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Optimizing Time and Cost Efficiency in Delayed Construction Project Using Project Crashing Approach (A Case Study of a Geothermal Power Plant Operator in Indonesia)

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ABSTRACT: Electricity is a fundamental need that supports modern life across household, industries, and public sector. To ensure the sustainability of electricity in Java and Bali, PT GSE,a Geothermal Power Plant in Pengalengan, West Java, conduct a base structure replacement project for cooling tower which innitialy using the wooden base structure into the Fibre Reinforced Polymer (FRP). This project, known as Project X, was executed by PT XYZ as the EPC contractor. During the execution, cooling tower unit – 1 faced significant delay, posing financial and reputational risks. This research aims to identify the root causes of the delay, evaluate the losses, and proposed solutions for time and cost efficiency using the project crashing method. This research combine interview with key personnel and secondary company data. The critical path analysis conducted by using the Activity on Node (AON) approach, activity mapping using Precedence Diagram Method (PDM), and calculation for additional cost due to overtime conducted by using minimum wages (UMK) for Kabupaten Bandung in 2025. S Curve analysis shows 10 weeks of delay, mainly due to frequent bad weather that prevented outdoor activities according to the HSSE policies. Financially, if there is no corrective action to handle the delay, PT XYZ would be subjected to a project penalty of Rp 2.734.770.052, as stipulated in the cooperation contract with PT GSE. To anticipate the losses, the proposed solution is project crashing by conducting overtime to the critical path activites, which is safer dan more efficient comparing to adding new additional resources. The implementation of project crashing calculated need extra funding about Rp 399.544.839 which only 14,61% compared to the potential penalty sanction. Beyond the financial impact, this strategy also maintains client trust and strengthen future business opportunities.

KEYWORDS: Construction, Project Crashing, PLTP, Project Delay, Project Management, Overtime.

INTRODUCTION

Electric power currently being the most essential energy source in everyday human life. Nearly almost all of human activity rely on electricity. In 2020, the electric usage in Indonesia reach 242.113 GWh with the household sector as the biggest consumer (112.848 GWh), followed by industry sector (70.588 GWh), business sector (42.858 Gwh), social sector (7.819 GWh), government office buildings (4.469 GWh), dan public lighting (3.532 GWh) (RUPTL PT. PLN for 2021 – 2030). Futhermore, the increase in electric vehicle (EV) usage in Indonesia also contribute to the rising demand for electricity demand.

In Indonesia, the electricity distributed by PLN is generated by two types of power plant, which is non – renewable energy (Non – EBT) and renewable energy (EBT). However, 58% of total electricity generation in Indonesai still relies on coal as the generating primary fuel source (Alvanis et al., 2024). The non – renewable energy power plant has few negative impacts to the environment such as air pollution, and the coal as the fuel resource are become more scarce over time. To mitigate the negative impact from the usage of non – renewable energy power plants, Indonesian government has initiated effort to doing the transition from non – renewable energy power plants to renewable energy power plants, such as the utilization of geothermal power.

Indonesia located in the ring of fire area, which mean that Indonesia has lot of potetial resource for gethermal energy power plant. Indonesia has a potential of 28.5 GWh of geothermal energy potential which distribute to in 12 power plants around the country (Ridho Al – Hakim, 2020). One of the geothermal power plant operators in Indonesia is PT GSE, which located in Pengalengan, West Java. PT GSE has been supplying electricity to the Java – Bali grid since 2000. One of the crucial part of the geothermal powerplants is cooling tower, which play a role to maintain the condencer temperature ensuring the production of electricity uninterrupted. In PT GSE, there are two cooling towers that have been operating since 2000. Over time, PT. GSE assessed that mechanical integrity of

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cooling towers as a part of PLTP system has gradually weakened and required for maintenance and replacement. After bidding process, PT. GSE delegated PT. XYZ as EPC (Engineering, Procurement, and Construction) contractor to execute Project X untuk elakukan maintenance and replacement for the entire cooling towers.

Project X has a milestone to replace the structure of the cooling tower from previously using wooden material, then replaced with Fiber Reinforced Polymer (FRP). However, during the execution, the progress of Project X is facing a delay, leading to the push back in the completion schedule, which leads PT XYZ to the risk of penalty and reputational damage. If no corrective actions are taken, Project X may face further delay, which resulting in greater consequences.

To prevent such things as above mentioned, this research will focused on implement of project crashing to address the project delay faced by PT XYZ. As the research subject, this research will conduct in the Project X construction phase by adding resources, including labor and equipment in order to accelerate the project completion. This research will conduct mapping using Precedence Diagramming Method (PDM) to identifu the critical path with the work sequence. The interview with key person also conducted to gain expert judgement needed fot the crashing process. This research will compare the additional cost incurred for the project crashing with the potential penalty cost may faced by PT XYZ due to the project completion delay, along with the impact to the completion schedule of Project X. Due to the concern of Project X Project Manager, this research will only focused on the construction phase in Unit – 1 on the Cell A&E, D&H, C&G, B&F activities.

BUSINESS ISSUE EXPLORATION

A. Current Condition

Currently, Project X has reach week 38 of the project execution, as can seen at the S Curve above, but the actual progress is below the initial plan. The S Curve then can be converted to Gannt Chart to gain a deep understanding of current progress of the Project X. Below serve the Gannt Chart for Project X:

