There are several constraints to consider, such as weather, environment, labor, tools, materials, and management factors in estimating the optimistic, most likely, and pessimistic duration of the project.

4.5.2.1 Expected Duration (TE)

After determining the estimated numbers for the optimistic duration (a), the pessimistic duration (b), and the most likely duration (m), then the next step is to calculate the relationship between the three duration to become the expected duration time, TE. The expected duration (TE) can be calculated with the following formula:
For example, the calculation of TE in one of the project activities, excavation of construction land for dam and intake activities (WBS: 1.2.1.1.1)

Optimistic duration (a) = 11 days Pessimistic duration (b) = 20 days Most likely duration (m) = 15 days, then,

$$TE = \frac{a + 4m + b}{6} = \frac{11 + 4(15) + 20}{6} = 15.17 \quad (4.1)$$

The remaining results of the calculation of the expected duration (TE) (Equation 4.1) can be seen in Table 4.1. Thus, the TE of the overall project (Equation 4.2) can be calculated by adding up the TE of critical activities, as follows:

$$\begin{aligned} TE_{critical} = {} & 25.5 + 15.17 + 9.5 + 2.17 + 1.17 + 2.17 + 13.17 + 13.5 + 5.17 + 2.17 \\ & + 2.17 + 12.83 + 2.17 + 3.17 + 2.17 + 3 + 2.17 + 3 + 2.17 + 3 + 5.17 \\ & + 2.17 + 3 + 18.83 + 10.17 + 13 + 2.17 = 180.05 \end{aligned} \quad (4.2)$$

4.5.2.2 Project Variances

Variance is a representation in a data collection of the distribution between numbers of duration. A probabilistic model is used in the PERT system, not a deterministic model. Any activities filled with uncertainty have a wide variety of predictions that will accomplish the task. Uncertainties include both favorable conditions (opportunities) and unfavorable situations (threats). Therefore, there are the optimistic duration (a), most likely (m), and the pessimistic duration (b). In the PERT method, the parameters that explain this problem are known as standard deviation and variance. The smaller the variance, the more certain activity can be completed, and vice versa. The following is an example of calculating variance in excavation activities (Equation 4.3):

$$v = \left(\frac{b - a}{6}\right)^2 = v = \left(\frac{20 - 11}{6}\right)^2 = 2.25 \quad (4.3)$$

In the variance column is the result of calculating the variance (v) of each activity in Table 4.1:

Table 4. 1 Project Evaluation and Review Technique (please check Table 8.3 in Appendix 6 for the set of data)

WBS	Task Name	Criti-cal Path	Cost (%)	Duration in the contract	Most Likely, *m* (day)	Optimist, *a* (day)	Pessimist, *b* (day)	Expec-ted time	Variance of each activities
1	**POWER PLANT CONSTRUCTION (Total)**		**100%**	**184**	**173**	**144**	**244**	**180.05**	**19.722**
1.1.1	Mobilization demobilization	Yes	0.770%	25	25	20	33	25.5	4.694
1.2.4.1.1	Excavation of pipe foundation blocks	Yes	0.632%	15	15	11	20	15.17	2.250

1.2.4.1.2	Bored pile Foundation 20 cm - 3 m	Yes	0.008%	10	9	8	13	9.5	0.694
1.2.4.1.3	Pile Foundation 10 cm - 3 m	Yes	0.027%	2	2	2	3	2.17	0.028
1.2.4.1.4	Landfill under the foundation 5 cm	Yes	0.044%	1	1	1	2	1.17	0.028
1.2.4.1.5	Installation of empty stone couple	Yes	0.226%	2	2	2	3	2.17	0.028
1.2.4.1.6	Installation of River stone foundation	Yes	0.070%	15	12	11	20	13.17	2.250
1.2.5.1.1	Excavation of soil foundation	Yes	2.794%	15	13	11	18	13.5	1.361
1.2.5.1.2	Pile foundation 10 cm - 3 m	Yes	0.301%	5	5	4	7	5.17	0.250
1.2.5.1.3	Landfill reclamation	Yes	0.053%	2	2	2	3	2.17	0.028
1.2.5.1.4	Landfill under the lane foundation	Yes	0.066%	2	2	2	3	2.17	0.028
1.2.5.2.1	Installation of Empty stone 15 cm	Yes	0.404%	15	12	11	18	12.83	1.361
1.2.5.3.2	Rebar concrete	Yes	0.408%	2	2	2	3	2.17	0.028
1.2.5.3.3	Formwork	Yes	0.632%	3	3	3	4	3.17	0.028
1.2.5.3.5	Concrete Rebar	Yes	0.088%	2	2	2	3	2.17	0.028
1.2.5.3.6	Formwork	Yes	0.082%	3	3	2	4	3	0.111
1.2.5.3.8	Concrete Rebar	Yes	0.205%	2	2	2	3	2.17	0.028
1.2.5.3.9	Formwork	Yes	0.241%	3	3	2	4	3	0.111
1.2.5.3.11	Concrete Rebar	Yes	0.285%	2	2	2	3	2.17	0.028
1.2.5.3.12	Formwork	Yes	0.455%	3	3	2	4	3	0.111
1.2.5.3.13	Concrete beam gavel 15/20 K225	Yes	0.302%	5	5	4	7	5.17	0.250
1.2.5.3.14	Concrete rebar	Yes	0.154%	2	2	2	3	2.17	0.028
1.2.5.3.15	Formwork	Yes	0.313%	3	3	2	4	3	0.111
1.3.1	Mechanical		7.514%	20	18	15	26	18.83	3.361
1.3.2.8	LV Panel Mounting	Yes	0.083%	10	10	8	13	10.17	0.694
1.3.1.4	Electronic Flow Controller 230/400V, 300 kW, 50Hz	Yes	1.133%	20	18	15	26	18.83	3.361
1.3.2.9	PHB Lighting Panel Installation	Yes	0.013%	10	10	8	13	10.17	0.694
1.4.1	Training, Commissioning Test and SLO	Yes	2.187%	13	13	9	17	13	1.778
1.4.2	Remote Monitoring System	Yes	0.400%	2	2	2	3	2.17	0.028

The variance on the critical path can affect the prediction of project completion time, which may result in delay. PERT uses variance in critical path activities to calculate the variance of the project. The project variance is the sum of the variances of critical activities (Equation 4.4):

$$\sigma_P^2 = \Sigma v_{critical}$$
$$= 4.694 + 2.25 + 0.694 + 0.028 + 0.028 + 0.028 + 2.25 + 1.36 + 0.25 + 0.028 + 0.028 + 1.361 + 0.028 + 0.028 + 0.028 + +0.111 + 0.028 + 0.111 + 0.028 + 0.111 + 0.25 + 0.028 + 0.111 + 3.361 + 0.694 + 1.778 + 0.028 = 19.722 \quad (4.4)$$

So that the project standard deviation (Equation 4.5):

$$\sigma_P = \sqrt{\Sigma v_{critical}} = \sqrt{19.722} = 4.4409 \quad (4.5)$$

4.5.2.3 Probability of Completing the Project on Time

In this section, it is to find the probability project will be done on or before the 184-day deadline. The total expected duration (TE) and standard deviation (σ_P) 180.05 and 4.4409, respectively. The relationship between the completion expected time (TE) and the due date (Td) days in the PERT method is expressed by Z formula as follows (Equation 4.6 and 4.7):

$$Z = (\text{Due date} - \text{Completion expected date}) / \sigma_P \quad (4.6)$$

$$Z = \frac{(184 - 180.05)}{4.4409} = 0.8902 \quad (4.7)$$

Z is the number of standard deviations of the deadline or target date from the mean or expected date.

Alluding to the Normal Table in Appendix 1, it shows where a Z - estimation of 0.8902 indicates a probability of 0.8133. Accordingly, there is an 81.33% possibility that the project can be completed in about 184 days or less.

then if it is calculated to find a probability of 99.99% with the value of the Appendix 1 table Normal distribution of 0.9999 or Z = 3.69, then the project completion is estimated at (Equation 4.8, 4.9, 4.10, and 4.11)

$$Z = \frac{(T - TE)}{\sigma_P} \quad (4.8)$$

$$3.69 = \frac{(T - 180.05)}{4.4409} \quad (4.9)$$

$$T = (3.69 \times 4.4409) + 180.05 \quad (4.10)$$

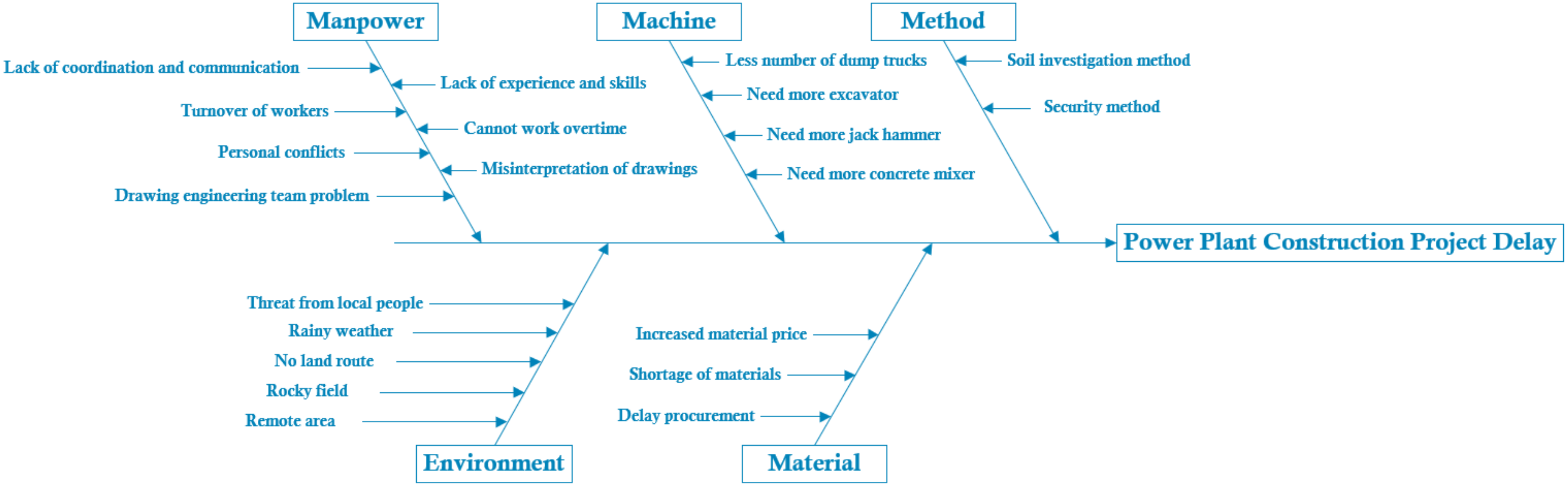
$$T = 16.39 + 180.05 = 196.44 \quad (4.11)$$

This means the project is estimated to be completed in 197 days, assuming the Project Manager will not do anything to speed up the work process.

4.6 Analysis of the Causes of Project Delay

From the analysis of the plan of the actual conditions taken from the s-curve, several factors have identified the causes of delay in the construction work. The analysis is to identify factors that cause delay by using a fishbone diagram or causes and effect analysis to explain each factor that causes work not to go according to plan and is slow. The results of the interviews with construction project manager are shown in Table 8.1, in Appendix 1. Five categories were considered, namely man, machine/equipment, material, environment, and method shown in Figure 4.4.

Figure 4. 4 Fishbone Diagram



The fishbone diagram above results from the identification of the factors causing the delay in project completion. It is explained in detail to facilitate understanding of the following problems:

A. Manpower

1. Lack of coordination and communication is the fundamental key to successful teamwork. In the implementation of construction projects, coordination requires good communication so that each group does not make mistakes. Workers who do not understand the briefing or instructions from the field coordinators are mostly from Papua. Local workers only understand the Papuan language and do not really understand the national language.
2. Workers lack experience and skills. Lack of skills and expertise of most workers can result in low labor productivity, which results in longer time to complete the project. The most common difficulties are concrete work and piping.
3. Work personnel transition or change is a natural thing to happen when the project is ongoing, but the slow mobilization or arrival of workers results in slower completion of work. Therefore, this project requires more capability to manage the workforce so that the team's integrity and needs are maintained. Delays in worker attendance can occur due to roadblocks to the location by local villagers.
4. Many local workers cannot work overtime to complete daily targets and follow the gap between plans and actuals. It is just because they want to go home late in the evening to get home on time.
5. Personal conflicts or personal problems between workers brought into the work environment can affect the quality of work. This conflict between workers occurs because of the gap in education and skills between workers. This has an impact on the work atmosphere and psychological stress, which can result in decreased personal productivity in the project.
6. Differences of opinion regarding pictures and misinterpretation of pictures by workers, for example, the layout and shape of building work. Thus, the buildings revision process is needed. It slows down the correct finish.
7. The drawing engineering team often makes revisions because the drawings cannot be applied in the field location due to inaccurate measurements. There was a design delay of up to 1 week due to design changes or the revision process. In this case, the construction team requested correction and confirmation to change the drawing or size to the drawing engineering team even though it was minor changes.

B. Machine

1. Less number of dump trucks slow down to material lifting process. This tool is used to lift raw materials such as concrete, cement, and diesel. Dump trucks are also used in mechanical and electrical activities, namely, to transport turbines.
2. Initially, the number of excavators was only one, causing the excavation process in the dam and intake construction activities and the powerhouse to be very slow. Now there are 2 diggers or excavators for digging rocky soil.
3. The number of jackhammers is actually needed more because there are many large stones in the ground that must be crushed in order to facilitate the excavation process.
4. The insufficient number of the small concrete mixer so that the casting or foundry process is slow. Using a small concrete mixer is easy to carry to the site, and a large mixer machine is difficult to bring to the project field. The impact also resulted from the slow procurement of concrete in a large project area.

C. Method

1. The soil investigation method in the field still resulted in an inaccurate analysis of the subsurface interpretation of the project area. In the field, it was not suspected that there were larger and more than expected stones. This is presumed to be the big distance between the drilling holes, resulting in less accurate subsurface images. The results of this inaccurate interpretation can affect the productivity and effectiveness of the procurement of tools, such as the number of diggers needed.
2. A more accurate and better security method is needed because there are security issues in the project area. Safety factors affect the psychology of construction workers that cause worker productivity.

D. Environment

1. Remote area causes slower mobilization. The project area requires helicopters and planes to deliver resources (such as cement, diesel, and masonry workers) to the project site. Human resources who have good experience and skills are brought in from outside the island of Papua, so they need a plane that is available once a day.
2. The rocky field condition causes difficulties in soil excavation. Excavation of this land takes a long time. This large stone soil forced the construction team to bring in one additional excavator because the stones' amount and size are larger than initial estimates. When a rock that is too large is lifted, it empties an area that should not be dug and needs to be replenished with soil.

3. There is no land route from the nearest residential area or town, making it difficult to mobilize. This makes the material supply using planes and helicopters.
4. Rainy weather is high enough up to 5000mm occurs almost every day because it is a mountainous area. The weather can slow down the work, especially the casting and excavation process.
5. There are threats from local people since there were shooting cases in an area 10 km from the location. The project area is at risk of a battleground due to various regional issues of agreement. This results in fear for the field workers. In addition, this issue also resulted in a change of the flight schedule from 6 times a week (Monday-Saturday) to 3 times a week.

E. Material

1. There was a delay in procuring supplies of consumable materials such as cement, diesel, sand, and gravel in the middle of project implementation. Another reason for this delay is the high cost of shipping materials, thus shipping large quantities of material. The project location is far away and cannot be accessed by land routes. Procurement delays can be caused by changes in the schedule of planes and helicopters coming into the project area. Construction companies are negligent in controlling delivery schedules. Activities cannot be continued, and worker productivity is low due to the unavailability of materials, which results in project delays.
2. There was a shortage of materials such as gabion wire and wood materials for formwork. Hence, the construction team had to increase the supply of materials from the available suppliers.
3. The construction team needs time to consider purchasing from suppliers that increase the material price. Although the price was initially set at the time of agreement from both parties, the supplier cannot follow the agreed price due to economic reasons such as scarcity and rising import prices in the middle of the procurement process. Limited suppliers generate the bargaining power of suppliers. Therefore, suppliers can ask construction companies to pay more according to the supplier's wishes.

After examining every cause of delays in construction projects carried out until the end of September, the researcher can determine what factors can cause project delays. From these inhibiting factors, it can be determined the most dominant inhibitor as the main cause of the delay. Then, carried out to determine the order based on the largest percentage of the causes of delay according to the predetermined categories, namely manpower, equipment, material, environment, and method.

Table 4. 2 Percentage and summary of the causes of project delay

Category	Number of causes	Percentage
Manpower	7	33.33%
Environment	5	23.81%
Machine	4	19.05%
Material	3	14.29%
Method	2	9.52%

Table 4.2 shows the percentage of each factor that causes project delays, the highest of which is the “manpower” factor involved in the power plant construction project. The first rank is the manpower factor, followed by the environment, machine, material, and method factors with the respective values of 33.33%, 23.81%, 19.05%, 14.29%, and 9.52%. The manpower factor is shown to be the main cause of the delay during the project, so that it is necessary to make improvements and refinements so that the potential delay in the next project can be reduced.

4.7 Case Study Conclusions

The aim of this construction project is to construct the power plant buildings and facilities and ensure that the business structure is properly established. This construction project must be completed in six months, from 29 September 2020 to 31 March 2021. This business project is a case study of a construction project that focuses on time management implementation. In section 4.2, there was a discussion about core conceptual stages of project management consisting of project initiation, project planning, project execution, project monitoring and controlling, and project closure. This work is still running in the controlling and monitoring stage. In construction activities, this project has four primary tasks consisting of preparatory work, civil works, mechanical and electrical works, and other works. There are 111 deliverables or events in construction work that must be done within 184 days. Based on analysis using the critical path method (in section 4.5.1), considering the entire activities and schedule, the project has 28 activities and 1 subtask that are critical. The critical activity is depicted in figure 4.2. Based on the s-curve, this work experienced progress problems by 13.1% from the target of 26.4% in December 2020. Based on the s-curve, the greatest progress delay is in pipe penstock subtask, especially in excavation activities. In table 4.1, it shows the calculation of PERT to determine the probability of the project completion considering the three-time estimates (most likely, optimist and pessimist). According to the calculation, the probability of the project completion in 184 days or less is 81.3%. And the project is estimated to be completed in 197 days. Therefore, the project manager needs to take action to improve performance and work speed.

Project delay analysis is carried out by implementing fishbone analysis. Analysis with the construction project manager categorizes five factors, namely manpower, machine/equipment, material, environment, and method. The problems in the manpower factor are lack of coordination and communication, lack of experience, turnover of workers, cannot work overtime, personal conflicts, misinterpretation of drawings, and drawing engineering team problem. The environment factor consists of several issues such as a remote area, rocky field, no land route, rainy weather, and the threat from local people. In the Machine factor, the problems are lack of the number of dump trucks, need more excavator, need more jackhammer, and need more concrete mixer. Problems with material factors are delay procurement, shortage of materials, and increased material price. Problems with the method factor are soil investigation method and security method. The manpower factor is the most dominant of the five factors that lead to delay, as shown in Table 4.2 since it has the highest percentage compared to the others.

5. Discussion of the Results

5.1 Strategy to Tackle the Causes of Project Delay

The duration planned by the construction team may have considered the worst and best possibilities in project implementation, although it did not consider the three duration estimates used in PERT. From the results calculated using PERT, the probability of delay is 19%. Based on PERT analysis, to obtain a chance of 99.99% on time, this project can run for 197 days. On the s-curve, this construction project lags by 13 percent. Therefore, project managers must carry out a strategy to respond to the causes of delays that have occurred and accelerate their work so that the project can be completed according to the target, which is 184 days.

According to the previous fishbone analysis, there are five categories that were the causes of delay in the work of a power plant construction project in Papua, namely manpower (lack of coordination and communication, lack of experience and skills, turnover of workers, cannot work overtime, personal conflicts, misinterpretation of drawings, and drawing engineering team problem), environment (remote area, rocky field, no land route, rainy weather, and the threat from local people), material (lack of the number of dump trucks, need more excavator, need more jackhammer, and need more concrete mixer), machine (delay procurement, shortage of materials, and increased material price), and method (soil investigation method and security method). From the results of the analysis and discussion in the previous section, it can be seen that delays are not only affected by the activity of executing the power plant construction project. Each project process also has negative impacts on the smooth running of the project if the implementation is not following the planned schedule. Good cooperation from all stakeholders determines the performance of each stage of work. For example, the planning and drawing process depends on the drawing engineering team's performance, civil and construction teams, and others, followed by a response from the project owner that confirms the planning. Each field's role can influence the next process, namely the process of purchasing equipment or renting equipment and machines to support construction operations.

In order to accelerate progress, the project manager has considered increasing the number of workers because some local workers cannot work overtime. Finding new workers is not a complicated matter in the Covid-19 pandemic. Many project workers have been laid off from several construction projects that were canceled. In this case, the budget to increase the number of workers and the overtime workers are still available. New workers will work in the afternoon until evening to replace workers who cannot work overtime. Therefore, based on the needs of the project, the construction project manager and his supervisor estimate that they will add 50 new workers for the evening shift.

Misinterpretation of drawing, lack of coordination and communication, especially among Papuans, are the issues in the manpower category. Difficulty in coordination and communication is caused by a lack of experience in construction projects, so that builder or construction skills are also issues in the workforce. Through interviews and discussions with the project manager, to solve this problem, the project manager needs to hold a meeting with the supervisor in charge of the construction workers with the aim of making an internal memo from the supervisor to the construction worker to make everyone work from the same series of directions and flow and clarify communication in a way that helps the organization run more efficiently. In addition, the project manager will classify based on their language skill, for example, by dividing Papuan people who understand Indonesian well and can explain to their colleagues who do not understand the directions into one activity group.

Another manpower problem is that the drawing team often has measurement errors, or there are parts of the building that do not apply to the location. Therefore, the drawing and revision process must be monitored by other engineers to obtain immediate approval from related stakeholders. The strategy used to keep the flow of image examinations running well is that each examiner is given a time limit of five days, and the time limit for image revision is given a time limit of five days. This time limit is closely monitored and issued a warning if some documents and pictures have exceeded the agreed deadline either by meeting or by electronic mail. The selection of a competent engineering team for the next project will help significantly in this process.

Regarding material issues, some materials such as cement and wood have delivery times issues because the construction sites are located far in the remote area. Slow delivery time causes the material to arrive late at the project site. The delay in the arrival of the material by the supplier affects the timeliness of the planned implementation. If the material arrives late, it will cause delays in all areas and allow cost overruns. Moreover, there is an unexpected incident that the available material has been used and running out faster than expected, so they must re-order from the same supplier if possible. For the wood material used for formwork, the supplier could not supply more, so the construction team ordered retail from another supplier.

Another issue in the material problem category, the supplier increases the price to be able to supply these materials due to the increase in the price of certain materials nationally. The increase in material prices will cause an increase in the planned costs. If the supplier increases the material price and is slow to deliver, it will consider purchasing the material in the closest city to the project location. And therefore, the project can be progressed as the daily target immediately.

Regarding the machine issue, the strategy that needs to be implemented immediately is to provide tools to increase the speed of work. Based on the delay factor analysis results, the crucial problem is that the number of tools used needs to be increased, especially excavation work and material mobilization to the location. The construction project manager plans to add two jackhammers, one concrete mixer, and one dump truck. The manager considers the additional plan based on his budget and efficiency calculation.

In environmental issues, the project field conditions have high rain intensity, so the construction team has prepared particular tents for equipment, materials, and workers. A protective tent can also protect the work area so that the rain does not damage the work. Technically, actions that need to be taken are to use tarpaulin in specific work areas that are easily damaged or endanger workers if exposed to rain or wind. Also, preparing a raincoat for the workers, preparing incandescent lamps and blower fans to support the drying process of working parts has to be dry, and installing lightning rods to protect workers will protect from rain. If necessary, use a mixture of materials to make the drying and hardening process of concrete run faster, especially for working on infrastructure projects such as floor plates and beam-columns. Besides, every weather report is recorded during project development. This data can be used for reports as well as reasons if needed to get an extension of the project work period without the need to get a fine. In the agreement, there are clauses regarding matters that regulate what if the project work is delayed.

Another external issue for the project is the threat of work from externals such as elements from the Free Papua Movement that can threaten contractor workers' safety. Initially, this external issue was not expected at the time of planning, so that no particular security method was applied at the beginning of the project. However, the case of the Free Papua Movement arose when the number of shootings near the location area increased. So that construction company has to improve the security system seriously. The way to increase the security system is by hiring several police officers to be on the project site. The presence of the police is expected to reduce risks associated with work activities in order to create a safe, efficient and productive workplace.

5.2 Suggestions for Improving & Updating Project Management Procedures

This section discusses to propose a recommendation for long-term business strategies using Building Information Modelling (BIM) that has been created for better project performance in the future based on the literature review. Using BIM in this construction project is because the construction company will be able to work more efficiently in terms of time, cost, and labor. According to Btoush and Harun (2017) research, BIM is a powerful tool for reducing delays in Jordan construction projects. Nonetheless, BIM is emerging as a new tool, both in the construction management and practical sphere of building construction. One of the beginning steps that can be taken to start BIM is redrawing one of the projects using the BIM-Archicad software.

The organizational model is supposed to pursue a collaborative networking approach as well as consider Service Science and adopt the latest digital technologies concerning BIM and Industry 4.0 (Silva et al., 2016). Through an intelligent Data Management System based on common and extensible data formats, BIM has facilitated the integration of 3D-CAD construction outcomes across the AEC supply chain. The implementation of the IFC e-libraries system for the AEC sector (BIM) is expected to boost supply chain performance. It establishes a connection between the owner's expectations and the acquisition of smart materials (Razy et al., 2019).

BIM has the potential to have a significant effect on the business by encouraging a technology drive towards supply chain integration. Vilas-Boas et al. (2019) presented a collaborative business model focused on quality control and assurance process, which offers conceptual continuity to re-introducing owner interests and contentment. It also makes the relationship between procurement of material and specifications of building more transparent and accountable. Furthermore, to improve the result of building, Building Energy Modelling (BEM) in BIM deals with an energy analysis to find better options to improve building energy efficiency and sustainable operations toward Life Cycle Assessment (LCA). The decrease in energy usage over the building's entire operating life has a significant positive environmental effect (Vilas-Boas et al., 2019).

According to Hall (2018), there are 10 (ten) top advantages of Building Information Modeling (BIM) in Construction, such as:

1. Better collaboration and cooperation
2. Cost estimation model-based
3. Preconstruction project visualization
4. Improved coordination and clash detection
5. Reduced cost and mitigated Risk
6. Improved schedule management
7. Increased Productivity and Prefabrication

8. Safer Construction Sites
9. Better outcome
10. Stronger facility management and building handover.

There are four (4) main features of BIM mentioned by The AEC Associates (2019) as follows:

1. Making the process (more extensive)
2. Easy access to information
3. A more comprehensive overview of the project
4. Lifelike views

To conclude this section, this will explain that using BIM in the project is expected to be able to solve Manpower problems that impact project activities. This project implements the traditional Design-Bid-Build (DBB) in Papua's construction activities, which introduces communication and coordination problems and problems among designing activities because the DBB method does not have the ability to integrate architectural designs with field activities. Using the Archicad software in BIM in this power plant construction project, this software can improve the performance of the architectural drawing team to accelerate the architectural design and editing processes and ensure uninterrupted project activities. The architecture misinterpretation in this project would not occur if BIM were implemented. BIM will enable to insertion of Mechanical, Electrical, and Plumbing (MEP) information, which provides a more detailed observation of this whole construction project. Therefore, the company needs to develop BIM for construction projects and provide training on BIM operations to the technical staff. So, the architects, installers (software engineers), project managers, construction managers, engineers, and builders should be able to implement BIM and work with BIM properly in construction projects, in order to generate a much better synchronization among themselves.

5.2.1 Building Life Cycle Assessment

Life Cycle Assessment (LCA) is to assess and evaluate the global environmental impact during the life span of a building from "cradle to grave", as also a mode to design low environmental impact products, so buildings are built with environmentally friendly materials (Bribian et al., 2009; Monahan & Powell, 2011; Karimpour et al., 2013; Ajayi et al., 2015). Although it has a complicated process, several simplification processes can be proposed, such as neglect transport (especially for short distances and light materials), ancillary materials, or cutting waste.

Traditionally, the materials used in constructing a building have low energy costs and low environmental impact. Compared to nowadays, constructing a building used more global materials that increase the energy costs and environmental impacts, such as concrete, PVC, cement, and aluminum (Bribian et al., 2009). A comparative study held by Monahan & Powell (2011) comparing the embodied carbon of a house constructed using panelized timber frame (modern construction) with traditional masonry construction, where the conventional building has 51% greater embodied carbon than the modern ones. This shows that despite timber is used as the predominant and cladding material in the building structure, and concrete still becomes the most significant material by proportion being embodied by the carbon by 36%, and the rest in the substructure (Ajayi et al., 2015).

On the other hand, implementing BIM will also enhance the LCA methodology's impact, which can be used to determine the importance of building components, lifecycle stages, and even comparing different building typologies and specifications. Regardless of the material specifications, buildings based on renewable energy are environmentally preferable rather than using fossil fuels in their lifecycle because the operational stage contributes far more impacts than all other steps over the lifecycle buildings. Most of the energy demand in a building during its life cycle comes from the operating energy, despite the climate and other contextual differences. Therefore, optimization of embodied impacts in constructing a low-energy building will be more imperative to be considered in LCA of buildings, so it increases the net benefit of total life cycle energy and operational energy demand, and the embodied energy (Sartori & Hestnes, 2006; Chang et al., 2012; Karimpour et al., 2013).

As the building life cycle typically consists of five phases: raw materials and manufacturing, construction, operation, maintenance, and demolition stages (Seo and Hwang 2001), some studies neglect one step or another in the implementation of LCA, as it is time-consuming in the application in the AEC industry (Ajayi et al., 2015). The energy of operation will be explored in section 5.2.2. The energy is also consumed during the manufacturing of building materials, their transportation and assembly into buildings, as well as the maintenance and demolition of buildings, but those phases have mostly been ignored when assessing the energy performance of buildings due to not significant (Lombard et al., 2004).

The framework for Life Cycle Assessment (LCA) is defined in ISO 14040:2006 (Ooteghem & Xu, 2012), which includes the description of the LCA's goal and scope, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, and the life cycle interpretation phase. The initial phase of LCA is goal and scope definition which includes defining the purposes, functional unit, the system boundary, audiences, level of detail, and how the environmental burdens will be allocated. The next phase is Life Cycle Inventory (LCI) which is the compilation of an inventory of the input/output data regarding the system. It focuses mostly on the production chain of products to calculate the energy and material flow of each (overall) life phase(s) of the building (Chang et al., 2012).

The third phase will be a Life Cycle Impact Assessment (LCIA) that evaluates the significance of potential environmental impacts using the LCI results and provides information for the final interpretation phase (Ramesh et al., 2010; Monahan & Powell, 2011). Environmental consequences (such as climate change, ozone depletion, eutrophication, and acidification) are estimated based on energy use, waste generation, and other factors. The Life Cycle Impact Assessment (LCIA) in energy use interprets greenhouse gas emissions and resource extractions into a limited number of environmental impacts. In fact, the environmental impact might be measured for seven different categories, namely Climate Change (Cc) (kgCO2-Eq), Human Toxicity (Ht) (kg1,4- DCB-Eq), Agricultural Land Use (Lu) (m2a), Stratospheric Ozone Depletion (Od) (kg CFC-11-Eq), Fossil depletion (Fd)(kg oil-Eq), Particulate matter (kg PM 10-eq) and Water depletion (m3), which add up to the carbon emissions resulting from the energy consumption. The results of the LCIA interpretation show the environmental impact on three higher aggregation levels, being the 1) damage to human health, 2) damage to the ecosystem, and 3) damage to resource availability (RIVM, 2011).

The last phase of LCA is the interpretation of the preceding assessment to the whole building and alternative configurations as the bases of comparing commonly used building specifications, which later can be summarized to make the conclusions, recommendations, and decision making (Ramesh et al., 2010; Monahan & Powell, 2011; Karimpour et al., 2013; Ajayi et al., 2015).

To conclude this section, LCA is important to be implemented because it would have a positive impact to support sustainability in this power plant construction project in Papua. By applying LCA in this construction, it would have helped in designing to have more durable and accurate buildings. In fact, this aims to avoid unnecessary energy consumption and carbon dioxide emissions, so the building could have achieved sustainable performance criteria such as LEED and BREEAM (Vilas-Boas et al., 2019) in an easier way. Those impacts were not considered in this classical project where the life cycle concept was only meant for the construction process from initiation until closing (vide section 2.1), as it is the typical in traditional project management.

To sum up, LCA (after ISO 14040:2006) can support the design process that designers can achieve an outstanding performance by examining inventory analysis and impact assessment to support sustainability and reduce adverse impacts on human health, biodiversity, and resource shortage.

5.2.2 Life Cycle Energy Analysis

In constructing the building, there should be an analysis of the building's life cycle energy, which is all energy requirements of a building during its lifetime from the first step of manufacturing to the demolition stage. One of the benefits of life cycle energy analysis is that there will be known phases of high energy demand. The method can also be enhanced by reducing the energy consumption of these stages and reducing emissions of greenhouse gases. This Life Cycle Energy Analysis (LCEA) of a building includes the following dimensions (Ramesh et al., 2010; Karimpour et al., 2013):

a. Embodied energy is all energy needed by the building in its manufacturing phase. This involves the resources used to extract, transport, process and use the raw materials used at the construction site for the manufacture and assembly of new goods, the transport of products, and construction.
    - Initial embodied energy is all energy used by the building in its initial construction phase, such as manufacturing and transporting materials to the project location.
    - Recurring embodied energy is all energy used by the building to rehabilitate and replace the expiring materials needed to construct the building. In other words, this energy is used by the building in its maintenance phase during the entire life of the building.

b. Operating energy includes energy used by the building for all activities, i.e., for maintaining comfort, and day-to-day conditions, until its demolition phase; this energy is related to the use of the building over its life span. For example, operating energy is used for building's heating, ventilation, and air conditioning (HVAC) and, for water, and other electrical appliances.

c. Demolition is the last stage of the building life cycle where all related energy is needed by the structure to obliterate the old built asset and move the waste material to landfill locales or reusing plants.