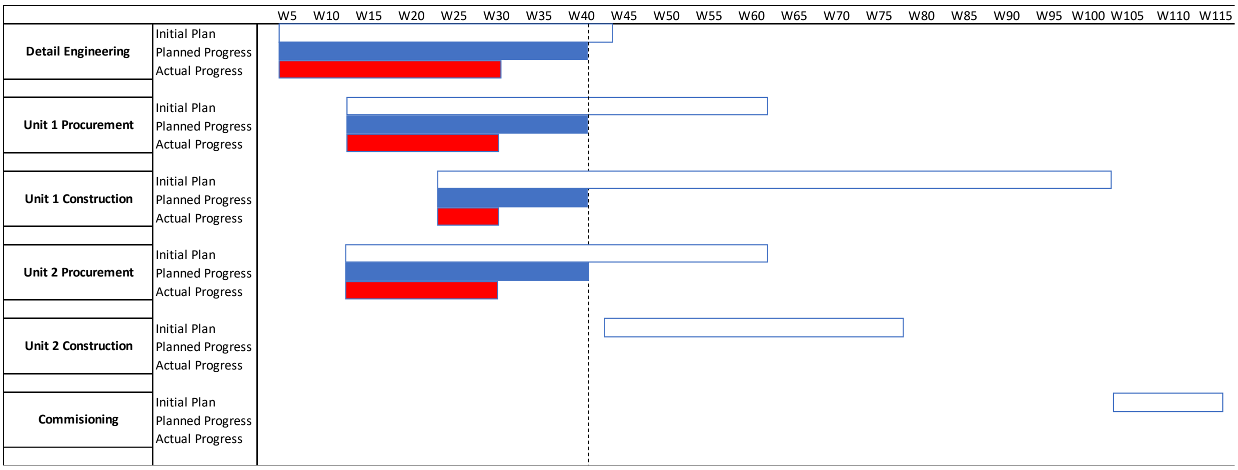

Figure 1. Project X Gannt Chart

The Gannt Chart above shows that current progress of Project X still equal to week 28 progress, while currently Project X has reach week 38 of project execution, which means that project X is 10 week behind the plan schedule. The analysis of current condition then conducted by projecting the impact of the delay project to the entire sequence of activities which require additional duration of project completions. Below shown the snippet of delay projection in Cell A&E of Project X and the planned progress for the comparison:

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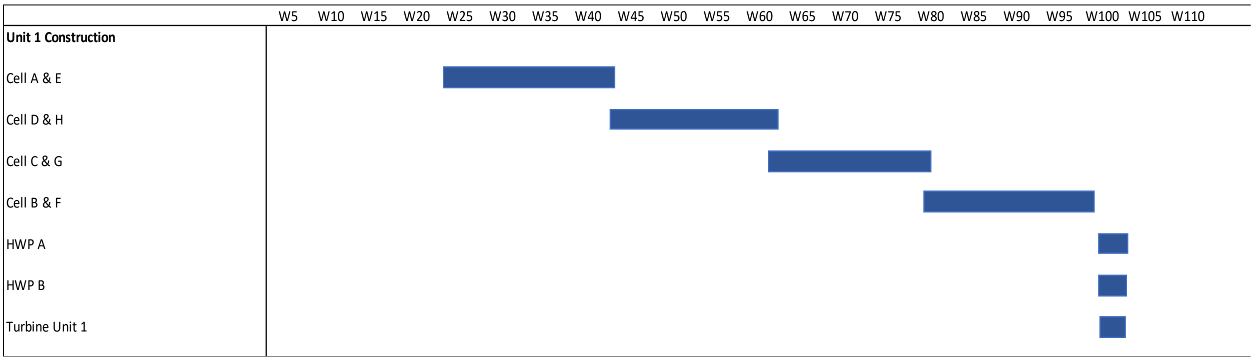

Figure 2. Initial Planned Progress for Cell A&E

Figure 3. Actual Progress and Projection for Cell A&E

The current progress is represented by the solid red bar, while the projected is represented with the hollow red bar. Based on the Gannt Chart above, it can be seen that at Week 38, the progress should be has reach "Install New Header, Distribution Pipe & Fill Pack, and Drift Eliminator" activity on Cell A&E. In actual, the progress still reach "Install FRP Structure" activity on Cell A&E, which clearly reflected the 10 week of project delay. Due to this delay, PT XYZ facing potential financial loss of around Rp Rp 2.734.770.052 based on the agreed working contract which state the formula of penalty calculatin as follows:

$$Penalty = \Sigma\, delayed\ days\ x\ 0{,}1\%\ x\ Project\ Value$$

This amount of financial loss will occur if there are no any corrective action to recover from the project delay. Thus, the strategy development proposed to prevent this penalty fees will be elaborated in the business solution section. To gain deep understanding according to the Project X current situation, author will serves the delay activity sequence mapping using PDM (Presedence Diagram Method) as shown below:

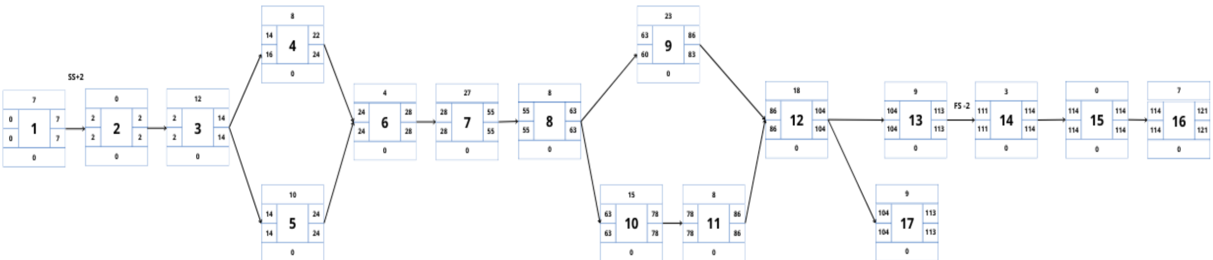

Figure 4. PDM for delay Cell A&E, D&H, C&G,B&F Before Crashed

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B. Research Framework

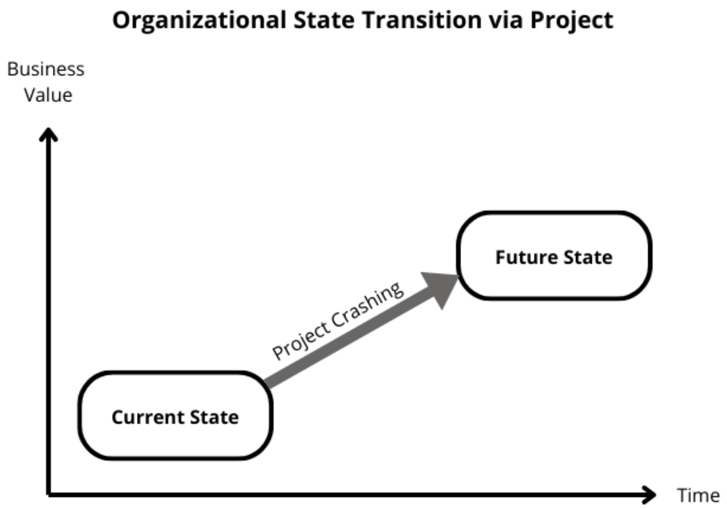

Figure 5. Research Framework
Source: (Project Management Institute, 2017)

This research framework represents the relation between current state, proposed method, and future state after intervention conducted. This framework serves as the conceptual guide that outline the strategic direction and methodologies applied to resolve the delayed project of Project X.