According to Ramesh et al. (2010), operating energy accounts for the majority of building life cycle energy usage (80-90 percent), followed by embodied energy (10-20 percent), and demolition and other process energy accounts for negligible or minor, in a traditional non-green building. However, in the case of this construction project, the power plant construction project is in a tropical environment that is not hot nor too cold, so there is no need for air heating, hot water, and air conditioner, which require large power or energy. Thus, a Building Energy Modelling (BEM) Analysis would show that the operating energy would be small in the power plant building. So that, the main concern would be embodied energy. Furthermore, demolition is the last phase of a building's life in which the operation of demolition machinery contributes for most of the energy consumption during this cycle (Kofoworola & Gheewala, 2009). Demolition materials will be sent to the landfill site. In Demolition phase, there will be costs and energy for the decontamination and cleaning of the site until reaching the state of greenfield.

In the case of a power plant construction project, the involved construction activities would consume a relevant amount of energy, and so it is necessary to take into account the impact on its sustainability by analyzing the energy consumed. By assessing the energy requirements and by operating BIM to support better decision-making and planning, this project might have less material shortage problems and consequences that lead to unnecessary energy consumption. Therefore, the project manager should have used BIM integrated with BEM and LCEA during project phases to increase the efficiency, sustainability, and quality of the project.

6. Conclusion

The conclusion of this project is outlined in this chapter. Accordingly, the section will begin by reviewing the case of the project. Then, it will be argued that the objectives will be met using the research questions as a guide. In this way, the study offers the result of this report to address the research questions that triggered the investigation in the first place. Finally, it will present the project contributions (section 6.2), the limitations of the project (section 6.3), and the recommendations for future work (section 6.4).

6.1 Final Conclusion

This study was needed because there was a delay in the project construction to build a power plant in Papua. The project was still ongoing, but the progress delay was far from what was expected or deviated from its target. The project is expected to be done on day 184, but according to the s-curve in Figure 4.3, progress was only about 13.1 percent on day 92, from the expected target of 26.4 percent, at that time, which may lead to the conclusion that there was a delay of 13.4 percent. Moreover, project initiation, project planning, project execution, project monitoring and controlling, and project closure are the conceptual phases of project management that were applied in this project in terms of the traditional project life cycle, which did not consider the sustainability aspect.

Collected primary data has shown that the construction project breaks down into four primary tasks: preparatory work, civil works, mechanical and electrical work, and other works. The power plant development project comprises 111 deliverables or activities within their subtasks. Civil work is the majority of the work in a power plant construction project, contributing about 85% of the overall cost. However, the company found some problems during the project, which result in deviations from the original plan. Therefore, the purpose of this study is to find out, analyze and eliminate the factors that cause progress delay occurred within the project construction by studying the results of schedule generated by Microsoft Project and Microsoft Excel, the software used to operationalize the CPM and PERT methods.

Four Research Questions (RQ) were defined in this context and in order to achieve the *purpose* of this study, which is *identifying, analyzing, and propose recommendations to solve the problems that occurred in power plant construction in Papua*, as follows:

RQ1. What activities are included in the Critical Path Method, and how do they relate to each other?

RQ2. What is the probability that the project will be completed in less than the target time?
RQ3. Why did the progress delay happen in the power plant construction plant project?
RQ4. How can the company resolve the progress delay and accelerate the project so it will be completed on the target plan?

Regarding RQ1, there are 28 tasks and one subtask (mechanical work) in the critical path out of a total of 111 activities. Four activities among critical activities are parallel with other activities. Since they have the same timeline and duration as other critical activities, these parallel tasks are still on the critical path. Meanwhile, the remaining activities are not considered critical activities because they have a float time which means they can be delayed for a certain time without causing a delay in the completion of the overall construction project. In brief, the crucial activities in project construction begin with mobilization and continue with several activities in Civil Works, followed by electrical and electrical work and commissioning. Eventually, the remote monitoring system is the last deliverable in this project construction works, which is expected to be completed on March 31, 2021.

There is a possibility that the project would be late (RQ2), so it is necessary to determine that probability before making decisions to reduce work time or crashing. To answer RQ2, PERT is a useful method that can analyze the duration of each job and the expected duration. To use this method, the project manager estimated the optimistic duration, the most likely duration, and the pessimistic duration for each activity. The three-time estimates can be seen in table 4.1 and table 8.4. Based on normal probability calculations, this project would be completed on day-184 or sooner is 81.33%. Based on statistical calculations, the project would be finished on the day-197 with the assumption that the manager does not change resources. Therefore, the construction team needs crash time, which means action to reduce the project's overall duration after analyzing the alternatives. Furthermore, this project must be investigated the causes of delay that occur before adding resources.

After analyzing the progress of the project schedule and the project duration as the objectives of this study, the results of progress delay were summarized (vide section 4.6). As the purpose of this study is to find out and analyze the problems related to the construction of the power plant, this project concluded that there are five factors that cause work progress to not align with the plan (RQ3). These factors are manpower, machine, method, environment, and material. Issue of experience, understanding of drawings are the problems in the manpower group. Some workers are unable to work overtime. There is also an issue with the drawing team. Environmental issues include rainy conditions, lack of a land road, a rocky zone, threats from locals, and a remote location. Moreover, a shortage of dump trucks, a need for more excavators, jackhammers, and concrete mixers are machine problems. In addition, higher material prices, shortages, and procurement are included in the material issues, even though the material is adequately stored and used. Furthermore, in the “method” factor, there are soil investigation and security methods issues that need to be addressed. To summarize, the manpower factor is the most significant out of the five factors that cause delays, as shown in table 4.2, because it contributes to the most significant proportion of the overall delay.

The project team needs to resolve the causes of delay and accelerate the project (RQ4) in order to achieve the final objectives. The findings of this study show that project managers need to improve their resources in terms of workers, machines, material management, and project management methods and tools. The team's communication and coordination must be improved, and the number of workers must be increased. In order to accelerate the project's progress, certain machines must be added. Consequently, the construction team would be able to address the current delays, and the project would be completed on time.

This study also recommends that Building Information Modelling should have been used in this construction project because it can also help to solve problems concerning the building stakeholders and to make better decisions at the construction stage of this project. The use of BIM in this project helps stakeholders such as builders, engineers, architects, and several types of contractors to collaborate and integrate better. This integration could solve the problems of design misinterpretation, lack of communication, and coordination that occur in the traditional Design-Bid-Build project. Implementing Life Cycle Assessment would also help in making the design better and more sustainable because it has a positive impact on the aspects of resources, the environment, and human health. Finally, the project manager should have used BIM and Building Energy Modelling with life cycle energy analysis to improve the project's sustainability performance and quality because it helps to make better decisions and planning by analyzing all energy consumption in the first place.

6.2 Research Contribution

The business project case study is expected to be an application of project management best practices. It explains the obstacles that occur in the field and the solutions provided to overcome problems that exist during the project by traditional project management techniques. This study provides an overview of a construction work of a power plant in the foremost, outermost, and left area. This case study report is expected to become a solution for the company project as well as an academic and management reference by implementing the recommendations in chapter 5.1. The contribution to research is to show the results of investigations of construction project work carried out in remote areas, so this study shows the various challenges of construction projects. Moreover, the contribution to research is also to add insight into construction management studies, especially in the methods of controlling a project and the Building Information Modeling, which is a useful tool and provides added value to construction projects.

6.3 Project Limitations

One limitation of this study is related to the cost of the project. This study is not provided detailed project costs such as manpower costs, material costs, and other costs. The absence of detailed cost data is due to the confidentiality of the company's commercial data. Crash recommendations would be more accurate if cost data is available. The second limitation is that the author did not directly observe the field. Direct observation can enrich the analysis of real field conditions. The third limitation of this study is not observing the project after the recommendations are implemented.

6.4 Future Work Suggestions

This study is focused on finding problems in the construction project in Papua and providing recommendations. For future work suggestions and extend this study, it is necessary to evaluate the implementation of BIM and BEM integrated with Life Cycle Assessment and Life Cycle Energy Analysis. Besides that, the next work can also analyze how BIM can work well if the construction is in a remote area where the internet connection is poor.

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8. Appendices

Appendix 1. Interview Section

Appendix 1 presents the interview section in order to have necessary data regarding the project with the various topics to support this business case study. This is an in-depth interview, so the interview revealed all the needed information, gave recommendations. The interviewee is the Construction Project Manager with 7 years of working experience in the company. He is responsible for planning, controlling, and leading projects.

Table 8. 1 Interview

Duration & Schedule	Topic	Questions	Answer
1 hour on 12th October 2020	Project introduction, project initiation, and project planning	What is the goal of the project? Why is this project important? What is the deliverable of the project? Who are the stakeholders of the project? How to manage the stakeholders? How to initiate the project? How did the company do planning?	The construction company is a company that has experience in power plant construction. The goal of the construction is to provide a building for the power plant generator and ensure the building is properly built. It started with the government wishing to expand power in the Papua area. This region is a remote area. In this project, stakeholders are the government, a construction company, suppliers, and construction workers. The construction company is to execute the construction from the beginning until the power plant can work to produce electric power. The construction company has project managers who lead the project and supervise the progress and give the stakeholders the reports. The project initiation is where the stakeholders gathered information and identified with equipment, tools, and material requirements. Moreover, it gave data about field conditions to the owners, contractors, and

			engineer groups associated with this project. Project planning includes developing a schedule and job series. In the power plant construction project work schedule, project preparation defines operation period and time lag, floating time, and critical direction. The planning stage of the project considers potential hurdles that may impact the work of the construction project. This project is expected to run in 184 days. This project must be finished on time, which corresponds to the aim of the plans of the government and companies. The construction team expected the project to finish on time with about 400 construction employees. In addition, project planning was about the process of building design and measuring each component supplied before an open tender was made.
1 hour on 21st October 2020	Project execution, project monitoring and controlling, and project closure	How does the company execute the project? How does the project manager monitor and control the project? How does the reporting process during monitoring? What will the company do in project closure?	The execution started with the coordination of all project stakeholders, which began with a meeting and briefing by the construction staff's field supervisor. Communication is the most important element in project implementation for a successful project. In the project, contact is essential since it seeks to achieve daily goals. Every working process must be transparent for various roles in the sector. The performance of the supplier is also examined by project managers. The project manager makes a regular report containing the percentage of job successes, such as the amount of the building contract and the estimate of the total rate of

			progress toward the expected target. The obstacles, difficulties, and barriers encountered during the project are shown in a regular report. The construction company will hand over the final report on the entire project from the project managers to the project sponsor and other stakeholders. Since the project is still halfway through, so the project closure activities have not started yet. This closing process will be carried out if each division has completed its assignment and provided reports and then receive approval from the project sponsor and parties involved during the process. Suppose each division has completed its project and given documentation. In that case, this closing procedure will be carried out and will then obtain approval from the project sponsor and parties involved during the process.
1 hour on 3rd November 2020	Activities and progress	What are the main activities in the project? What did the workers do during preparatory work? What do the workers do during civil works? What is mechanical and electrical works? What are the other works?	The main activities are preparatory works, civil works, mechanical and electrical works, and other works. Work that consists of mobilization and demobilization is preparatory work. All the stakeholders agree that the preparatory work has been done. Civil works are intended to build and host the electrical generation facilities of the power plant. With around 85 percent of the overall project expense, civil works are the most dominant work in the power plant construction project. The purpose of mechanical and electrical work is to install electrical equipment that is listed in the Bill of Quantities

			document with certain requirements. It consists of two subtasks, namely mechanical and electrical works of installation. Other activities include preparation, commissioning checks, SLO (Operation Eligibility Certificate), and remote monitoring systems, as well as other activities. Commissioning is intended for electric power and installations that are capable of functioning in compliance with organizational specifications or standards.
1 hour on 10th November 2020	Optimist, pessimist, and most likely duration in each activity	based on your experience, what is the optimist, most likely, and pessimist time duration in each activity?	For this question, all duration data is well collected in the PERT table in Appendix 6, Table 8.4.
1 hour on 2nd December 2020	Causes of delay	Considering the Ishikawa diagram, what are the causes of the delay? About the Manpower category, was the document well interpreted? Do they have good skills and sufficient experience in construction? Is there any personal problem that may affect the working process? About the environment, is the delay of construction affected by the environment? Is there any external factor that may affect the working place? About the machine, are the equipment sufficient? Did the machine have a problem? Are the machines properly maintained? About the material category, does the procurement has a problem? Was the material	The manager stated that the manpower group has problems with experience, expertise, and understanding of drawings; some employees are unable to work extra hours, and there is a problem with the drawing team. Threats from locals, rainy conditions, no land road, rocky zone, and remote location are among the environmental issues. Machine problems include a shortage of dump trucks, a need for more excavators, a need for more jackhammers, and a need for more concrete mixers, but the machines are well-maintained and function properly. Material problems include higher material prices, shortages, and procurement delays, but the material is adequately stored and used. Method issues are soil investigation and security methods, but for now, there is no

		handled (stored, dispensed, used & disposed of) properly? About the method, is the soil investigation a suitable method? Is the controlling and monitoring method not efficient? Is there any regulation of documentation that has to be changed?	regulation that needs to be changed because it is not easy to change rules in the middle of the project work. However, we are still open to any recommendations or input regarding the management system. To conclude, there are five categories that affect the project delay, which are Manpower, machine, environment, method, and material.
1 hour on 9th December 2020	Strategy to resolve the problem	What is the strategy for overcoming problems in human resource, environment, material, machine, and method problems? Do you prefer to use BIM for the next project?	In terms of human resources, the project manager has considered hiring more people because some local employees are unable to work overtime. In the Covid-19 pandemic, finding new jobs is not a difficult task. The project manager will meet with the supervisor in charge of the construction workers with the goal of preparing an internal memo from the supervisor to the workers to ensure that everyone follows the same set of instructions and that communication is clarified in a way that makes the company operate more efficiently. In the case of material problems, if the supplier raises the material price and is slow to produce, the company will consider buying the material in the city nearest to the project site. As a result, the work can be moved forward as a daily goal immediately. Concerning the machine issue, the team planned to add two jackhammers, one concrete mixer, and one dump truck. The manager considers the additional strategy based on the budget and performance calculations. The construction crew has set up special tents for equipment, supplies, and personnel. The

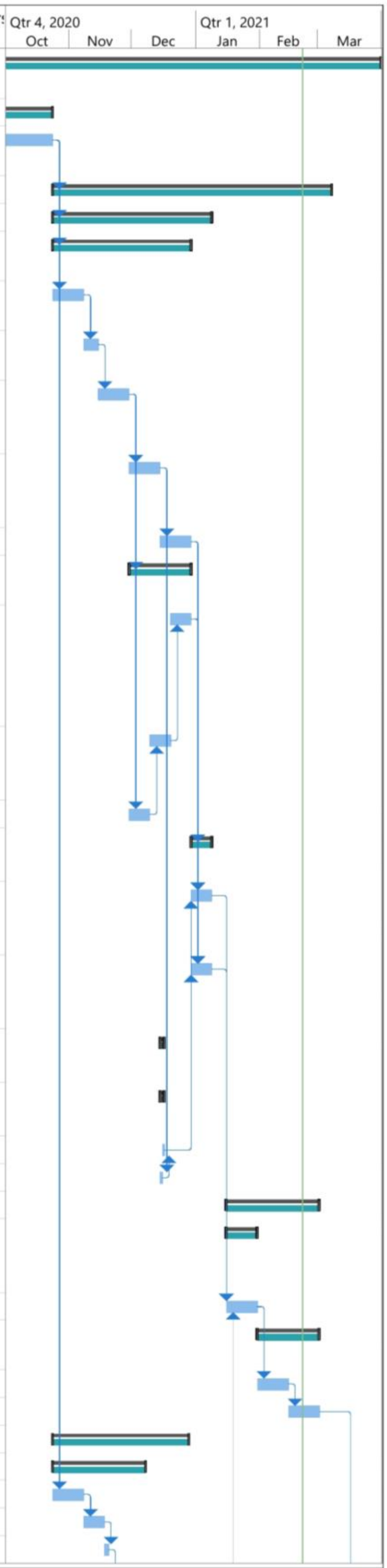
			team will use a mixture of materials to speed up the drying and hardening of concrete, particularly when working on infrastructure projects like floor plates and beam-columns. Another external problem is the threat of work, such as the Free Papua Movement organization, which could endanger contractor workers' safety. Hiring more police officers to be stationed on the project site is one way to improve the security system. Police involvement is expected to minimize risks associated with job operations, resulting in a secure, effective, and productive workplace. In terms of BIM, for Indonesian companies, it is not easy to implement it fully. There are research and development departments in the company that focus on BIM. The company needs more talented human resources.

Appendix 2. Activities and Schedule

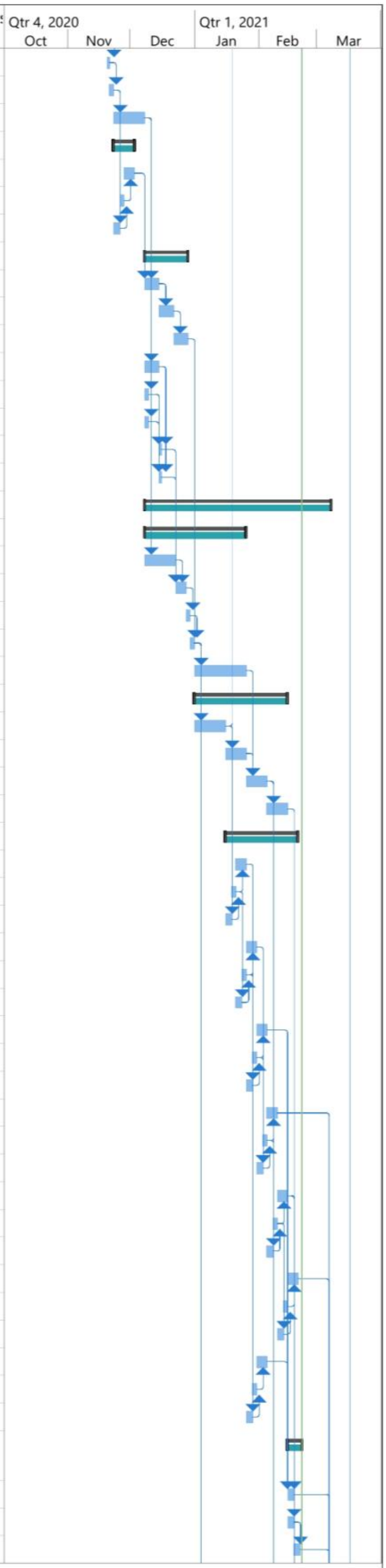
Appendix 2 is a type of data that is from the report and project documents from the company. It presents activities, the schedule, and the work breakdown structure. The table includes all activities or construction work, from preparatory work to commissioning and remote monitoring systems. The table was made by Microsoft Project to show the Gantt Chart.

Figure 8. 1 Project Activities

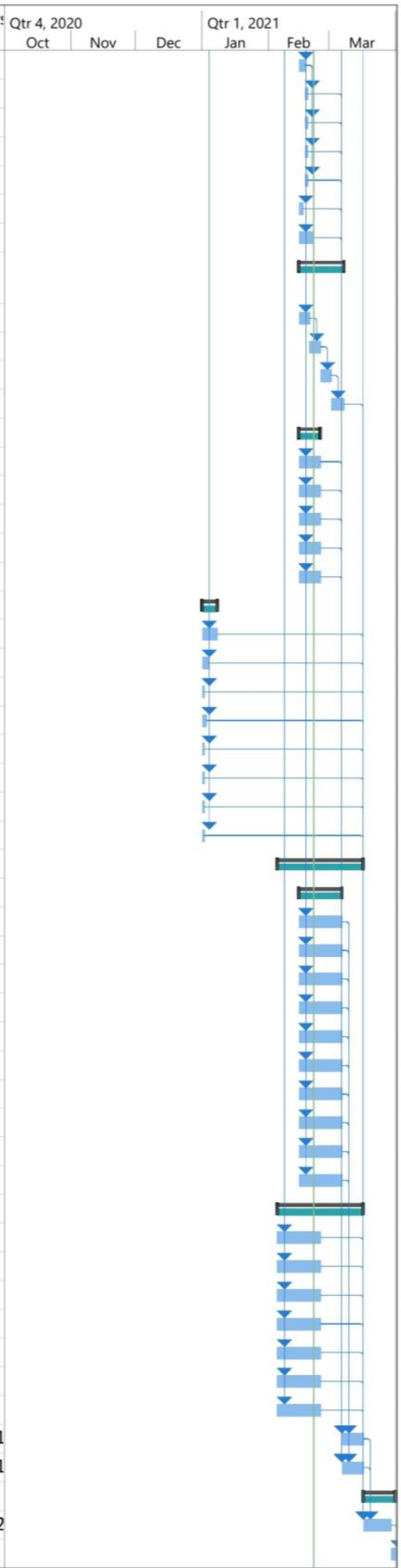
ID	WBS	Task Name	Duration	Start	Finish	Predecessors
1	**1**	**POWER PLANT CONSTRUCTION**	**184 days**	**Tue 9/29/20**	**Wed 3/31/21**	
2	**1.1**	**PREPARATORY WC**	**25 days**	**Tue 9/29/20**	**Fri 10/23/20**	
3	1.1.1	Mobilization demobilization	25 days	Tue 9/29/20	Fri 10/23/20	
4	**1.2**	**CIVIL WORK**	**135 days**	**Sat 10/24/20**	**Sun 3/7/21**	**3**
5	**1.2.1**	**DAM& Intake**	**77 days**	**Sat 10/24/20**	**Fri 1/8/21**	**3**
6	**1.2.1.1**	**Intake channel**	**67 days**	**Sat 10/24/20**	**Tue 12/29/20**	**3**
7	1.2.1.1.	Excavation of	15 days	Sat 10/24/20	Sat 11/7/20	3
8	1.2.1.1.	Pile foundation	7 days	Sun 11/8/20	Sat 11/14/20	7
9	1.2.1.1.	River stone masonry	15 days	Sun 11/15/20	Sun 11/29/20	8
10	1.2.1.1.	River stone masonry	15 days	Mon 11/30/20	Mon 12/14/20	9
11	1.2.1.1.	Gabions	15 days	Tue 12/15/2(	Tue 12/29/2(	10
12	**1.2.1.2**	**Work of concrete +**	**30 days**	**Mon 11/30/20**	**Tue 12/29/20**	**9**
13	1.2.1.2.	Service floor + floor step on the intake	10 days	Sun 12/20/20	Tue 12/29/20	14
14	1.2.1.2.	Concrete Rebar (reinforcem	10 days	Thu 12/10/20	Sat 12/19/20	15
15	1.2.1.2.	Formwork	10 days	Mon 11/30/2	Wed 12/9/20	9
16	**1.2.1.3**	**Open Intake Channel**	**10 days**	**Wed 12/30/20**	**Fri 1/8/21**	**13**
17	1.2.1.3.	Intake door size (1500 mm	10 days	Wed 12/30/20	Fri 1/8/21	13,11,21
18	1.2.1.3.	Coarse filter L 50.50.5	10 days	Wed 12/30/20	Fri 1/8/21	13,11,21
19	**1.2.2**	**Settling Tank Building**	**2 days**	**Tue 12/15/20**	**Wed 12/16/20**	
20	**1.2.2.1**	**Roof work, Sluice Drain**	**2 days**	**Tue 12/15/20**	**Wed 12/16/20**	
21	1.2.2.1.	Metal tile r	1 day	Wed 12/16/2	Wed 12/16/2	22
22	1.2.2.1.	Roof tile ro	1 day	Tue 12/15/2(	Tue 12/15/2(	10
23	**1.2.3**	**Tailrace**	**45 days**	**Sat 1/16/21**	**Mon 3/1/21**	
24	**1.2.3.1**	**Earthwork / Foundation / Concrete**	**15 days**	**Sat 1/16/21**	**Sat 1/30/21**	
25	1.2.3.1.	Open chan	15 days	Sat 1/16/21	Sat 1/30/21	58,17,18
26	**1.2.3.2**	**Open Channel**	**30 days**	**Sun 1/31/21**	**Mon 3/1/21**	
27	1.2.3.2.	Open chan	15 days	Sun 1/31/21	Sun 2/14/21	25
28	1.2.3.2.	Open chan	15 days	Mon 2/15/21	Mon 3/1/21	27
29	**1.2.4**	**Pipe Penstock (**	**66 days**	**Sat 10/24/20**	**Mon 12/28/2**	
30	**1.2.4.1**	**Earthwork / (**	**45 days**	**Sat 10/24/20**	**Mon 12/7/2(**	
31	1.2.4.1.	Excavation	15 days	Sat 10/24/20	Sat 11/7/20	3
32	1.2.4.1.	Foundation	10 days	Sun 11/8/20	Tue 11/17/2(	31
33	1.2.4.1.	Foundation	2 days	Wed 11/18/2	Thu 11/19/2(	32



ID	WBS	Task Name	Duration	Start	Finish	Predecessors
34	1.2.4.1.·	Landfill unc	1 day	Fri 11/20/20	Fri 11/20/20	33
35	1.2.4.1.	Empty ston	2 days	Sat 11/21/20	Sun 11/22/2(	34
36	1.2.4.1.(	River stone	15 days	Mon 11/23/2	Mon 12/7/20	35
37	**1.2.4.2**	**Reinforced Cc**	**10 days**	**Mon 11/23/2**	**Wed 12/2/2(**	
38	1.2.4.2.	Reinforced	5 days	Sat 11/28/20	Wed 12/2/20	39
39	1.2.4.2.	Rebar conc	2 days	Thu 11/26/2(	Fri 11/27/20	40
40	1.2.4.2.	Formwork	3 days	Mon 11/23/2	Wed 11/25/2	35
41	**1.2.4.3**	**Plumbing Wo**	**21 days**	**Tue 12/8/20**	**Mon 12/28/2**	
42	1.2.4.3.	Pipe weld j(	7 days	Tue 12/8/20	Mon 12/14/2	36,38
43	1.2.4.3.	Anchor plat	7 days	Tue 12/15/2(	Mon 12/21/2	42
44	1.2.4.3.	Finishing ir(	7 days	Tue 12/22/2(	Mon 12/28/2	43
45	1.2.4.3.·	Penstock, d	7 days	Tue 12/8/20	Mon 12/14/2	36
46	1.2.4.3.	Stiffener, m	2 days	Tue 12/8/20	Wed 12/9/20	36
47	1.2.4.3.(	Saddle inclu	2 days	Tue 12/8/20	Wed 12/9/20	36
48	1.2.4.3.	PVC pipe di	1 day	Tue 12/15/2(	Tue 12/15/2(	45,46,47
49	1.2.4.3.	Gate valve	1 day	Tue 12/15/2(	Tue 12/15/2(	45,46,47
50	**1.2.5**	**Powerhouse**	**90 days**	**Tue 12/8/20**	**Sun 3/7/21**	
51	**1.2.5.1**	**Earthworks**	**49 days**	**Tue 12/8/20**	**Mon 1/25/21**	
52	1.2.5.1.	Excavation	15 days	Tue 12/8/20	Tue 12/22/2(	36
53	1.2.5.1.	Pile founda	5 days	Wed 12/23/2	Sun 12/27/2(	52,48,49
54	1.2.5.1.	Landfill recl	2 days	Mon 12/28/2	Tue 12/29/2(	53
55	1.2.5.1.·	Landfill unc	2 days	Wed 12/30/2	Thu 12/31/2(	54,44
56	1.2.5.1.	Gabion (soi	25 days	Fri 1/1/21	Mon 1/25/21	55
57	**1.2.5.2**	**Masonry Wor**	**45 days**	**Fri 1/1/21**	**Sun 2/14/21**	
58	1.2.5.2.	Masonry of	15 days	Fri 1/1/21	Fri 1/15/21	55
59	1.2.5.2.	Installation	10 days	Sat 1/16/21	Mon 1/25/21	58
60	1.2.5.2.	Masonry of	10 days	Tue 1/26/21	Thu 2/4/21	59,56
61	1.2.5.2.·	Plaster mo	10 days	Fri 2/5/21	Sun 2/14/21	60
62	**1.2.5.3**	**Reinforced Cc**	**35 days**	**Sat 1/16/21**	**Fri 2/19/21**	
63	1.2.5.3.	Concrete sl	5 days	Thu 1/21/21	Mon 1/25/21	64
64	1.2.5.3.	Rebar conc	2 days	Tue 1/19/21	Wed 1/20/21	65
65	1.2.5.3.	Formwork	3 days	Sat 1/16/21	Mon 1/18/21	58
66	1.2.5.3.·	Practical co	5 days	Tue 1/26/21	Sat 1/30/21	67
67	1.2.5.3.	Concrete R	2 days	Sun 1/24/21	Mon 1/25/21	68
68	1.2.5.3.(	Formwork	3 days	Thu 1/21/21	Sat 1/23/21	64
69	1.2.5.3.	Concrete cc	5 days	Sun 1/31/21	Thu 2/4/21	70
70	1.2.5.3.	Concrete R	2 days	Fri 1/29/21	Sat 1/30/21	71
71	1.2.5.3.	Formwork	3 days	Tue 1/26/21	Thu 1/28/21	67
72	1.2.5.3.	Concrete b	5 days	Fri 2/5/21	Tue 2/9/21	73
73	1.2.5.3.	Concrete R	2 days	Wed 2/3/21	Thu 2/4/21	74
74	1.2.5.3.	Formwork	3 days	Sun 1/31/21	Tue 2/2/21	70,66
75	1.2.5.3.	Concrete b	5 days	Wed 2/10/21	Sun 2/14/21	76
76	1.2.5.3.	Concrete re	2 days	Mon 2/8/21	Tue 2/9/21	77
77	1.2.5.3.	Formwork	3 days	Fri 2/5/21	Sun 2/7/21	73
78	1.2.5.3.	Concrete ta	5 days	Mon 2/15/21	Fri 2/19/21	79
79	1.2.5.3.	Concrete re	2 days	Sat 2/13/21	Sun 2/14/21	80
80	1.2.5.3.	Formwork	3 days	Wed 2/10/21	Fri 2/12/21	76
81	1.2.5.3.	Rated Conc	5 days	Sun 1/31/21	Thu 2/4/21	82
82	1.2.5.3.	Concrete re	2 days	Fri 1/29/21	Sat 1/30/21	83
83	1.2.5.3.	Formwork	3 days	Tue 1/26/21	Thu 1/28/21	63
84	**1.2.5.4**	**Frame and Door Work**	**7 days**	**Mon 2/15/21**	**Sun 2/21/21**	
85	1.2.5.4.	Plywood pa	3 days	Mon 2/15/21	Wed 2/17/21	75,69,81
86	1.2.5.4.	Frames + W	3 days	Mon 2/15/21	Wed 2/17/21	75
87	1.2.5.4.	Install plain	3 days	Thu 2/18/21	Sat 2/20/21	86