Current State represents the current condition of the business or company. Currently, the condition of work progress of Project X, which is held by PT. XYZ faces a delay of 35,66% which is calculated by comparing the actual progress with Project X's initial progress plan. If acceleration is not implemented, there will be a penalty based on the working contract that state there would be a penalty of 0,1% per day from the project value with a maximal penalty of 20% from the project value, which is PT. XYZ will face liquidated damage of $ 172.464,53 or Rp 2.734.770.052 with the assumption that the current exchange rate is Rp 15.875 per US Dollar. Moreover, the reputation of PT. XYZ also at stake in front of the client through Project X. The delay of Project X significantly impacts PT. XYZ future business opportunit y, which will inevitably decline due to the damaged reputation caused by the delay of Project X.

The arrow with the "Project" mark on it represents the method used to achieve the future state. Through this research, the authour intends to propose improvements to the project by doing project crashing. This proposed solution is carried out by doing an analysis of the project work sequence and doing a discussion with the project manager and project controller of Project X regarding the tasks that can have their work system changed from a sequential (series) process to a parallel process to make the project more efficient. Moreover, the author also intends to propose additional resources, either human resources or equipment to accelerate the progress of the project's current progress.

The Future State represents the expected result from the arrow with "Project" mark on it, expecting a positive outcome from the project compared to the current state. In the future state, the author is projecting that the work progress will realign with the schedule outlined in the initial plan, allowing PT. XYZ to complete Project X within the agreed timeframe. It is expected that PT XYZ can be safeguarded from potential liquidated damage that may be incurred due to delayed project. Proposed additional resources are also expected to accelerate the progress of Project X, potentially enabling its completion ahead of the initial plan. Besides avoiding penalties, this acceleration aims to make a positive and satisfactory impression on the client regarding the execution of project X. The acceleration of this project is expected to increase the business value of Project X over time.

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C. Research Method

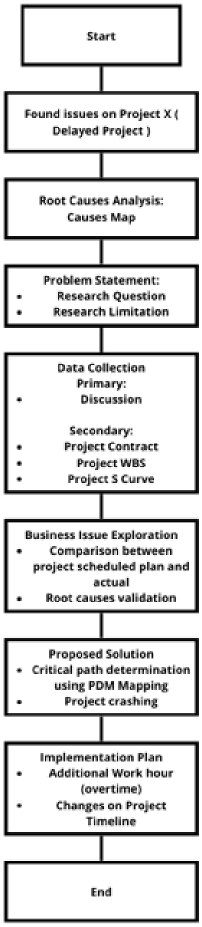

Figure 6. Research Methodology

This research starts with the discussion regarding to the information and introduction about the company, then followed by the discussion about the issues faced by PT XYZ. Estimate of root causes then conducted in order to create a mapping of the root causes which caused the problem using causes map analysis. The issues that discussed previously then adapted into questions, limitations, and objectives which used for this research. The discussion conducted is then supported with the supporting data needed will be used to carry out this research. Next, based on the results of the discussion, the progress can be compared between the initial project plan and its actual progress so far. This comparison then serves as the problem basis for this research. Moreover, the discussion includes the validation of root cause that have been made previously. After identifying the root cause of the problem, several solutions will be proposed to address the issues faced by the company. Ultimately, an implementation plan will be presented to PT XYZ.

D. Data Collection Method

Data used in this research are divided into two types of data, which is primary and secondary. Primary data was collected by doing face to face discussion with three key people who considered having a significant role and responsibility in project management for Project X. These three persons are the project manager, the project controller, and the project estimator.

Below shown several questions raised and discussed with the key people in order to gather information for this research:

1. What is the root cause of the delay in completing this project?
2. How does the project completion delay impact to PT XYZ?
3. What are the penalty provisions imposed by the client regarding the delay in project completion? Is there a maximum limit?

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4. What acceleration options have been planned and implemented? How effective have these acceleration measures been?
5. How does the addition of working hour influence the project completion time?
6. How many workers are currently assigned to each activity?
7. What is the expected crashing target for each activity?

Apart from the discussion data, secondary data also used to support this research, such as:

1. Project Contract, to have a deep understanding regarding of the work agreement approve by client and contractor.
2. Work Breakdown Structure (WBS), to review the work packages and task list to be done in the project.
3. Project S Curve, to have a deep understanding regarding the project's work sequences. These data will then be used as a basis to implementing project crashing to accelerate the project completion.
4. Data regarding Employee Minimum Wage (UMK) 2025 for Kabupaten Bandung.

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E. Data Analysis Method

Data analysis method will be conducted by comparing the current progress to the innitial plan progress using the S Curve diagram. The gap between those two condition then identifies as the calculate potential project delays. Below serves the S Curve used to comparing the initial project plan with the actual condition:

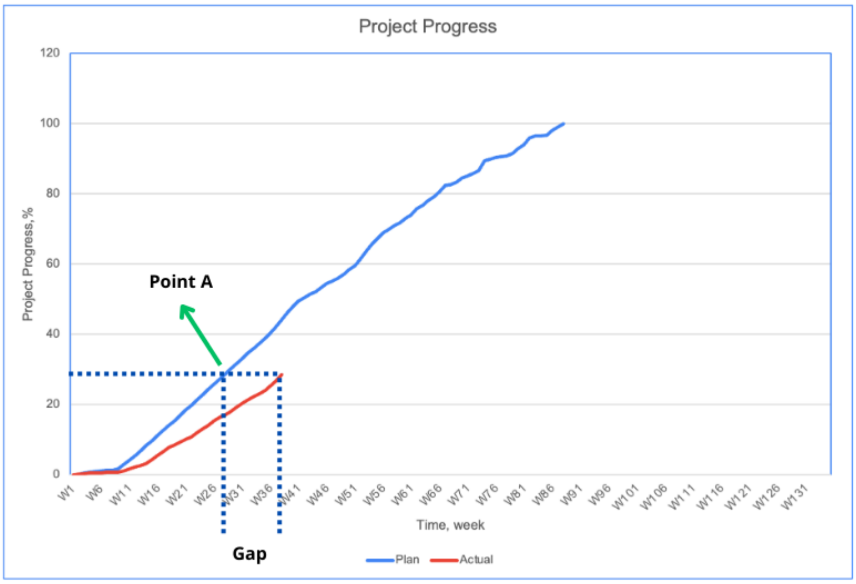

Figure 7. Gap Calculation Illustration

The sum of days of project delay can be calculated by drawing a horizontal line at the actual progress point and intersecting it with the line of planned progress towards the Y-axis. After the intersection point is defined, an imaginary vertical line is drawn toward the X-axis until the line intersects with the X-axis, which represents the time in week unit. The intersection point between the X-axis and the imaginary line can be defined as point A.