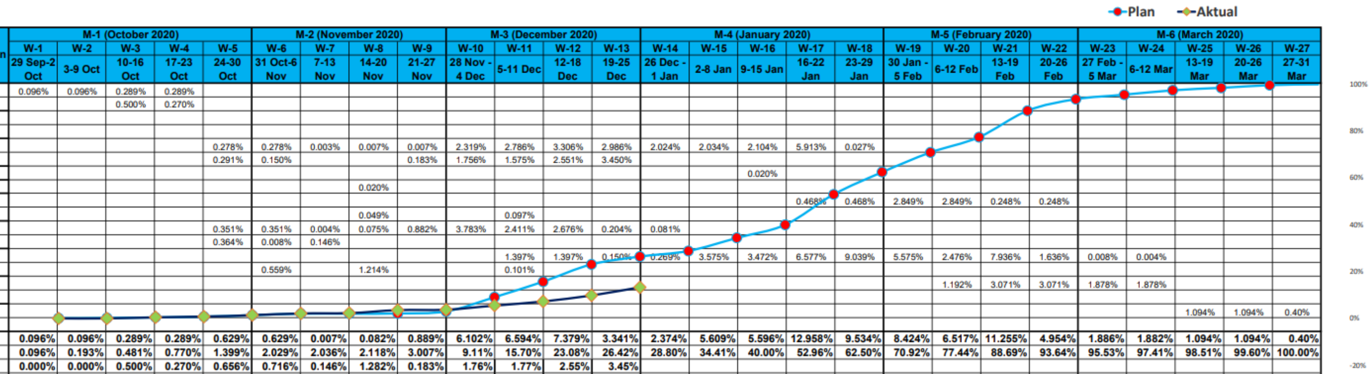
ID	WBS	Task Name	Duration	Start	Finish	Predecessors
88	1.2.5.4.·	Door frame	3 days	Mon 2/15/21	Wed 2/17/21	75
89	1.2.5.4.	Door hinge	1 day	Thu 2/18/21	Thu 2/18/21	88
90	1.2.5.4.	Window hi	1 day	Thu 2/18/21	Thu 2/18/21	88
91	1.2.5.4.	door handl	1 day	Thu 2/18/21	Thu 2/18/21	88
92	1.2.5.4.	Window ha	1 day	Thu 2/18/21	Thu 2/18/21	88
93	1.2.5.4.	Door panel	2 days	Mon 2/15/21	Tue 2/16/21	75
94	1.2.5.4.	Steel roolin	7 days	Mon 2/15/21	Sun 2/21/21	75
95	**1.2.5.5**	**Painting work +**	**21 days**	**Mon 2/15/21**	**Sun 3/7/21**	
96	1.2.5.5.	Wall paint i	5 days	Mon 2/15/21	Fri 2/19/21	61
97	1.2.5.5.	Ceiling pain	5 days	Sat 2/20/21	Wed 2/24/21	96
98	1.2.5.5.	Lisplang pai	5 days	Thu 2/25/21	Mon 3/1/21	97
99	1.2.5.5.·	rainwater d	6 days	Tue 3/2/21	Sun 3/7/21	98
100	**1.2.5.6**	**Roof + Cover**	**10 days**	**Mon 2/15/21**	**Wed 2/24/21**	
101	1.2.5.6.	Stance wor	10 days	Mon 2/15/21	Wed 2/24/21	75
102	1.2.5.6.	Stance wor	10 days	Mon 2/15/21	Wed 2/24/21	75
103	1.2.5.6.	Class II woc	10 days	Mon 2/15/21	Wed 2/24/21	75
104	1.2.5.6.·	Metal tile r	10 days	Mon 2/15/21	Wed 2/24/21	75
105	1.2.5.6.	Wooden ce	10 days	Mon 2/15/21	Wed 2/24/21	75
106	**1.2.5.7**	**Utility / Instal**	**7 days**	**Fri 1/1/21**	**Thu 1/7/21**	
107	1.2.5.7.	Infiltration	7 days	Fri 1/1/21	Thu 1/7/21	55
108	1.2.5.7.	Procureme	3 days	Fri 1/1/21	Sun 1/3/21	55
109	1.2.5.7.	Installation	1 day	Fri 1/1/21	Fri 1/1/21	55
110	1.2.5.7.·	Closet insta	2 days	Fri 1/1/21	Sat 1/2/21	55
111	1.2.5.7.	Installation	1 day	Fri 1/1/21	Fri 1/1/21	55
112	1.2.5.7.	Installation	1 day	Fri 1/1/21	Fri 1/1/21	55
113	1.2.5.7.	Installation	1 day	Fri 1/1/21	Fri 1/1/21	55
114	1.2.5.7.	Installation	1 day	Fri 1/1/21	Fri 1/1/21	55
115	**1.3**	**MECHANICAL AND**	**40 days**	**Fri 2/5/21**	**Tue 3/16/21**	
116	**1.3.1**	**Mechanical**	**20 days**	**Mon 2/15/21**	**Sat 3/6/21**	
117	1.3.1.1	Turbine (cross	20 days	Mon 2/15/21	Sat 3/6/21	75
118	1.3.1.2	Speed Increas	20 days	Mon 2/15/21	Sat 3/6/21	75
119	1.3.1.3	Generator (fo	20 days	Mon 2/15/21	Sat 3/6/21	75
120	1.3.1.4	Electronic Flo	20 days	Mon 2/15/21	Sat 3/6/21	75
121	1.3.1.5	Powerhouse v	20 days	Mon 2/15/21	Sat 3/6/21	75
122	1.3.1.6	Hoist Crane M	20 days	Mon 2/15/21	Sat 3/6/21	75
123	1.3.1.7	Digital Load C	20 days	Mon 2/15/21	Sat 3/6/21	75
124	1.3.1.8	ME Toolkit	20 days	Mon 2/15/21	Sat 3/6/21	75
125	1.3.1.9	Transformato	20 days	Mon 2/15/21	Sat 3/6/21	75
126	1.3.1.1C	Transformato	20 days	Mon 2/15/21	Sat 3/6/21	75
127	**1.3.2**	**Electrical install**	**40 days**	**Fri 2/5/21**	**Tue 3/16/21**	
128	1.3.2.1	Single Switch	20 days	Fri 2/5/21	Wed 2/24/21	60
129	1.3.2.2	Double Switcl	20 days	Fri 2/5/21	Wed 2/24/21	60
130	1.3.2.3	Installation of	20 days	Fri 2/5/21	Wed 2/24/21	60
131	1.3.2.4	Installation of	20 days	Fri 2/5/21	Wed 2/24/21	60
132	1.3.2.5	Installation of	20 days	Fri 2/5/21	Wed 2/24/21	60
133	1.3.2.6	Installation of	20 days	Fri 2/5/21	Wed 2/24/21	60
134	1.3.2.7	Lightning Prot	20 days	Fri 2/5/21	Wed 2/24/21	60
135	1.3.2.8	LV Panel Mou	10 days	Sun 3/7/21	Tue 3/16/21	120,117,11
136	1.3.2.9	PHB Lighting F	10 days	Sun 3/7/21	Tue 3/16/21	120,117,11
137	**1.4**	**OTHER WORKS**	**15 days**	**Wed 3/17/21**	**Wed 3/31/21**	
138	1.4.1	Training, Commi	13 days	Wed 3/17/21	Mon 3/29/21	136,135,12
139	1.4.2	Remote Monitor	2 days	Tue 3/30/21	Wed 3/31/21	138



Appendix 3. Weekly S-Curve Diagram

The Data was collected from a weekly report which was made in December 2020. The objective of drawing an S-Curve is to show the difference between project implementation time and the accumulated value of project implementation progress from the start to the current progress. The benefit of the S-curve is as an indicator tool and a monitoring project implementation schedule. This S-curve displays two graphs, namely a graph which is a plan, and a graph which is the realization of the implementation. This diagram was created in Microsoft Excel. It required a project schedule that includes a cost estimation plan in each activity, target time or cost of each activity, actual of work completion, and the actual costs incurred.

Figure 8. 2 Weekly S-Curve



No.	Uraian	Keterangan	Rp-Ra	%	Start	Finish	Duration	M-1 (October 2020)					M-2 (November 2020)				M-3 (December 2020)				M-4 (January 2020)					M-5 (February 2020)				M-6 (March 2020)				
								W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	W-9	W-10	W-11	W-12	W-13	W-14	W-15	W-16	W-17	W-18	W-19	W-20	W-21	W-22	W-23	W-24	W-25	W-26	W-27
								29 Sep-2 Oct	3-9 Oct	10-16 Oct	17-23 Oct	24-30 Oct	31 Oct-6 Nov	7-13 Nov	14-20 Nov	21-27 Nov	28 Nov - 4 Dec	5-11 Dec	12-18 Dec	19-25 Dec	26 Dec - 1 Jan	2-8 Jan	9-15 Jan	16-22 Jan	23-29 Jan	30 Jan - 5 Feb	6-12 Feb	13-19 Feb	20-26 Feb	27 Feb - 5 Mar	6-12 Mar	13-19 Mar	20-26 Mar	27-31 Mar
1	Preparatory Work	*FINISH*	Rp	0.770%	29-Sep	23-Oct	25	0.096%	0.096%	0.289%	0.289%																									
			Ra	0.770%						0.500%	0.270%																									
2	Civil Work	*Continue*	Rp	85.552%	24-Oct	7-Mar	135																													
			Ra	12.513%																																
2.1	Dam & Intake	*Continue*	Rp	24.073%	24-Oct	8-Jan	77					0.278%	0.278%	0.003%	0.007%	0.007%	2.319%	2.786%	3.306%	2.986%	2.024%	2.034%	2.104%	5.913%	0.027%									
			Ra	9.956%	24-Oct							0.291%	0.150%			0.183%	1.756%	1.575%	2.551%	3.450%														
2.2	Dettling Tank	*FINISH*	Rp	0.020%	15-Dec	16-Dec	2																0.020%											
			Ra	0.020%	14-Nov	20-Nov	7								0.020%																			
2.3	Tailrace	*Continue*	Rp	7.129%	16-Jan	1-Mar	45																	0.468%	0.468%	2.849%	2.849%	0.248%	0.248%					
			Ra	0.146%	14-Nov										0.049%			0.097%																
2.4	Pipa Penstock	*Continue*	Rp	10.819%	24-Oct	28-Dec	66					0.351%	0.351%	0.004%	0.075%	0.882%	3.783%	2.411%	2.676%	0.204%	0.081%													
			Ra	0.518%	24-Oct							0.364%	0.008%	0.146%																				
2.5	Powerhouse	*Continue*	Rp	43.512%	8-Dec	7-Mar	90											1.397%	1.397%	0.150%	0.269%	3.575%	3.472%	6.577%	9.039%	5.575%	2.476%	7.936%	1.636%	0.008%	0.004%			
			Ra	1.874%	31-Oct								0.559%		1.214%			0.101%																
3	Mechanical and Electrical Works		Rp	11.090%	5-Feb	16-Mar	40																				1.192%	3.071%	3.071%	1.878%	1.878%			
			Ra	0.000%																														
4	Other works		Rp	2.588%	17-Mar	31-Mar	15																									1.094%	1.094%	0.40%
			Ra	0.000%																														
#	TOTAL PLAN		Rp					0.096%	0.096%	0.289%	0.289%	0.629%	0.629%	0.007%	0.082%	0.889%	6.102%	6.594%	7.379%	3.341%	2.374%	5.609%	5.596%	12.958%	9.534%	8.424%	6.517%	11.255%	4.954%	1.886%	1.882%	1.094%	1.094%	0.40%
#	CUMMULATIVE PLAN							0.096%	0.193%	0.481%	0.770%	1.399%	2.029%	2.036%	2.118%	3.007%	9.11%	15.70%	23.08%	26.42%	28.80%	34.41%	40.00%	52.96%	62.50%	70.92%	77.44%	88.69%	93.64%	95.53%	97.41%	98.51%	99.60%	100.00%
#	TOTAL ACTUAL		Ra					0.000%	0.000%	0.500%	0.270%	0.656%	0.716%	0.146%	1.282%	0.183%	1.76%	1.77%	2.55%	3.45%														
#	CUMMULATIVE ACTUAL							0.000%	0.000%	0.500%	0.770%	1.426%	2.142%	2.288%	3.570%	3.753%	5.51%	7.28%	9.83%	13.28%														
#	DEV							-0.096%	-0.193%	0.019%	0.000%	0.026%	0.113%	0.252%	1.452%	0.745%	-3.60%	-8.42%	-13.2%	-13.1%														

Appendix 4. Critical Path Method Table

The activities and the detailed data were collected from a weekly report. The table was made by using Microsoft Project. It enables to generate Earliest Start, Latest Start, Earliest Finish, and Latest Finish, therefore, the float time will be obtained. The float time of 0 day is the critical path.

Table 8. 2 Critical Path Method Table

WBS	Task Name	Du-ration	Start	Finish	Prede-cessors	Critical Path	Total Slack	Ear-liest start	Latest Start	Ear-liest finish	Latest Finish	Criti-cal Path	Cost%
1	**POWER PLANT CONSTRUCTION (Total)**	**184 days**	**Tue 9/29/20**	**Wed 3/31/21**		**Yes**	**0 days**	**Tue 9/29/20**	**Tue 9/29/20**	**Wed 3/31/21**	**Wed 3/31/21**		**100%**
1.1	**PREPARATORY WORK**	**25 days**	**Tue 9/29/20**	**Fri 10/23/20**		**Yes**	**0 days**	**Tue 9/29/20**	**Tue 9/29/20**	**Fri 10/23/20**	**Fri 10/23/20**		**0.770%**
1.1.1	Mobilization demobilization	25 days	Tue 9/29/20	Fri 10/23/20		Yes	0 days	Tue 9/29/20	Tue 9/29/20	Fri 10/23/20	Fri 10/23/20	Yes	0.770%
1.2	**CIVIL WORK**	**135 days**	**Sat 10/24/20**	**Sun 3/7/21**	**3**	**Yes**	**0 days**	**Sat 10/24/20**	**Sat 10/24/20**	**Sun 3/7/21**	**Tue 3/16/21**		**85.552%**
1.2.1	**DAM& Intake**	**77 days**	**Sat 10/24/20**	**Fri 1/8/21**	**3**	**Yes**	**0 days**	**Sat 10/24/20**	**Sat 10/24/20**	**Fri 1/8/21**	**Sat 1/30/21**		**24.073%**
1.2.1.1	**Intake channel Building Works**	**67 days**	**Sat 10/24/20**	**Tue 12/29/20**	**3**	**No**	**22 days**	**Sat 10/24/20**	**Sun 11/15/20**	**Tue 12/29/20**	**Wed 1/20/21**		**2.349%**
1.2.1.1.1	Excavation of construction land	15 days	Sat 10/24/20	Sat 11/7/20	3	No	22 days	Sat 10/24/20	Sun 11/15/20	Sat 11/7/20	Sun 11/29/20	No	0.556%
1.2.1.1.2	Pile foundation 10 cm - 3 m	7 days	Sun 11/8/20	Sat 11/14/20	7	No	22 days	Sun 11/8/20	Mon 11/30/20	Sat 11/14/20	Sun 12/6/20	No	0.003%
1.2.1.1.3	River stone masonry channel 1:8	15 days	Sun 11/15/20	Sun 11/29/20	8	No	22 days	Sun 11/15/20	Mon 12/7/20	Sun 11/29/20	Mon 12/21/20	No	0.015%
1.2.1.1.4	River stone masonry stucco 1:8	15 days	Mon 11/30/20	Mon 12/14/20	9	No	22 days	Mon 11/30/20	Tue 12/22/20	Mon 12/14/20	Tue 1/5/21	No	1.475%

1.2.1.1.5	Gabions	15 days	Tue 12/15/20	Tue 12/29/20	10	No	22 days	Tue 12/15/20	Wed 1/6/21	Tue 12/29/20	Wed 1/20/21	No	0.300%
1.2.1.2	**Work of concrete + install**	**30 days**	**Mon 11/30/20**	**Tue 12/29/20**	**9**	**No**	**22 days**	**Mon 11/30/20**	**Tue 12/22/20**	**Tue 12/29/20**	**Wed 1/20/21**		**21.669%**
1.2.1.2.1	Service floor + floor step on the intake door + pillar column K225	10 days	Sun 12/20/20	Tue 12/29/20	14	No	22 days	Sun 12/20/20	Mon 1/11/21	Tue 12/29/20	Wed 1/20/21	No	11.772%
1.2.1.2.2	Concrete Rebar (reinforcement steel)	10 days	Thu 12/10/20	Sat 12/19/20	15	No	22 days	Thu 12/10/20	Fri 1/1/21	Sat 12/19/20	Sun 1/10/21	No	6.735%
1.2.1.2.3	Formwork	10 days	Mon 11/30/20	Wed 12/9/20	9	No	22 days	Mon 11/30/20	Tue 12/22/20	Wed 12/9/20	Thu 12/31/20	No	3.162%
1.2.1.3	**Open Intake Channel Work**	**10 days**	**Wed 12/30/20**	**Fri 1/8/21**	**13**	**No**	**22 days**	**Wed 12/30/20**	**Thu 1/21/21**	**Fri 1/8/21**	**Sat 1/30/21**		**0.054%**
1.2.1.3.1	Intake door size (1500 mm x 2000 mm) x 2 pieces	10 days	Wed 12/30/20	Fri 1/8/21	13,11,21	No	22 days	Wed 12/30/20	Thu 1/21/21	Fri 1/8/21	Sat 1/30/21	No	0.046%
1.2.1.3.2	Coarse filter L 50.50.5 size 2 x 1.5 m	10 days	Wed 12/30/20	Fri 1/8/21	13,11,21	No	22 days	Wed 12/30/20	Thu 1/21/21	Fri 1/8/21	Sat 1/30/21	No	0.008%
1.2.2	**Settling Tank Building**	**2 days**	**Tue 12/15/20**	**Wed 12/16/20**		**Yes**	**0 days**	**Tue 12/15/20**	**Tue 12/15/20**	**Wed 12/16/20**	**Wed 1/20/21**		**0.020%**
1.2.2.1	**Roof work, Sluice Drain**	**2 days**	**Tue 12/15/20**	**Wed 12/16/20**		**No**	**35 days**	**Tue 12/15/20**	**Tue 1/19/21**	**Wed 12/16/20**	**Wed 1/20/21**		**0.020%**
1.2.2.1.1	Metal tile roof covering	1 day	Wed 12/16/20	Wed 12/16/20	22	No	35 days	Wed 12/16/20	Wed 1/20/21	Wed 12/16/20	Wed 1/20/21	No	0.019%
1.2.2.1.2	Roof tile rooftop	1 day	Tue 12/15/20	Tue 12/15/20	10	No	35 days	Tue 12/15/20	Tue 1/19/21	Tue 12/15/20	Tue 1/19/21	No	0.001%

1.2.3	**Tailrace**	**45 days**	**Sat 1/16/21**	**Mon 3/1/21**		**Yes**	**0 days**	**Sat 1/16/21**	**Sat 1/16/21**	**Mon 3/1/21**	**Tue 3/16/21**		**7.129%**
1.2.3.1	**Earthwork / Foundation / Concrete**	**15 days**	**Sat 1/16/21**	**Sat 1/30/21**		**No**	**15 days**	**Sat 1/16/21**	**Sun 1/31/21**	**Sat 1/30/21**	**Sun 2/14/21**		**0.936%**
1.2.3.1.1	Open channel minerals 1-2 m	15 days	Sat 1/16/21	Sat 1/30/21	58,17,18	No	15 days	Sat 1/16/21	Sun 1/31/21	Sat 1/30/21	Sun 2/14/21	No	0.936%
1.2.3.2	**Open Channel Work and others**	**30 days**	**Sun 1/31/21**	**Mon 3/1/21**		**No**	**15 days**	**Sun 1/31/21**	**Mon 2/15/21**	**Mon 3/1/21**	**Tue 3/16/21**		**6.193%**
1.2.3.2.1	Open channel river stone Masonry	15 days	Sun 1/31/21	Sun 2/14/21	25	No	15 days	Sun 1/31/21	Mon 2/15/21	Sun 2/14/21	Mon 3/1/21	No	5.698%
1.2.3.2.2	Open channel plastering	15 days	Mon 2/15/21	Mon 3/1/21	27	No	15 days	Mon 2/15/21	Tue 3/2/21	Mon 3/1/21	Tue 3/16/21	No	0.495%
1.2.4	**Pipe Penstock (4x125 m) + Anchor block / saddle**	**66 days**	**Sat 10/24/20**	**Mon 12/28/20**		**Yes**	**0 days**	**Sat 10/24/20**	**Sat 10/24/20**	**Mon 12/28/20**	**Tue 12/29/20**		**10.819%**
1.2.4.1	**Earthwork / Concrete Block Foundation**	**45 days**	**Sat 10/24/20**	**Mon 12/7/20**		**Yes**	**0 days**	**Sat 10/24/20**	**Sat 10/24/20**	**Mon 12/7/20**	**Mon 12/7/20**		**1.007%**
1.2.4.1.1	Excavation of pipe foundation blocks	15 days	Sat 10/24/20	Sat 11/7/20	3	Yes	0 days	Sat 10/24/20	Sat 10/24/20	Sat 11/7/20	Sat 11/7/20	Yes	0.632%
1.2.4.1.2	Foundation bore pile 20 cm - 3 m	10 days	Sun 11/8/20	Tue 11/17/20	31	Yes	0 days	Sun 11/8/20	Sun 11/8/20	Tue 11/17/20	Tue 11/17/20	Yes	0.008%
1.2.4.1.3	Foundation pile 10 cm - 3 m	2 days	Wed 11/18/20	Thu 11/19/20	32	Yes	0 days	Wed 11/18/20	Wed 11/18/20	Thu 11/19/20	Thu 11/19/20	Yes	0.027%
1.2.4.1.4	Landfill under the foundation 5 cm	1 day	Fri 11/20/20	Fri 11/20/20	33	Yes	0 days	Fri 11/20/20	Fri 11/20/20	Fri 11/20/20	Fri 11/20/20	Yes	0.044%
1.2.4.1.5	Empty stone couple masonry	2 days	Sat 11/21/20	Sun 11/22/20	34	Yes	0 days	Sat 11/21/20	Sat 11/21/20	Sun 11/22/20	Sun 11/22/20	Yes	0.226%

1.2.4.1.6	River stone foundation masonry	15 days	Mon 11/23/20	Mon 12/7/20	35	Yes	0 days	Mon 11/23/20	Mon 11/23/20	Mon 12/7/20	Mon 12/7/20	Yes	0.070%
1.2.4.2	**Reinforced Concrete Work**	**10 days**	**Mon 11/23/20**	**Wed 12/2/20**		**No**	**6 days**	**Mon 11/23/20**	**Sun 11/29/20**	**Wed 12/2/20**	**Tue 12/8/20**		**4.439%**
1.2.4.2.1	Reinforced concrete anchor block, concrete penstock K225	5 days	Sat 11/28/20	Wed 12/2/20	39	No	6 days	Sat 11/28/20	Fri 12/4/20	Wed 12/2/20	Tue 12/8/20	No	3.783%
1.2.4.2.2	Rebar concrete	2 days	Thu 11/26/20	Fri 11/27/20	40	No	6 days	Thu 11/26/20	Wed 12/2/20	Fri 11/27/20	Thu 12/3/20	No	0.225%
1.2.4.2.3	Formwork	3 days	Mon 11/23/20	Wed 11/25/20	35	No	6 days	Mon 11/23/20	Sun 11/29/20	Wed 11/25/20	Tue 12/1/20	No	0.431%
1.2.4.3	**Plumbing Work + Others**	**21 days**	**Tue 12/8/20**	**Mon 12/28/20**		**No**	**1 day**	**Tue 12/8/20**	**Wed 12/9/20**	**Mon 12/28/20**	**Tue 12/29/20**		**5.373%**
1.2.4.3.1	Pipe weld joint installed	7 days	Tue 12/8/20	Mon 12/14/20	36,38	No	1 day	Tue 12/8/20	Wed 12/9/20	Mon 12/14/20	Tue 12/15/20	No	0.483%
1.2.4.3.2	Anchor plate to foundation block	7 days	Tue 12/15/20	Mon 12/21/20	42	No	1 day	Tue 12/15/20	Wed 12/16/20	Mon 12/21/20	Tue 12/22/20	No	0.246%
1.2.4.3.3	Finishing iron paint + anchor plate	7 days	Tue 12/22/20	Mon 12/28/20	43	No	1 day	Tue 12/22/20	Wed 12/23/20	Mon 12/28/20	Tue 12/29/20	No	0.163%
1.2.4.3.4	Penstock, dia = 30"mm, thickness = 6,0 mm, total length 4 x 125 m	7 days	Tue 12/8/20	Mon 12/14/20	36	No	7 days	Tue 12/8/20	Tue 12/15/20	Mon 12/14/20	Mon 12/21/20	No	3.082%
1.2.4.3.5	Stiffener, material dia = DN 30", thickness = 6 mm	2 days	Tue 12/8/20	Wed 12/9/20	36	No	12 days	Tue 12/8/20	Sun 12/20/20	Wed 12/9/20	Mon 12/21/20	No	0.546%

1.2.4.3.6	Saddle including teflon / asphalt coating, armature and strap, dia 30"	2 days	Tue 12/8/20	Wed 12/9/20	36	No	12 days	Tue 12/8/20	Sun 12/20/20	Wed 12/9/20	Mon 12/21/20	No	0.082%
1.2.4.3.7	PVC pipe dia = 10"for drain	1 day	Tue 12/15/20	Tue 12/15/20	45,46,47	No	7 days	Tue 12/15/20	Tue 12/22/20	Tue 12/15/20	Tue 12/22/20	No	0.447%
1.2.4.3.8	Gate valve dia = 10"for drain	1 day	Tue 12/15/20	Tue 12/15/20	45,46,47	No	7 days	Tue 12/15/20	Tue 12/22/20	Tue 12/15/20	Tue 12/22/20	No	0.323%
1.2.5	**Powerhouse**	**90 days**	**Tue 12/8/20**	**Sun 3/7/21**		**Yes**	**0 days**	**Tue 12/8/20**	**Tue 12/8/20**	**Sun 3/7/21**	**Tue 3/16/21**		**43.512%**
1.2.5.1	**Earthworks**	**49 days**	**Tue 12/8/20**	**Mon 1/25/21**		**Yes**	**0 days**	**Tue 12/8/20**	**Tue 12/8/20**	**Mon 1/25/21**	**Wed 2/3/21**		**16.294%**
1.2.5.1.1	Excavation of foundation soil	15 days	Tue 12/8/20	Tue 12/22/20	36	Yes	0 days	Tue 12/8/20	Tue 12/8/20	Tue 12/22/20	Tue 12/22/20	Yes	2.794%
1.2.5.1.2	Pile foundation 10 cm - 3 m	5 days	Wed 12/23/20	Sun 12/27/20	52,48,49	Yes	0 days	Wed 12/23/20	Wed 12/23/20	Sun 12/27/20	Sun 12/27/20	Yes	0.301%
1.2.5.1.3	Landfill reclamation	2 days	Mon 12/28/20	Tue 12/29/20	53	Yes	0 days	Mon 12/28/20	Mon 12/28/20	Tue 12/29/20	Tue 12/29/20	Yes	0.053%
1.2.5.1.4	Landfill under the foundation of the lane	2 days	Wed 12/30/20	Thu 12/31/20	54,44	Yes	0 days	Wed 12/30/20	Wed 12/30/20	Thu 12/31/20	Thu 12/31/20	Yes	0.066%
1.2.5.1.5	Gabion (soil wall protection)	25 days	Fri 1/1/21	Mon 1/25/21	55	No	9 days	Fri 1/1/21	Sun 1/10/21	Mon 1/25/21	Wed 2/3/21	No	13.080%
1.2.5.2	**Masonry Work**	**45 days**	**Fri 1/1/21**	**Sun 2/14/21**		**Yes**	**0 days**	**Fri 1/1/21**	**Fri 1/1/21**	**Sun 2/14/21**	**Tue 2/23/21**		**9.718%**
1.2.5.2.1	Masonry of Empty stone 15 cm	15 days	Fri 1/1/21	Fri 1/15/21	55	Yes	0 days	Fri 1/1/21	Fri 1/1/21	Fri 1/15/21	Fri 1/15/21	Yes	0.404%
1.2.5.2.2	Installation of split stone 1:8	10 days	Sat 1/16/21	Mon 1/25/21	58	No	9 days	Sat 1/16/21	Mon 1/25/21	Mon 1/25/21	Wed 2/3/21	No	3.786%

1.2.5.2.3	Masonry of brick 1:6	10 days	Tue 1/26/21	Thu 2/4/21	59,56	No	9 days	Tue 1/26/21	Thu 2/4/21	Thu 2/4/21	Sat 2/13/21	No	3.721%
1.2.5.2.4	Plaster mortar 1:6	10 days	Fri 2/5/21	Sun 2/14/21	60	No	9 days	Fri 2/5/21	Sun 2/14/21	Sun 2/14/21	Tue 2/23/21	No	1.806%
1.2.5.3	**Reinforced Concrete Work**	**35 days**	**Sat 1/16/21**	**Fri 2/19/21**		**Yes**	**0 days**	**Sat 1/16/21**	**Sat 1/16/21**	**Fri 2/19/21**	**Sat 3/6/21**		**13.139%**
1.2.5.3.1	Concrete sloof 20/30 K225	5 days	Thu 1/21/21	Mon 1/25/21	64	No	27 days	Thu 1/21/21	Wed 2/17/21	Mon 1/25/21	Sun 2/21/21	No	0.747%
1.2.5.3.2	Rebar concrete	2 days	Tue 1/19/21	Wed 1/20/21	65	Yes	0 days	Tue 1/19/21	Tue 1/19/21	Wed 1/20/21	Wed 1/20/21	Yes	0.408%
1.2.5.3.3	Formwork	3 days	Sat 1/16/21	Mon 1/18/21	58	Yes	0 days	Sat 1/16/21	Sat 1/16/21	Mon 1/18/21	Mon 1/18/21	Yes	0.632%
1.2.5.3.4	Practical column concrete 15/15 K225	5 days	Tue 1/26/21	Sat 1/30/21	67	Yes	0 days	Tue 1/26/21	Tue 1/26/21	Sat 1/30/21	Sat 1/30/21	No	0.079%
1.2.5.3.5	Concrete Rebar	2 days	Sun 1/24/21	Mon 1/25/21	68	Yes	0 days	Sun 1/24/21	Sun 1/24/21	Mon 1/25/21	Mon 1/25/21	Yes	0.088%
1.2.5.3.6	Formwork	3 days	Thu 1/21/21	Sat 1/23/21	64	Yes	0 days	Thu 1/21/21	Thu 1/21/21	Sat 1/23/21	Sat 1/23/21	Yes	0.082%
1.2.5.3.7	Concrete column structure 20/20 K225	5 days	Sun 1/31/21	Thu 2/4/21	70	No	27 days	Sun 1/31/21	Sat 2/27/21	Thu 2/4/21	Wed 3/3/21	No	0.310%
1.2.5.3.8	Concrete Rebar	2 days	Fri 1/29/21	Sat 1/30/21	71	Yes	0 days	Fri 1/29/21	Fri 1/29/21	Sat 1/30/21	Sat 1/30/21	Yes	0.205%
1.2.5.3.9	Formwork	3 days	Tue 1/26/21	Thu 1/28/21	67	Yes	0 days	Tue 1/26/21	Tue 1/26/21	Thu 1/28/21	Thu 1/28/21	Yes	0.241%
1.2.5.3.10	Concrete beam ring 20/30 K225	5 days	Fri 2/5/21	Tue 2/9/21	73	No	25 days	Fri 2/5/21	Tue 3/2/21	Tue 2/9/21	Sat 3/6/21	No	0.502%
1.2.5.3.11	Concrete Rebar	2 days	Wed 2/3/21	Thu 2/4/21	74	Yes	0 days	Wed 2/3/21	Wed 2/3/21	Thu 2/4/21	Thu 2/4/21	Yes	0.285%
1.2.5.3.12	Formwork	3 days	Sun 1/31/21	Tue 2/2/21	70,66	Yes	0 days	Sun 1/31/21	Sun 1/31/21	Tue 2/2/21	Tue 2/2/21	Yes	0.455%

1.2.5.3.13	Concrete beam gavel 15/20 K225	5 days	Wed 2/10/21	Sun 2/14/21	76	Yes	0 days	Wed 2/10/21	Wed 2/10/21	Sun 2/14/21	Sun 2/14/21	Yes	0.302%
1.2.5.3.14	Concrete rebar	2 days	Mon 2/8/21	Tue 2/9/21	77	Yes	0 days	Mon 2/8/21	Mon 2/8/21	Tue 2/9/21	Tue 2/9/21	Yes	0.154%
1.2.5.3.15	Formwork	3 days	Fri 2/5/21	Sun 2/7/21	73	Yes	0 days	Fri 2/5/21	Fri 2/5/21	Sun 2/7/21	Sun 2/7/21	Yes	0.313%
1.2.5.3.16	Concrete tail race+Channel K225	5 days	Mon 2/15/21	Fri 2/19/21	79	No	15 days	Mon 2/15/21	Tue 3/2/21	Fri 2/19/21	Sat 3/6/21	No	3.206%
1.2.5.3.17	Concrete rebar	2 days	Sat 2/13/21	Sun 2/14/21	80	No	15 days	Sat 2/13/21	Sun 2/28/21	Sun 2/14/21	Mon 3/1/21	No	1.066%
1.2.5.3.18	Formwork	3 days	Wed 2/10/21	Fri 2/12/21	76	No	15 days	Wed 2/10/21	Thu 2/25/21	Fri 2/12/21	Sat 2/27/21	No	0.703%
1.2.5.3.19	Rated Concrete around 10 K175	5 days	Sun 1/31/21	Thu 2/4/21	82	No	27 days	Sun 1/31/21	Sat 2/27/21	Thu 2/4/21	Wed 3/3/21	No	2.374%
1.2.5.3.20	Concrete rebar	2 days	Fri 1/29/21	Sat 1/30/21	83	No	27 days	Fri 1/29/21	Thu 2/25/21	Sat 1/30/21	Fri 2/26/21	No	0.887%
1.2.5.3.21	Formwork	3 days	Tue 1/26/21	Thu 1/28/21	63	No	27 days	Tue 1/26/21	Mon 2/22/21	Thu 1/28/21	Wed 2/24/21	No	0.100%
1.2.5.4	**Frame and Door Work**	**7 days**	**Mon 2/15/21**	**Sun 2/21/21**		**No**	**13 days**	**Mon 2/15/21**	**Sun 2/28/21**	**Sun 2/21/21**	**Sat 3/6/21**		**0.636%**
1.2.5.4.1	Plywood panel door 4 cm	3 days	Mon 2/15/21	Wed 2/17/21	75,69,81	No	17 days	Mon 2/15/21	Thu 3/4/21	Wed 2/17/21	Sat 3/6/21	No	0.056%
1.2.5.4.2	Frames + Window panels	3 days	Mon 2/15/21	Wed 2/17/21	75	No	14 days	Mon 2/15/21	Mon 3/1/21	Wed 2/17/21	Wed 3/3/21	No	0.119%
1.2.5.4.3	Install plain glass 5 mm	3 days	Thu 2/18/21	Sat 2/20/21	86	No	14 days	Thu 2/18/21	Thu 3/4/21	Sat 2/20/21	Sat 3/6/21	No	0.061%
1.2.5.4.4	Door frame + window +	3 days	Mon 2/15/21	Wed 2/17/21	75	No	16 days	Mon 2/15/21	Wed 3/3/21	Wed 2/17/21	Fri 3/5/21	No	0.038%