After the potential losses and the sum of potential delayed, the next step is to analyze the project's WBS and work sequences. The task lists then can be arranged according to its sequences using the Activity on Nodes (AON) method. The AON method is used because it is considered easier to understand because AON does not require dummy activity nodes to define the relation between each activity. This simplifies the process of applying the Critical Path Analysis in order to crash the project using PDM Mapping. After all of the task lists have been arranged according to it sequences by using AON, then the author will hold a discussion with the project manager regarding the work sequence efficiency. Some of the key points to be discussed include:

1. Tasks that can be performed in parallel with another task
2. Task that the execution can be accelerated

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3. Number of workers assigned to each activity
4. Expected acceleration (time reduction) for each activity

After all of the necessary data was collected and new PDM or activity sequence has beed determined, the next step is to calcute the additional cost needed due to overtime implemented in project crashing, The basis of the calculation is by using the worker basic salary (UMK) for Kabupaten Bandung in 2025. By using the rate of UMK 2025, the hourly rate for the worker can be determined as follow:

Hourly Rate		
UMK Kab. Bandung 2025	3.757.284,86	Rupiah
Daily Rate	150.291,39	Rupiah
Working Hour / day	8,00	Hour/day
Hourly Rate	18.786,42	Rupiah

Figure 8. Hourly Rate Calculation

After determining the workers' hourly wage, the next step was to identify the number of workers assigned to each activity, along with the normal and crashed durations. This information is essential for calculating the total man-hours required to achieve the targeted acceleration. The data regarding manpower allocation and duration targets were obtained through discussions with key personnel from Project X. The calculation of the required man-hour is outlined below:

Additional Required Working Hour After Crashed		
Worker	X	Man
Duration Before Crashed	X	Days
	-	Hours
Duration After Crashed	X	Days
Total Manhour Before Crashed	-	Manhour
Total Working Hour Required per Day After Crashed	-	Hours/day
Additional Working Hour Required After Crashed	-	Hours/day
Total Overtime Manhour per day	-	Manhour/day
Total Overall Overtime Manhour	-	Manhour

Figure 9. Additional Required Working Hour after Crashed Calculation

After identifying the additional man-hours required, the calculation was adjusted to comply with the applicable government regulations. The man-hour calculation was divided into two categories: the first overtime hour and the subsequent hours. For instance, if 3 hours of overtime are applied, the first hour is calculated separately from the remaining two hours, following the regulated overtime rate structure. An illustration of both calculation schemes is provided below:

Total Manhour per Day (1st Hour)		
Manpower	X	Man
Working Hour/day	1,00	Hours/day
Working Duration	X	Days
Total Manhour Required	-	Manhours

Figure 10. Total Man Hour per Day (1st Hour) Calculation

Total Manhour per Day (2nd Hour,3rd Hour,.....)		
Manpower	X	Man
Working Hour/day	-	Hours/day
Working Duration	X	Days
Total Manhour Required	-	Manhours

Figure 11. Total Man Hour per Day (Subsequent Hours) Calculation

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After the overtime rate has been defined, the result will be summed to determine the total cost required to perform overtime for each activity per cell. Below is the method used to calculate the total overtime rate per activity per single cell:

Total Overtime Rate		
1st Hour Overtime Rate	-	Rupiah
2nd & 3rd Overtime Rate	-	Rupiah
Total Additional Manhour	-	Manhour
Total Overtime Rate	-	Rupiah
	-	Dollar

Figure 12. Total Overtime Rate Calculation

After the total overtime rate was determined, the cost was multiplied by the number of cells being crashed. Although the cooling tower consists of four cells, some activities had already been completed on Cell A&E, so certain overtime costs were only multiplied by three for the remaining cells. Once the overtime costs for each activity were calculated, the activities were compiled and sorted based on their Cost per Unit Time, from the lowest to the highest. The value of Cost per Unit Time can be determined using the equation below:

$$\Delta = (CC - NC)/(NT - CT)$$

Where:
Δ : Cost per Unit Time
CC : Crashed Cost (Rupiah)
NC : Normal Cost (Rupiah)
NT : Normal Time (Days)
CT : Crashed Time (Days)

Once the value of Cost per Unit Time has been determined, the activity list can be sorted based on the value of Cost per Unit Time from the lowest to the highest. This approach aligns with the basic fundamental of project crashing, which is to accelerate the project completion with the lowest cost possible, while achieving the maximum reduction of project duration.

BUSINESS SOLUTION

In this business solution, the author will provide the solution to minimize the financial and reputational risk due to the project delay. The solution will be devided into several steps and ultimately the calculation of the additional cost for the overtime.

1. **Analyze the activity sequence**
   The activity sequence will be analyzed to determine which activities choosen to be crashed. This process require expert judgement, which in this case is by conducting interview with the Project Manager and Project Control of the Project X. Expert judgement needed to determine which activity is the most possible to be crashed and also determine the crash duration based on their experiences. In this step, total of workers for every activity also will be determine based on the project plan. The data of workers needed to ultimately calculating the additional overtime cost to prevent major losses. After the data of crash duration and worker amount obtained, the activities then sorted by the Cost per Unit Time. This action based on the main principle of project crashing, which is to gain the maximal result by the minimal effort. Below serve the list activities which choosen to be crashed, along with its duration:

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Activity	Description	Normal Duration per Cell (Days)	Duration After Crashed	Total Time Saved per Cell	Total Time Saved Overall	Description
1	Set up Scaffolding	7	7	-	-	Not Crashed
2	Shutdown	0	0	-	-	Not Crashed
3	Dismantle Cable Tray & Instrument	12	8	4	12	Crashed
4	Remove Fan, Motor & Equipments	8	6	2	6	Crashed
5	Remove Header, Distribution Pipe & Fill Pack, Drift Eliminator	10	7	3	9	Crashed
6	Remove Wooden Structure	4	4	-	-	Not Crashed
7	Install FRP Structure & Inspection	27	22	5	15	Crashed
8	Install New Top Deck Platform	8	6	2	8	Crashed
9	Install New Partition Wall, Clading & Drift Eliminator	23	20	3	12	Crashed
10	Install New Fan, Motor & Equipments	15	13	2	8	Crashed
11	Fan Motor Alignment	8	7	1	4	Crashed
12	Install New Header, Distribution Pipe & Fill Pack, and Drift Eliminator	18	18	-	-	Not Crashed
13	Install Cable Tray & Instrument	9	7	2	8	Crashed
14	Megger Cable Test	3	2	1	4	Crashed
15	Startup	-	-	-	-	Not Crashed
16	Final Inspection & Commissioning	7	5	2	8	Crashed

Figure 13. Activities List and Duration after Crashing Conducted

This step is not the crashing step, this step only gives references to the activity list and its crash possibility. The outcome of this step is the list of each activity following the crashed duration and the option between crashed or not crashed based on the Cost per Unit Time calculation. The activities which choosed to be crashed usually has the low cost of Cost per Unit time with a long crash duration. Due to the similar activies for every four cells, the calculation will only conducted once and being the refrence and guidance for the other cells.

2. **Crashing the activities**

This step provide the project sequence after crashing based on the calculation conducted and sorted activity in the previous step. After crashing, the activities of every cell will be having a same duration due to the similarity of the tasks. Below serves the PDM after the work sequence have been crashed:

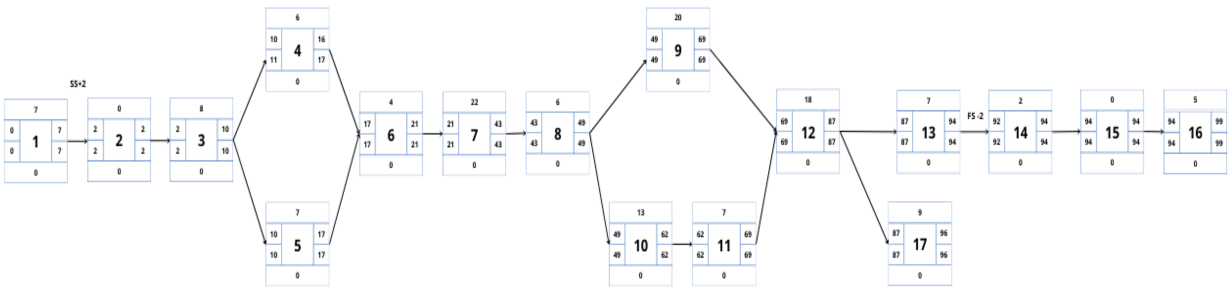

Figure 14. PDM Mapping After Crashed per Cell

As can be seen at the figure above, total duration of the work sequences reduce from before 121 days into 99 days after crashing. After implementing the new activities duration to every each cell, the result is the project is able to accelerate for

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12 weeks, which mean its 2 weeks more early that the plan schedule. Below serves the Gannt Chart of the project activities after crashed:

Figure 15. Gannt Chart of Unit – 1 after Crashed

From the Gannt Chart above, it can be seen that after project crashing implemented, Unit – 1 predicted to be completed in week – 99, whereas it was originally predicted to be completed by week – 111 due to the project delay.

3. Calculating the additional cost for overtime

After determining the crashed activities and projecting the crashing result, the additional cost for overtime will be calculated. The basis of the overtime calculation is refers to Minister of Manpower Regulation (Permenaker) Article 3 No. 102 of 2004 which elaborate the rules of overtime calculation as follow:

Table 1. Rules of Overtime Calculation

Overtime	Formula
First Hour in Workday	1,5 x Hourly Rate
2nd Hour and Onward in Workday	2 x Hourly Rate

Moreover, the basis of the overtime calculation also refers to the Minimum Wage (UMK) of Kabupaten Bandung in 2025. After all of the data needed have been gained, the calculation of overtime rate will be conducted. Below shows the example of overtime calculation in the "Dismantle Cable Tray & Instrument" activity:

Hourly Rate		
UMK Kab. Bandung 2025	3.757.284,86	Rupiah
Daily Rate	150.291,39	Rupiah
Working Hour / day	8,00	Hour/day
Hourly Rate	18.786,42	Rupiah

Figure 16. Hourly Rate Calculation

Hourly rate gained from dividing the UMK Kab bandung with 200 working hour a month. This hourly rate provide the basis hourly rate for each worker. The next step is to calculate the additional required working hour after crashed as shown at the figure below:

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Additional Required Working Hour After Crashed		
Worker	10,00	Man
Duration Before Crashed	12,00	Days
	96,00	Hours
Duration After Crashed	8,00	Days
Total Manhour Before Crashed	960,00	Manhour
Total Working Hour Required per Day After Crashed	12,00	Hours/day
Additional Working Hour Required After Crashed	4,00	Hours/day
Total Overtime Manhour per day	40,00	Manhour/day
Total Additional Overtime Manhour	320,00	Manhour

Figure 17. Additional Required Working Hour After Crashed Calculation

The amount of worker obtained from interview with the Project Manager and Project Controller of Project X, along with the duration after crashed. Total working hour required per day after crashed means the required duration of working hour per day after crashed, gained by adding normal 8 hours of working hour by the additional overtime 4 hours. Overtime manhour per day gained by multiplying the additional overtime with total of worker to gain the total additional overtime man hour. After additional overtime manhour has been determined, the next step is to divide the manhour calculation based on the Permenaker's rule as shown below:

Total Manhour Required (1st Hour)		
Manpower	10,00	Man
Working Hour/day	1,00	Hours/day
Working Duration	8,00	Days
Total Manhour Required	80,00	Manhours

Total Manhour Required (2nd Hour,3rd Hour,.....)		
Manpower	10,00	Man
Working Hour/day	3,00	Hours/day
Working Duration	8,00	Days
Total Manhour Required	240,00	Manhours

Figure 18. Calculation of Manhour

The calculation of manhour required divided based on the Permenaker's rules as mentioned before. Due to this activity requires 4 hours of overtime per day, then the calculation divided into 2 section, the 1st hour and the subsequent hours due to the differentiation of overtime rate calculation as shown below:

1st Hour Overtime Rate		
Weight Factor	1,50	x
Hourly Rate	18.786,42	Rupiah
Total Manhour Required	80,00	Manhours
Overtime Rate	2.254.370,92	Rupiah

2nd & 3rd Hour Overtime Rate		
Weight Factor	2,00	x
Hourly Rate	18.786,42	Rupiah
Total Manhour Required	240,00	Manhours
Overtime Rate	9.017.483,66	Rupiah