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1.2.5.4.5	Door hinges 3"ex brand	1 day	Thu 2/18/21	Thu 2/18/21	88	No	16 days	Thu 2/18/21	Sat 3/6/21	Thu 2/18/21	Sat 3/6/21	No	0.015%
1.2.5.4.6	Window hinges 2"ex brand	1 day	Thu 2/18/21	Thu 2/18/21	88	No	16 days	Thu 2/18/21	Sat 3/6/21	Thu 2/18/21	Sat 3/6/21	No	0.013%
1.2.5.4.7	door handle + key ex cisco	1 day	Thu 2/18/21	Thu 2/18/21	88	No	16 days	Thu 2/18/21	Sat 3/6/21	Thu 2/18/21	Sat 3/6/21	No	0.002%
1.2.5.4.8	Window handle+wind hook ex lamskar	1 day	Thu 2/18/21	Thu 2/18/21	88	No	16 days	Thu 2/18/21	Sat 3/6/21	Thu 2/18/21	Sat 3/6/21	No	0.007%
1.2.5.4.9	Door panel+frame PVC km/toilet	2 days	Mon 2/15/21	Tue 2/16/21	75	No	18 days	Mon 2/15/21	Fri 3/5/21	Tue 2/16/21	Sat 3/6/21	No	0.008%
1.2.5.4.10	Steel rooling door 3 m x 2,5 m	7 days	Mon 2/15/21	Sun 2/21/21	75	No	13 days	Mon 2/15/21	Sun 2/28/21	Sun 2/21/21	Sat 3/6/21	No	0.317%
1.2.5.5	**Painting work + Drainage**	**21 days**	**Mon 2/15/21**	**Sun 3/7/21**		**No**	**9 days**	**Mon 2/15/21**	**Wed 2/24/21**	**Sun 3/7/21**	**Tue 3/16/21**		**0.595%**
1.2.5.5.1	Wall paint int.+ext.	5 days	Mon 2/15/21	Fri 2/19/21	61	No	9 days	Mon 2/15/21	Wed 2/24/21	Fri 2/19/21	Sun 2/28/21	No	0.461%
1.2.5.5.2	Ceiling paint	5 days	Sat 2/20/21	Wed 2/24/21	96	No	9 days	Sat 2/20/21	Mon 3/1/21	Wed 2/24/21	Fri 3/5/21	No	0.119%
1.2.5.5.3	Lisplang paint 25 cm	5 days	Thu 2/25/21	Mon 3/1/21	97	No	9 days	Thu 2/25/21	Sat 3/6/21	Mon 3/1/21	Wed 3/10/21	No	0.007%
1.2.5.5.4	rainwater drains PVC 2"+knee+glue	6 days	Tue 3/2/21	Sun 3/7/21	98	No	9 days	Tue 3/2/21	Thu 3/11/21	Sun 3/7/21	Tue 3/16/21	No	0.008%
1.2.5.6	**Roof + Cover Work**	**10 days**	**Mon 2/15/21**	**Wed 2/24/21**		**No**	**10 days**	**Mon 2/15/21**	**Thu 2/25/21**	**Wed 2/24/21**	**Sat 3/6/21**		**3.028%**
1.2.5.6.1	Stance work	10 days	Mon 2/15/21	Wed 2/24/21	75	No	10 days	Mon 2/15/21	Thu 2/25/21	Wed 2/24/21	Sat 3/6/21	No	0.221%

1.2.5.6.2	Stance work	10 days	Mon 2/15/21	Wed 2/24/21	75	No	10 days	Mon 2/15/21	Thu 2/25/21	Wed 2/24/21	Sat 3/6/21	No	0.336%
1.2.5.6.3	Class II wooden roof frame	10 days	Mon 2/15/21	Wed 2/24/21	75	No	10 days	Mon 2/15/21	Thu 2/25/21	Wed 2/24/21	Sat 3/6/21	No	0.952%
1.2.5.6.4	Metal tile roof covering	10 days	Mon 2/15/21	Wed 2/24/21	75	No	10 days	Mon 2/15/21	Thu 2/25/21	Wed 2/24/21	Sat 3/6/21	No	1.096%
1.2.5.6.5	Wooden ceiling frame class II 4/6 +fiber cement 4 mm	10 days	Mon 2/15/21	Wed 2/24/21	75	No	10 days	Mon 2/15/21	Thu 2/25/21	Wed 2/24/21	Sat 3/6/21	No	0.423%
1.2.5.7	**Utility / Installation Work**	**7 days**	**Fri 1/1/21**	**Thu 1/7/21**		**No**	**68 days**	**Fri 1/1/21**	**Wed 3/10/21**	**Thu 1/7/21**	**Tue 3/16/21**		**0.103%**
1.2.5.7.1	Infiltration well + septic tank 2x2x2	7 days	Fri 1/1/21	Thu 1/7/21	55	No	68 days	Fri 1/1/21	Wed 3/10/21	Thu 1/7/21	Tue 3/16/21	No	0.006%
1.2.5.7.2	Procurement of bathtubs	3 days	Fri 1/1/21	Sun 1/3/21	55	No	72 days	Fri 1/1/21	Sun 3/14/21	Sun 1/3/21	Tue 3/16/21	No	0.003%
1.2.5.7.3	Installation of 1/2"tub faucet	1 day	Fri 1/1/21	Fri 1/1/21	55	No	74 days	Fri 1/1/21	Tue 3/16/21	Fri 1/1/21	Tue 3/16/21	No	0.002%
1.2.5.7.4	Closet installation	2 days	Fri 1/1/21	Sat 1/2/21	55	No	73 days	Fri 1/1/21	Mon 3/15/21	Sat 1/2/21	Tue 3/16/21	No	0.009%
1.2.5.7.5	Installation of floor drain	1 day	Fri 1/1/21	Fri 1/1/21	55	No	74 days	Fri 1/1/21	Tue 3/16/21	Fri 1/1/21	Tue 3/16/21	No	0.001%
1.2.5.7.6	Installation of pipe 3/4"clean water	1 day	Fri 1/1/21	Fri 1/1/21	55	No	74 days	Fri 1/1/21	Tue 3/16/21	Fri 1/1/21	Tue 3/16/21	No	0.028%
1.2.5.7.7	Installation of pipe 2"dirty water	1 day	Fri 1/1/21	Fri 1/1/21	55	No	74 days	Fri 1/1/21	Tue 3/16/21	Fri 1/1/21	Tue 3/16/21	No	0.020%
1.2.5.7.8	Installation of pipe 3"dirty water	1 day	Fri 1/1/21	Fri 1/1/21	55	No	74 days	Fri 1/1/21	Tue 3/16/21	Fri 1/1/21	Tue 3/16/21	No	0.034%

1.3	**MECHANICAL AND ELECTRICAL WORKS**	**40 days**	**Fri 2/5/21**	**Tue 3/16/21**		**Yes**	**0 days**	**Fri 2/5/21**	**Fri 2/5/21**	**Tue 3/16/21**	**Tue 3/16/21**		**11.090%**
1.3.1	**Mechanical**	**20 days**	**Mon 2/15/21**	**Sat 3/6/21**		**Yes**	**0 days**	**Mon 2/15/21**	**Mon 2/15/21**	**Sat 3/6/21**	**Sat 3/6/21**		**7.514%**
1.3.1.1	Turbine (crossflow 4x250 kVA)	20 days	Mon 2/15/21	Sat 3/6/21	75	Yes	0 days	Mon 2/15/21	Mon 2/15/21	Sat 3/6/21	Sat 3/6/21	No	1.112%
1.3.1.2	Speed Increaser	20 days	Mon 2/15/21	Sat 3/6/21	75	Yes	0 days	Mon 2/15/21	Mon 2/15/21	Sat 3/6/21	Sat 3/6/21	No	3.235%
1.3.1.3	Generator (for hydro application) 380/440V max 2200 rpm, 50 Hz	20 days	Mon 2/15/21	Sat 3/6/21	75	Yes	0 days	Mon 2/15/21	Mon 2/15/21	Sat 3/6/21	Sat 3/6/21	No	1.213%
1.3.1.4	Electronic Flow Controller 230/400V, 300 kW, 50Hz	20 days	Mon 2/15/21	Sat 3/6/21	75	Yes	0 days	Mon 2/15/21	Mon 2/15/21	Sat 3/6/21	Sat 3/6/21	Yes	1.133%
1.3.1.5	Powerhouse wiring	20 days	Mon 2/15/21	Sat 3/6/21	75	Yes	0 days	Mon 2/15/21	Mon 2/15/21	Sat 3/6/21	Sat 3/6/21	No	0.092%
1.3.1.6	Hoist Crane Manual with capacity of 5 ton	20 days	Mon 2/15/21	Sat 3/6/21	75	Yes	0 days	Mon 2/15/21	Mon 2/15/21	Sat 3/6/21	Sat 3/6/21	No	0.022%
1.3.1.7	Digital Load Control + Ballast 50kW 230/400V 50Hz	20 days	Mon 2/15/21	Sat 3/6/21	75	Yes	0 days	Mon 2/15/21	Mon 2/15/21	Sat 3/6/21	Sat 3/6/21	No	0.143%
1.3.1.8	ME Toolkit	20 days	Mon 2/15/21	Sat 3/6/21	75	Yes	0 days	Mon 2/15/21	Mon 2/15/21	Sat 3/6/21	Sat 3/6/21	No	0.123%
1.3.1.9	Transformator PS 25 kvA 20kV/0,4	20 days	Mon 2/15/21	Sat 3/6/21	75	Yes	0 days	Mon 2/15/21	Mon 2/15/21	Sat 3/6/21	Sat 3/6/21	No	0.037%

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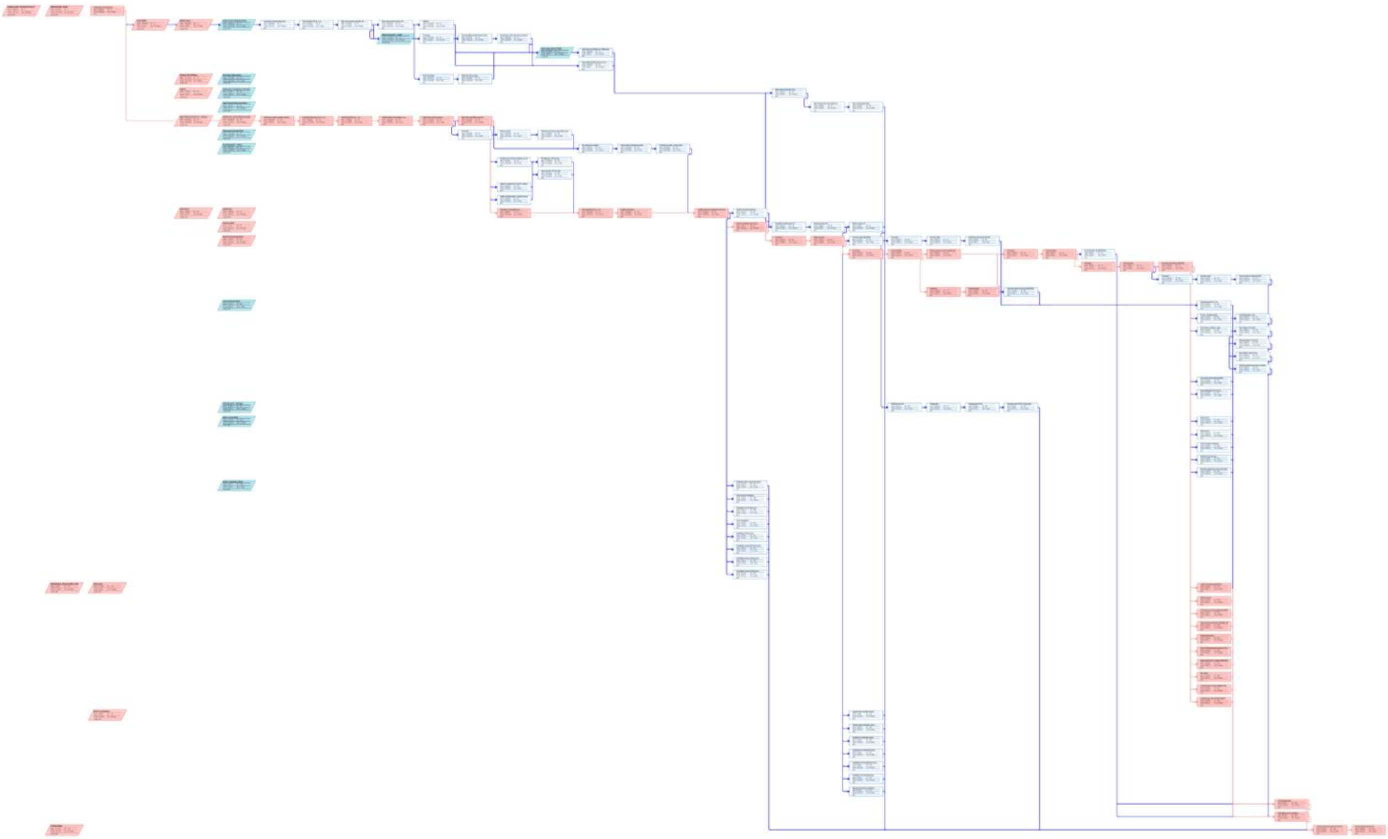
1.3.1.10	Transformator 315 kVA 400 V/20 kV	20 days	Mon 2/15/21	Sat 3/6/21	75	Yes	0 days	Mon 2/15/21	Mon 2/15/21	Sat 3/6/21	Sat 3/6/21	No	0.405%
1.3.2	**Electrical installation**	**40 days**	**Fri 2/5/21**	**Tue 3/16/21**		**Yes**	**0 days**	**Fri 2/5/21**	**Thu 2/25/21**	**Tue 3/16/21**	**Tue 3/16/21**		**3.576%**
1.3.2.1	Single Switch Installation Work	20 days	Fri 2/5/21	Wed 2/24/21	60	No	20 days	Fri 2/5/21	Thu 2/25/21	Wed 2/24/21	Tue 3/16/21	No	0.098%
1.3.2.2	Double Switch Installation Work	20 days	Fri 2/5/21	Wed 2/24/21	60	No	20 days	Fri 2/5/21	Thu 2/25/21	Wed 2/24/21	Tue 3/16/21	No	0.118%
1.3.2.3	Installation of 100-Watt Socket	20 days	Fri 2/5/21	Wed 2/24/21	60	No	20 days	Fri 2/5/21	Thu 2/25/21	Wed 2/24/21	Tue 3/16/21	No	0.059%
1.3.2.4	Installation of a 250-Watt Socket	20 days	Fri 2/5/21	Wed 2/24/21	60	No	20 days	Fri 2/5/21	Thu 2/25/21	Wed 2/24/21	Tue 3/16/21	No	0.059%
1.3.2.5	Installation of the 35-Watt XL lamp	20 days	Fri 2/5/21	Wed 2/24/21	60	No	20 days	Fri 2/5/21	Thu 2/25/21	Wed 2/24/21	Tue 3/16/21	No	0.512%
1.3.2.6	Installation of XL 14-Watt lamp	20 days	Fri 2/5/21	Wed 2/24/21	60	No	20 days	Fri 2/5/21	Thu 2/25/21	Wed 2/24/21	Tue 3/16/21	No	0.784%
1.3.2.7	Lightning Protection Installation	20 days	Fri 2/5/21	Wed 2/24/21	60	No	20 days	Fri 2/5/21	Thu 2/25/21	Wed 2/24/21	Tue 3/16/21	No	1.850%
1.3.2.8	LV Panel Mounting	10 days	Sun 3/7/21	Tue 3/16/21	120,117,118,119,121,122,123,124,125,126,101,102,103,104,105,72,78,85,87,89,90,91,92,93,94	Yes	0 days	Sun 3/7/21	Sun 3/7/21	Tue 3/16/21	Tue 3/16/21	No	0.083%

1.3.2.9	PHB Lighting Panel Installation	10 days	Sun 3/7/21	Tue 3/16/21	120,117,118,119,121,122,123,124,125,126,101,102,103,104,105,72,78,85,87,89,90,91,92,93,94	Yes	0 days	Sun 3/7/21	Sun 3/7/21	Tue 3/16/21	Tue 3/16/21	Yes	0.013%
1.4	**OTHER WORKS**	**15 days**	**Wed 3/17/21**	**Wed 3/31/21**		**Yes**	**0 days**	**Wed 3/17/21**	**Wed 3/17/21**	**Wed 3/31/21**	**Wed 3/31/21**		**2.588%**
1.4.1	Training, Commissioning Test and SLO	13 days	Wed 3/17/21	Mon 3/29/21	136,135,128,129,130,131,132,133,134,107,108,109,110,111,112,113,114,28,99	Yes	0 days	Wed 3/17/21	Wed 3/17/21	Mon 3/29/21	Mon 3/29/21	Yes	2.187%
1.4.2	Remote Monitoring System	2 days	Tue 3/30/21	Wed 3/31/21	138	Yes	0 days	Tue 3/30/21	Tue 3/30/21	Wed 3/31/21	Wed 3/31/21	Yes	0.400%

Appendix 5. Critical Path

An Activity Network Diagram is a diagram of project activities that shows the sequential relationships of activities using arrows and nodes. The diagram was made by using Microsoft Project. The critical path activities show in the red nodes in Figure 8.3.

Figure 8. 3 Critical Path Activities



Appendix 6. Project Evaluation Review Technique Table

Program Evaluation Review Technique (PERT) chart is a tool for estimating or forecasting project schedule. Microsoft Excel software helped to analyze the duration of project activities. The PERT method considers three-time estimates, which are optimistic duration (a), pessimistic duration (b), and most likely duration (m). Three-time estimates are the subjective judgment determined by the project manager based on his experience. Expected time duration, the variance, and its standard deviation were obtained by using the PERT formulas and shown in Table 8.3.

Table 8. 3 Project Evaluation and Review Technique Table

WBS	Task Name	Criti-cal Path	Cost (%)	Duration in the contract	Most Likely, *m* (day)	Optimist, *a* (day)	Pessimist, *b* (day)	Expected time	Variance of each activities
1	**POWER PLANT CONSTRUCTION (Total)**		**100%**	**184**	**173**	**144**	**244**	**180.05**	**19.722**
1.1	**PREPARATORY WORK**		**0.770%**	**25**	**25**	20	33	25.5	4.694
1.1.1	Mobilization demobilization	Yes	0.770%	25	25	20	33	25.5	4.694
1.2	**CIVIL WORK**		**85.552%**	**135**	**126**	**105**	**178**	**131.17**	**148.028**
1.2.1	**DAM & Intake**		**24.073%**	**77**	**77**	**59**	**102**	**78.19**	**51.361**
1.2.1.1	**Intake channel Building Works**		**2.349%**	**67**	**67**	**49**	**90**	**67.85**	**46.694**
1.2.1.1.1	Excavation of construction land	No	0.556%	15	15	11	20	15.17	2.250
1.2.1.1.2	Pile foundation 10 cm - 3 m	No	0.003%	7	7	5	10	7.17	0.694
1.2.1.1.3	River stone masonry channel 1:8	No	0.015%	15	15	11	20	15.17	2.250
1.2.1.1.4	River stone masonry stucco 1:8	No	1.475%	15	15	11	20	15.17	2.250
1.2.1.1.5	Gabions	No	0.300%	15	15	11	20	15.17	2.250
1.2.1.2	**Work of concrete + install**		**21.669%**	**30**	**30**	**24**	**39**	**30.51**	**6.250**
1.2.1.2.1	Floor of intake + pillar column K225	No	11.772%	10	10	8	13	10.17	0.694

1.2.1.2.2	Concrete Rebar (reinforcement steel)	No	6.735%	10	10	8	13	10.17	0.694
1.2.1.2.3	Formwork	No	3.162%	10	10	8	13	10.17	0.694
1.2.1.3	**Open Intake Channel Work**		**0.054%**	**10**	**10**	**8**	**13**	**10.17**	**0.694**
1.2.1.3.1	Intake door size (1500 mm x 2000 mm) x 2 pieces	No	0.046%	10	10	8	13	10.17	0.694
1.2.1.3.2	Coarse filter L 50.50.5 size 2 x 1.5 m	No	0.008%	10	10	8	13	10.17	0.694
1.2.2	**Settling Tank Building**		**0.020%**	**2**	**2**	**2**	**4**	**2.34**	**0.111**
1.2.2.1	**Roof work, Sluice Drain**		**0.020%**	**2**	**2**	**2**	**4**	**2.34**	**0.111**
1.2.2.1.1	Metal tile roof covering	No	0.019%	1	1	1	2	1.17	0.028
1.2.2.1.2	Roof tile rooftop	No	0.001%	1	1	1	2	1.17	0.028
1.2.3	**Tailrace**		**7.129%**	**45**	**45**	**33**	**60**	**45.51**	**20.250**
1.2.3.1	**Earthwork / Foundation / Concrete**		**0.936%**	**15**	**15**	**11**	**20**	**15.17**	**2.250**
1.2.3.1.1	Open channel minerals 1-2 m	No	0.936%	15	15	11	20	15.17	2.250
1.2.3.2	**Open Channel Work and others**		**6.193%**	**30**	**30**	**22**	**40**	**30.34**	**9**
1.2.3.2.1	Installation of open channel stone times	No	5.698%	15	15	11	20	15.17	2.250
1.2.3.2.2	Open channel plastering	No	0.495%	15	15	11	20	15.17	2.250
1.2.4	**Pipe Penstock (4x125 m) + Anchor block / saddle**		**10.819%**	**66**	**62**	**52**	**91**	**65.17**	**42.250**
1.2.4.1	**Earthwork / Concrete Block Foundation**		**1.007%**	**45**	**41**	**35**	**61**	**43.33**	**18.778**
1.2.4.1.1	Excavation of pipe foundation blocks	Yes	0.632%	15	15	11	20	15.17	2.250
1.2.4.1.2	Bored pile Foundation 20 cm - 3 m	Yes	0.008%	10	9	8	13	9.5	0.694
1.2.4.1.3	Pile Foundation 10 cm - 3 m	Yes	0.027%	2	2	2	3	2.17	0.028
1.2.4.1.4	Landfill under the foundation 5 cm	Yes	0.044%	1	1	1	2	1.17	0.028

1.2.4.1.5	Installation of empty stone couple	Yes	0.226%	2	2	2	3	2.17	0.028
1.2.4.1.6	Installation of River stone foundation	Yes	0.070%	15	12	11	20	13.17	2.250
1.2.4.2	**Reinforced Concrete Work**		**4.439%**	**10**	**10**	**9**	**14**	**10.51**	**0.694**
1.2.4.2.1	Reinforced concrete anchor block, concrete penstock K225	No	3.783%	5	5	4	7	5.17	0.250
1.2.4.2.2	Rebar concrete	No	0.225%	2	2	2	3	2.17	0.028
1.2.4.2.3	Formwork	No	0.431%	3	3	3	4	3.17	0.028
1.2.4.3	**Plumbing Work + Others**		**5.373%**	**21**	**21**	**17**	**30**	**21.83**	**4.694**
1.2.4.3.1	Pipe weld joint installed	No	0.483%	7	7	5	10	7.17	0.694
1.2.4.3.2	Anchor plate to block foundation	No	0.246%	7	7	6	10	7.33	0.444
1.2.4.3.3	Finishing iron paint + anchor plate	No	0.163%	7	7	6	10	7.33	0.444
1.2.4.3.4	Penstock, dia = 30"mm, thickness = 6,0 mm, total length 4 x 125 m	No	3.082%	7	7	6	10	7.33	0.444
1.2.4.3.5	Stiffener, material dia = DN 30", thickness = 6 mm	No	0.546%	2	2	2	3	2.17	0.028
1.2.4.3.6	Saddle including teflon / asphalt coating, armature and strap, dia 30"	No	0.082%	2	2	2	3	2.17	0.028
1.2.4.3.7	PVC pipe dia = 10" for drain	No	0.447%	1	1	1	2	1.17	0.028
1.2.4.3.8	Gate valve dia = 10"for drain	No	0.323%	1	1	1	2	1.17	0.028
1.2.5	**Powerhouse**		**43.512%**	**90**	**85**	**70**	**117**	**87.83**	**61.361**
1.2.5.1	**Earthworks**		**16.294%**	**49**	**47**	**39**	**61**	**48**	**13.444**
1.2.5.1.1	Excavation of soil foundation	Yes	2.794%	15	13	11	18	13.5	1.361
1.2.5.1.2	Pile foundation 10 cm - 3 m	Yes	0.301%	5	5	4	7	5.17	0.250
1.2.5.1.3	Landfill reclamation	Yes	0.053%	2	2	2	3	2.17	0.028
1.2.5.1.4	Landfill under the lane foundation	Yes	0.066%	2	2	2	3	2.17	0.028
1.2.5.1.5	Gabion (soil wall protection)	No	13.080%	25	25	20	30	25	2.778

1.2.5.2	**Installation Work**		**9.718%**	**45**	**42**	**35**	**57**	**43.34**	**13.444**
1.2.5.2.1	Installation of Empty stone 15 cm	Yes	0.404%	15	12	11	18	12.83	1.361
1.2.5.2.2	Installation of split stone 1:8	No	3.786%	10	10	8	13	10.17	0.694
1.2.5.2.3	Installation of brick 1:6	No	3.721%	10	10	8	13	10.17	0.694
1.2.5.2.4	Plaster mortar 1:6	No	1.806%	10	10	8	13	10.17	0.694
1.2.5.3	**Reinforced Concrete Work**		**13.139%**	**35**	**35**	**29**	**49**	**36.36**	**11.111**
1.2.5.3.1	Concrete sloof 20/30 K225	No	0.747%	5	5	4	7	5.17	0.250
1.2.5.3.2	Rebar concrete	Yes	0.408%	2	2	2	3	2.17	0.028
1.2.5.3.3	Formwork	Yes	0.632%	3	3	3	4	3.17	0.028
1.2.5.3.4	Practical column concrete 15/15 K225	No	0.079%	5	5	4	7	5.17	0.250
1.2.5.3.5	Concrete Rebar	Yes	0.088%	2	2	2	3	2.17	0.028
1.2.5.3.6	Formwork	Yes	0.082%	3	3	2	4	3	0.111
1.2.5.3.7	Concrete column structure 20/20 K225	No	0.310%	5	5	4	7	5.17	0.250
1.2.5.3.8	Concrete Rebar	Yes	0.205%	2	2	2	3	2.17	0.028
1.2.5.3.9	Formwork	Yes	0.241%	3	3	2	4	3	0.111
1.2.5.3.10	Concrete beam ring 20/30 K225	No	0.502%	5	5	4	7	5.17	0.250
1.2.5.3.11	Concrete Rebar	Yes	0.285%	2	2	2	3	2.17	0.028
1.2.5.3.12	Formwork	Yes	0.455%	3	3	2	4	3	0.111
1.2.5.3.13	Concrete beam gavel 15/20 K225	Yes	0.302%	5	5	4	7	5.17	0.250
1.2.5.3.14	Concrete rebar	Yes	0.154%	2	2	2	3	2.17	0.028
1.2.5.3.15	Formwork	Yes	0.313%	3	3	2	4	3	0.111
1.2.5.3.16	Concrete tail race+Channel K225	No	3.206%	5	5	4	7	5.17	0.250
1.2.5.3.17	Concrete rebar	No	1.066%	2	2	2	3	2.17	0.028
1.2.5.3.18	Formwork	No	0.703%	3	3	2	4	3	0.111
1.2.5.3.19	Rated Concrete around 10 K175	No	2.374%	5	5	4	7	5.17	0.250
1.2.5.3.20	Concrete rebar	No	0.887%	2	2	2	3	2.17	0.028

1.2.5.3.21	Formwork	No	0.100%	3	3	2	4	3	0.111
1.2.5.4	**Frame and Door Work**		**0.636%**	**7**	**7**	**6**	**10**	**7.33**	**0.444**
1.2.5.4.1	Plywood panel door 4 cm	No	0.056%	3	3	2	4	3	0.111
1.2.5.4.2	Frames + Window panels	No	0.119%	3	3	2	4	3	0.111
1.2.5.4.3	Install plain 5 mm glass	No	0.061%	3	3	2	4	3	0.111
1.2.5.4.4	Door frame + window + jalusi	No	0.038%	3	3	2	4	3	0.111
1.2.5.4.5	Door hinges 3"ex brand	No	0.015%	1	1	1	2	1.17	0.028
1.2.5.4.6	Window hinges 2"ex brand	No	0.013%	1	1	1	2	1.17	0.028
1.2.5.4.7	door handle + key ex cisco	No	0.002%	1	1	1	2	1.17	0.028
1.2.5.4.8	Window handle+wind hook ex lamskar	No	0.007%	1	1	1	2	1.17	0.028
1.2.5.4.9	Door panel+frame PVC km/toilet	No	0.008%	2	2	2	3	2.17	0.028
1.2.5.4.10	Steel rooling door 3 m x 2,5 m	No	0.317%	7	7	6	10	7.33	0.444
1.2.5.5	**Painting work + Drainage**		**0.595%**	**21**	**21**	**16**	**29**	**21.51**	**4.694**
1.2.5.5.1	Wall paint int.+ext.	No	0.461%	5	5	4	7	5.17	0.250
1.2.5.5.2	Ceiling paint	No	0.119%	5	5	4	7	5.17	0.250
1.2.5.5.3	Lisplang paint 25 cm	No	0.007%	5	5	3	7	5	0.444
1.2.5.5.4	rainwater drains PVC 2"+knee+glue	No	0.008%	6	6	5	8	6.17	0.250
1.2.5.6	**Roof + Cover Work**		**3.028%**	**10**	**10**	**8**	**13**	**10.17**	**0.694**
1.2.5.6.1	Stance work	No	0.221%	10	10	8	13	10.17	0.694
1.2.5.6.2	Stance work	No	0.336%	10	10	8	13	10.17	0.694
1.2.5.6.3	Class II wooden roof frame	No	0.952%	10	10	8	13	10.17	0.694
1.2.5.6.4	Metal tile roof covering	No	1.096%	10	10	8	13	10.17	0.694
1.2.5.6.5	Wooden ceiling frame class II 4/6 +fiber cement 4 mm	No	0.423%	10	10	8	13	10.17	0.694
1.2.5.7	**Utility / Installation Work**		**0.103%**	**7**	**7**	**6**	**10**	**7.33**	**0.444**

1.2.5.7.1	Infiltration well + septic tank 2x2x2	No	0.006%	7	7	6	10	7.33	0.444
1.2.5.7.2	Procurement of bathtubs	No	0.003%	3	3	2	4	3	0.111
1.2.5.7.3	Installation of 1/2"tub faucet	No	0.002%	1	1	1	2	1.17	0.028
1.2.5.7.4	Closet installation	No	0.009%	2	2	2	3	2.17	0.028
1.2.5.7.5	Installation of floor drain	No	0.001%	1	1	1	2	1.17	0.028
1.2.5.7.6	Installation of pipe 3/4"clean water	No	0.028%	1	1	1	2	1.17	0.028
1.2.5.7.7	Installation of pipe 2"dirty water	No	0.020%	1	1	1	2	1.17	0.028
1.2.5.7.8	Installation of pipe 3"dirty water	No	0.034%	1	1	1	2	1.17	0.028
1.3	**MECHANICAL AND ELECTRICAL WORKS**		**11.090%**	**40**	**38**	**32**	**55**	**39.85**	**14.694**
1.3.1	**Mechanical**		**7.514%**	**20**	**18**	**15**	**26**	**18.83**	**3.361**
1.3.1.1	Turbine (crossflow 4x250 kVA)	No	1.112%	20	18	15	26	18.83	3.361
1.3.1.2	Speed Increaser	No	3.235%	20	18	15	26	18.83	3.361
1.3.1.3	Generator (for hydro application) 380/440V max 2200 rpm, 50 Hz	No	1.213%	20	18	15	26	18.83	3.361
1.3.1.4	Electronic Flow Controller 230/400V, 300 kW, 50Hz	Yes	1.133%	20	18	15	26	18.83	3.361
1.3.1.5	Powerhouse wiring	No	0.092%	20	18	15	26	18.83	3.361
1.3.1.6	Hoist Crane Manual with capacity of 5 ton	No	0.022%	20	18	15	26	18.83	3.361
1.3.1.7	Digital Load Control + Ballast 50kW 230/400V 50Hz	No	0.143%	20	18	15	26	18.83	3.361
1.3.1.8	ME Toolkit	No	0.123%	20	18	15	26	18.83	3.361
1.3.1.9	Transformer PS 25 kvA 20kV/0,4 kV	No	0.037%	20	18	15	26	18.83	3.361
1.3.1.10	Transformer 315 kVA 400 V/20 kV	No	0.405%	20	18	15	26	18.83	3.361
1.3.2	**Electrical installation**		**3.576%**	**40**	**38**	**32**	**55**	**39.85**	**14.694**
1.3.2.1	Single Switch Installation Work	No	0.098%	20	20	15	26	20.17	3.361

1.3.2.2	Double Switch Installation Work	No	0.118%	20	20	15	26	20.17	3.361
1.3.2.3	Installation of 100 Watt Socket	No	0.059%	20	20	15	26	20.17	3.361
1.3.2.4	Installation of a 250 Watt Socket	No	0.059%	20	20	15	26	20.17	3.361
1.3.2.5	Installation of the 35 Watt XL lamp	No	0.512%	20	20	15	26	20.17	3.361
1.3.2.6	Installation of XL 14 Watt lamp	No	0.784%	20	20	15	26	20.17	3.361
1.3.2.7	Lightning Protection Installation	No	1.850%	20	20	15	26	20.17	3.361
1.3.2.8	LV Panel Mounting	Yes	0.083%	10	10	8	13	10.17	0.694
1.3.2.9	PHB Lighting Panel Installation	Yes	0.013%	10	10	8	13	10.17	0.694
1.4	**OTHER WORKS**		**2.588%**	**15**	**15**	**11**	**20**	**15.17**	**2.250**
1.4.1	Training, Commissioning Test and SLO	Yes	2.187%	13	13	9	17	13	1.778
1.4.2	Remote Monitoring System	Yes	0.400%	2	2	2	3	2.17	0.028