Figure 19. Calculation of Overtime Rate

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For the 1st hour, the calculation is using the weight factor of 1,5, which mean that the result of hourly rate multiply by the total manhour required need to multiplied by 1,5 to gain the total overtime rate for the 1st hour. This rules also implemented into the calculation of overtime rate for subsequent hours. Ultimately, after the overtime rate has been calculated, the total of overtime rate for one activity for each cell can be calculated as shown below:

Total Overtime Rate		
1st Hour Overtime Rate	2.254.370,92	Rupiah
2nd & 3rd Overtime Rate	9.017.483,66	Rupiah
Total Additional Manhour	320,00	Manhour
Total Overtime Rate	11.271.854,58	Rupiah
	683,14	Dollar

Figure 20. Calculation of Total Overtime Rate

This calculation is only calculated 1 activity for each cell, which means all of the activities that required to be crashed need to be calculated using the same method. Moreover, due to this calculation only calculated for one cell and Unit – 1 consist of 4 cells, the result of total overtime rate need to be multiplied by 4 to gain the total rate for all cells. Below serves the total calculation for all of the cells:

Activity	Description	Current Personnel per Cell (Man)	Normal Duration per Cell (Days)	Crashed Duration per Cell (Days)	Time Saved per Cell (Days)	Total Time Saved per Cell (Days)	Total Additional Manhour Required (Manhour)	Additional Overtime Required per Man per Day (Hours)	Total Overtime per Man per Man along Activity (Hours)	Overtime Meal Allowance (IDR)	Total Overtime Rate per Cell (IDR)	Total Overtime Rate per Cell after Allowance (IDR)	Cost per Unit Time (IDR)	Crashing Cost per Cell per Day (IDR)	Total Crashing Cost for 4 Cells (IDR)
14	Megger Cable Test	5	3	2	1	4	40,00	4,00	8,00	Rp 125.000,00	Rp 1.408.982	Rp 1.658.982	Rp 6.635.927	Rp 829.491	Rp 6.635.927
3	Dismantle Cable Tray & Instrument	10	12	8	4	12	320,00	4,00	32,00	Rp 250.000,00	Rp 11.271.855	Rp 13.271.855	Rp 9.953.891	Rp 1.658.982	Rp 39.815.564
16	Final Inspection & Commissioning	8	7	5	2	8	128,00	3,20	16,00	Rp 200.000,00	Rp 4.433.596	Rp 5.433.596	Rp 10.867.192	Rp 1.086.719	Rp 21.734.385
5	Remove Header, Distribution Pipe & Fill Pack, Drift Eliminator	12	10	7	3	9	288,00	3,43	24,00	Rp 300.000,00	Rp 10.031.951	Rp 12.131.951	Rp 12.131.951	Rp 1.733.136	Rp 36.395.852
4	Remove Fan, Motor & Equipments	12	8	6	2	6	192,00	2,67	16,00	Rp 300.000,00	Rp 6.537.676	Rp 8.337.676	Rp 12.506.513	Rp 1.389.613	Rp 25.013.027
11	Fan Motor Alignment	8	8	7	1	4	64,00	1,14	8,00	Rp 200.000,00	Rp 1.878.642	Rp 3.278.642	Rp 13.114.570	Rp 468.377	Rp 13.114.570
7	Install FRP Structure & Inspection	12	27	22	5	15	480,00	1,82	40,00	Rp 300.000,00	Rp 15.555.159	Rp 22.155.159	Rp 13.293.096	Rp 1.007.053	Rp 66.465.478
13	Install Cable Tray & Instrument	10	9	7	2	8	160,00	2,29	16,00	Rp 250.000,00	Rp 5.354.131	Rp 7.104.131	Rp 14.208.262	Rp 1.014.876	Rp 28.416.524
8	Install New Top Deck Platform	12	8	6	2	8	192,00	2,67	16,00	Rp 300.000,00	Rp 6.537.676	Rp 8.337.676	Rp 16.675.351	Rp 1.389.613	Rp 33.350.703
9	Install New Partition Wall, Clading & Drift Eliminator	12	23	20	3	12	288,00	1,20	24,00	Rp 300.000,00	Rp 8.566.609	Rp 14.566.609	Rp 19.422.146	Rp 728.330	Rp 58.266.438
10	Install New Fan, Motor & Equipments	16	15	13	2	8	256,00	1,23	16,00	Rp 400.000,00	Rp 7.664.861	Rp 17.584.093	Rp 35.168.186	Rp 1.352.623	Rp 70.336.373

Figure 21. Calculation of Total Overtime Rate

Table served above shows the overtime rate calculation of the required activities for crashing all of 4 cells. The result of total overtime cost required is Rp 399.544.839. The next section is to compare the crashing cost with the potential penalty cost.

4. **Comparing the additional overtime cost with the potential penalty cost**

The previous section has been calculated the overtime cost required to crash the project for Rp 399.544.839. Then the comparison of additional overtime cost with the potential penalty cost is needed to shows the effectivity of the project crashing to solve the problem faced by Project X. Below shows the table which provide the comparison:

Table 2. Comparison of Additional Cost and Potential Penalty

Total Overtime Cost Required	Potential Penalty
Rp 399.544.839	Rp 2.734.770.052
1	6,845

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From the comparison table above, it can be conclude that total overtime cost required only cost around 14,61% of the potential penalty faced by PT XYZ if there are no corrective action taken.

IMPLEMENTATION PLAN

This section explains how the business solution that was elaborated previously can be implemented in the project X. Moreover, it can also be elaborated the impact of this implementation to the completion time of the project X and the cost comparation between the cost needed for crashing the project and the potential cost needed that PT XYZ need to spend due to the penalty fees regarding to the project delay if project crashing were not carried out. In the business solution, it stated that the crashing implementation results in a project accelerations of 12 weeks, which mean it exceeds the defined target of 10 weeks. The outcome of this crashing can be observed in the Gantt chart below:

Figure 22. Gannt Chart After Crashing Conducted

The figure above is the Gantt Chart showing the result of project crashing implementation in Construction Unit – 1. Compared to the initial Gantt chart regarding to the delay projection, it can be seen that the schedule has been accelerate for 12 weeks. This improvement is indicated by the fact that in the delay projection Gantt Chart, the completion of HWP A, HWP B, and Turbine Unit – 1 predicted to be done in Week – 111 due to the delayed activities. After the crashing is conducted, HWP A, HWP B, and Turbine Unit – 1are now projected to be done in week – 99. As mentioned before, the crashing only conducted at Cell A&E, Cell D&H, Cell C&G, and Cell B&F. The following figures presents a detailed breakdown of the project crashing implementation for each cells:

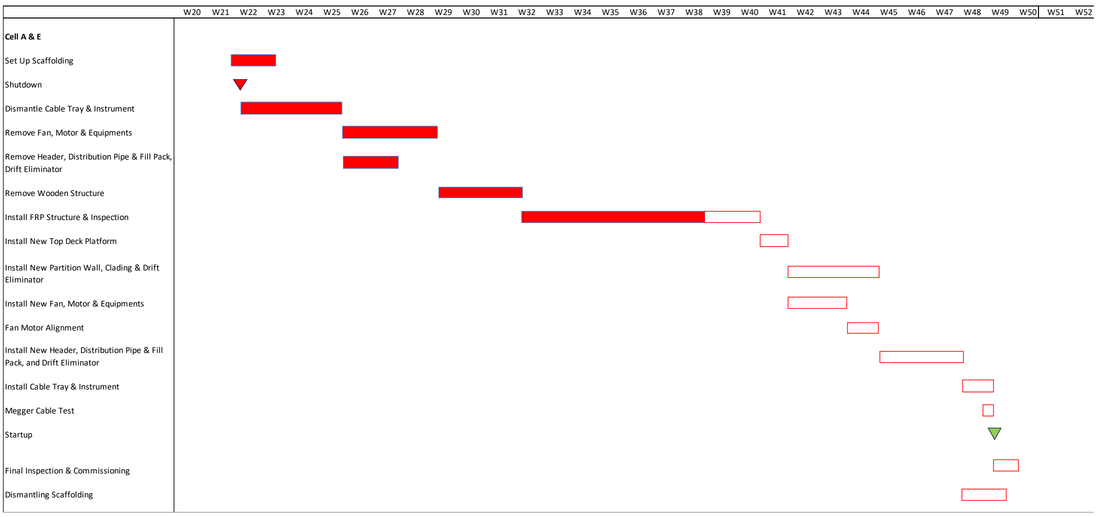

Figure 23. Implementation of Project Crashing at Cell A&E

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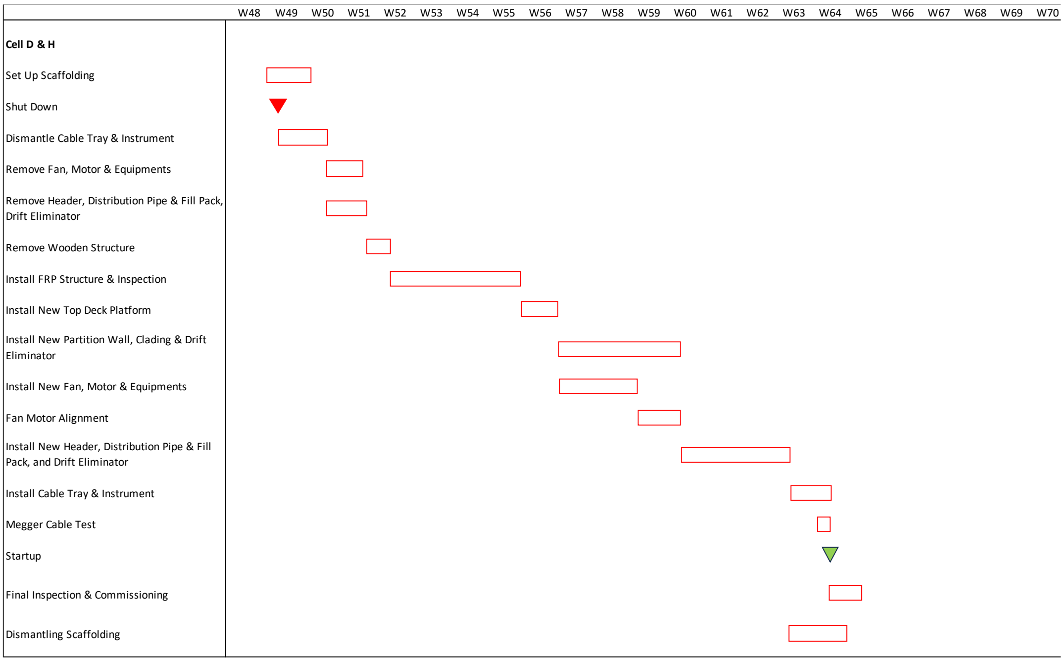

Figure 24. Implementation of Project Crashing at Cell D&H

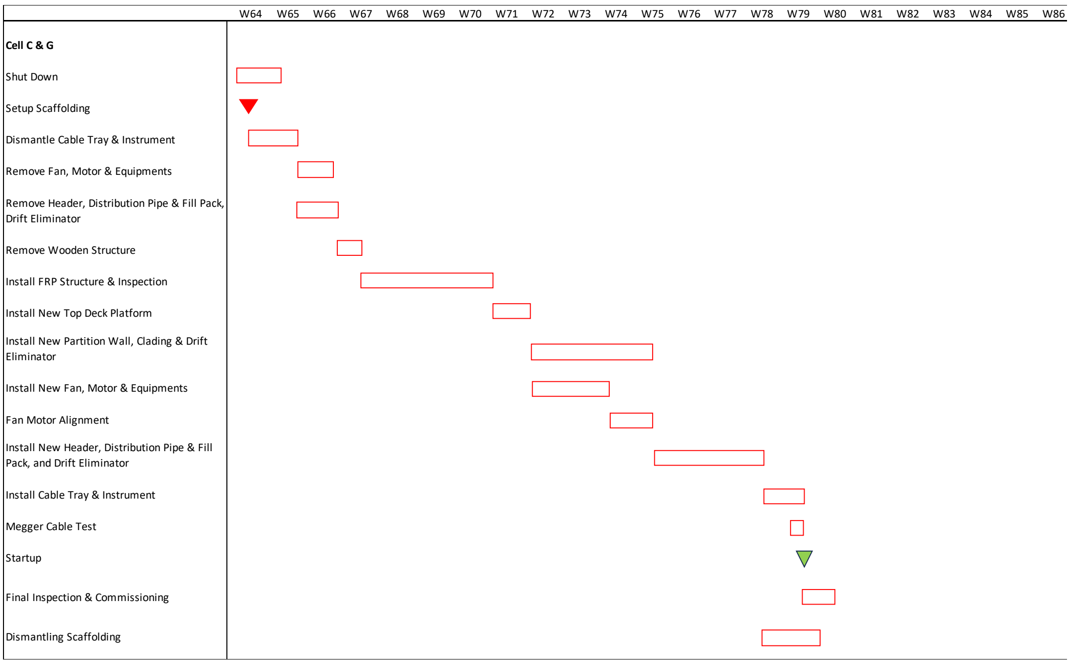

Figure 25. Implementation of Project Crashing at Cell C&G

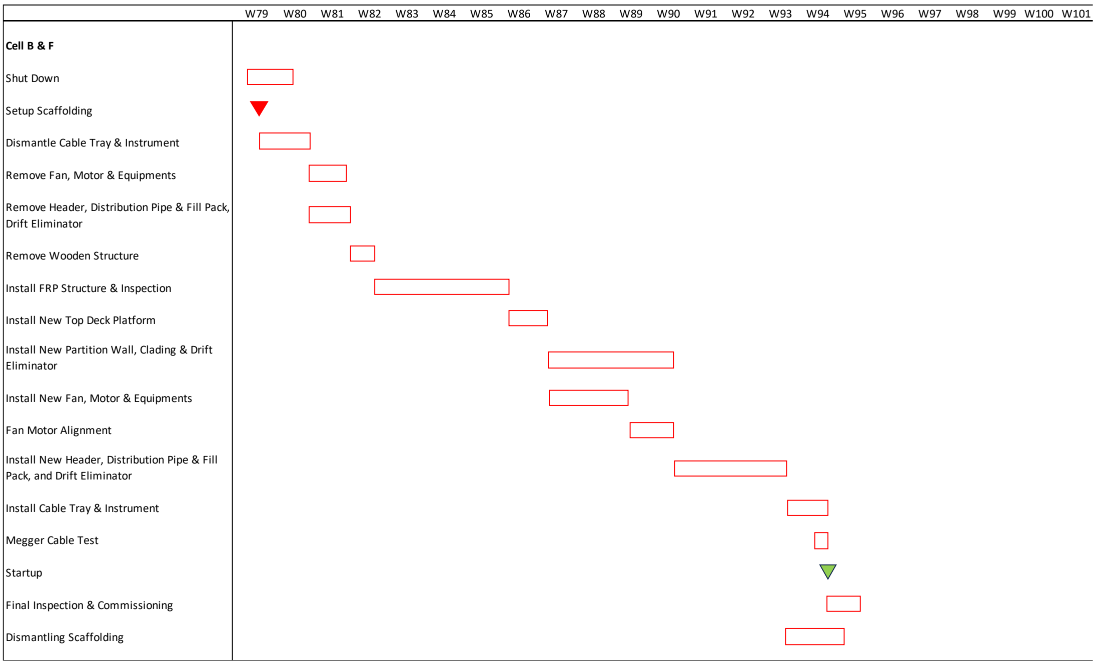

Figure 26. Implementation of Project Crashing at Cell B&F

If it calculated in percentage, the crashing cost required to accelerate the project by 12 weeks amounts only 14,61% compared to the penalty cost faced by PT XYZ if project crashing is not conducted. Moreover, with an expenditure of Rp 399.544.839, PT XYZ has save its reputation among of the clients by completing the project on time, or even earlier. This also provides a long term advantages for PT XYZ, particularly in terms of gaining easier access to the future project.

There are several things that need to be prepared before implementing this project crashing plan, which are:

- The company needs to carefully monitor the cash flow projection to determine whether it has sufficient funds to conduct the project crashing.
- Conduct review regarding to the safety during overtime and identify if there are any new potential risk due to the overtime activity.
- Develop a plan to enhance Healthy, Safety, Security, and Environment (HSSE) supervision during overtime activity.
- Develop a strategy to conduct evaluation regarding to the project crashing effectiveness.

If the aspects above have prepared by the company, then the project crashing implementation of the Project X can be executed accordance with the proposed plan. However, it is important to emphasize that there are uncontrollable external factor that may cause disturbance in the project crashing implementation to be conducted as plan, such as frequently bad weather conditions which frequently occur in the site. Therefore, it is considered necessary to allocate time and cost buffer to minimized the risk of delay beyond the projected timeline.

CONCLUSION

The conclusion of this research need to answer the research question. Thus, below served the conclusions of this research following with the research question:

Research Question 1: *What are the causes of the delays in completing Project X that have led to financial losses for the company?*

Based on the analysis conducted and the interview with the Project Manager, the main cause of this project delay is the bad weather that occurs frequently during the Unit – 1 construction. The bad weather occurs during the Unit – 1 construction significantly delayed the progress of the project's progress due to the company's safety regulation which state that it is prohibited for any outdoor activity during the bad weather. Such bad weather often lasted for extended periods. For example, the heavy rain occurs from 9 a.m. until 1 p.m., which caused the daily work become less productive and unable to meet the daily work target. This daily delay created a domino effect to the subsequent activities which caused the overall project delayed.

Research Question 2: *What business solutions can be proposed to address these losses?*
Based on the interview conducted with the Project Manager and based on the analysis, the solution proposed to face the project delay is with project crashing. In this research, project crashing conducted by adding the working time (overtime) for its personnel. The decision to use the overtime method rather than additional resource is regarding to the potential cost escalation due to the indirect cost which caused by the additional resource such as the mobilization and demobilization cost, life insurance cost, wear pack cost, and other cost that for each additional worker. Furthermore, the additional working time or overtime has fewer variables in the cost calculation, such as only including the overtime pay and additional meal allowance. Therefore, overtime is chosen to be the acceleration method used in this project.

Research Question 3: *What is the comparison between the cost of project acceleration and the penalty cost due to project delays?*
Based on the research and calculation conducted previously, this project acceleration cost about Rp 399.544.839 or $ 25.168,18 using an exchange rate of 15.875 per US Dollar. If compared to the potential penalty cost due to the project delay which cost about Rp 2.734.770.052 or about $ 172.464,53 using an exchange rate of 15.875 per US Dollar, the acceleration percentage only 14,61% of the potential penalty that would be incurred if project crashing not conducted.

Research Question 4: *How significant is the impact of project crashing on project cost and completion time?*
Based on the research finding and analysis conducted by using both primary and secondary data which has been collected before, project crashing by applying overtime to the Unit – 1 construction has shown a positive impact to the project completion. This is reflected in the effectiveness of the crashing strategy, which accelerate the project completion by 12 weeks. Else, project crashing also give a positive intangible impact which is the preservation of PT XYZ reputation among the client, resulting in the expectation in facilitated future project opportunities for PT XYZ.

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