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Selection of Alternative Working Methods using the Crashing and Microsoft Project Methods

Muhammad Djuneydi, Yudi Setio Prabowo, M. Oka Mahendra

Abstract: ***In carrying out the PPLP Banten Building construction project, the project experienced delays. The causes of delays are the addition of time, changes in shop drawings and material delays. Then, the solution in the Microsoft project is an alternative to the crashing method, involving 4 hours of overtime and work shifts. The research results obtained 18 jobs that are on the critical path of43 jobs. The normal total duration is 942 days, and the standard fee is Rp. 569.100.000 using AHSP. The results obtained indicate that the total duration of the alternative crashing, including 4 hours of overtime work, is 678 days, while the work shift is 530 days. The AHSP Project produces an alternative total cost of 4 hours of overtime of Rp. 3.066.675.000 and work shifts with accident costs of Rp. 1.223.565.000. The alternative cost of 4 hours of overtime using the AHSP project is Rp. 193.067.245,23 and work shifts using theAHSP project of Rp. 33.638.199,58, then the work shift alternativeis more economical and was chosen to be applied to the project. The results of the comparison of direct and indirect costs for the 4-hour overtime alternative are as follows: direct costs are Rp. 9.672.161.032,2 indirect costs Rp. 1,322,728,805.77 and direct costs for work shift alternatives: Rp. 9,512,731.986.58 costs. 1.273.456.116, 78. Then, the work shift alternative is more economical and is chosen for application to the project.***

Keywords**:** ***Microsoft Project, Crashing, Overtime, Shifts, Time, Costs.***

I. INTRODUCTION

In a construction project, there is a priority in the success of control, namely scheduling. Construction management plays a vital role in the success of a construction project. Cost, quality and time are the benchmarks that form the basisof construction management control. A common issue that often arises during field implementation planning is inadequate communication between the planner and the executor, which can hinder the performance of construction projects.

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When viewed from the perspective of construction project inhibition during implementation, it is not just a single factor, but rather several factors, including field conditions and situations, unfavourable weather changes, changes in planning design, and delays in material arrival, which slow down activities. Acceleration of project time is often undertaken when the project's progress is judged to have fallen behind schedule. Additionally, time acceleration can also be implemented during the planning stage. However, the acceleration of time has a significant impact on costs,quality, and risk. Therefore, the acceleration of project implementation time must be planned with careful consideration. The occurrence of delays during project construction led to cost overruns, and the project was not completed on schedule. Therefore, to succeed in a construction project, effective management is necessary to increase efficiency, productivity, and the quality of work, allowing for project monitoring and control measures to overcome problems that arise due to delays.

The object to be studied and analysed in this study is the Banten Province PPLP (Student Sports Education and Training Centre) building project for the 2020 fiscal year. Located on Jl. Raya Cilegon No. 517, Kel. Drangong, Kec. Takakan, City of Serang, Banten 42162, which PT built. Respati Jaya Pratama and PT. Bighi Prakasa Consultants, where during the construction of this project there were delays caused by several factors including the weather factor, changes to the foundation design on the plan, namely bored piles were replaced with piles, the arrival of the material to be used, namely piles because the project construction occurred during a pandemic Covid-19. In planning, the Banten Province PPLP (Student Sports Education and Training Centre) building project was scheduled to start on May 6, 2020, with a duration of 180 calendar days. Still, due to numerous obstacles, this project was delayed by 225 calendar days. Therefore, the completion of project delays must be accelerated in controlling duration and costs. Suppose the acceleration of scheduling is not carried out. In that case, this project is likely to experience cost overruns and fines under the agreement between the owner and the contractor, as it falls outside the terms of the contract. Costs increase from paying labour wages to achieve effectiveness through productivity, which accelerates project scheduling by using the crashing method. This method aims to complete the job by exchanging time and costs, both directly and indirectly. Through research, [1] discusses the analysis of project acceleration using the crashing method withthe addition of four hours and a work shiftsystem, but does not use the Microsoft Project for scheduling and calculatesworker wages using only the project's AHSP.

The researcher differentiates between the application of the crashing method, using an alternative of 4 hours of overtime work and work shifts, and compares the labour wage prices using the AHSP project.

The process utilises assistive devices, specifically Microsoft Project software, to adjust the relationship between workers on the critical path (or Critical Path) project. Acceleration is carried out to determine the conditions during normal project operations and after acceleration, using an alternative of 4 hours of overtime and work shifts with the most efficient duration and economic value. mical work costs to apply to thisproject

II. MICROSOFT PROJECT AND CRASHING

A. Microsoft Project

According to Syafriandi and Putri Lynna A. Luthan (2021), the book, a construction management text with a Microsoft Project application, defines Microsoft Project as a computer software application used to schedule projects, particularly construction projects. Microsoft Project helps record and monitor the use of resources, whether in theform of human resources, equipment, or materials. This application can also track labour requirements in each activity sector, record employee working hours and overtime hours, and calculate labour costs for various activities. This program can present reports on each position based on the developments that occur in the project.

B. Crashing

According to Frederika (2010) in [1] Speedingup project completion time is an attempt to finish the projectearlier than the completion time under normal circumstancesby holding this project acceleration there will be a reduction in the duration of activities that a crash program will have. The maximum crashing duration of an activity is the shortest duration for completing an activity that is technically still possible, assuming the resource is not a bottleneck. The maximum acceleration duration is limited by the size of the project or work location; however, four factors can be optimised to carry out acceleration in an activity, including increasing the number of workers, scheduling overtime work, utilising heavy equipment, and modifying construction methods in the field.

1. 4 Hours of Overtime

In project activities, overtime may sometimes be required under specific conditions. If overtime occurs, workers have more time to work than the normal duration that has been determined. Overtime work time is work time that exceeds 7 hours a day for six working days and 40 hours a week or 8 hoursa day for eight working days and 40 hours a week or working timeon weekly rest days and or on official holidays stipulated by Government Regulations Number 35 of 2021 Article 26 Paragraph 1 and according to the Labor Law Article 78 No. 13 of 2003 provisions for employee overtime are as follows:

1) The maximum overtime for workers is limited to 14 hours perweek.
2) Overtime work for employees may be performed for a maximum of 4 hours in a single day, not exceeding 4 hours in any given day.

The existence of overtime working hours among workers resulted in decreased work efficiency due to the factors associated with overtime hours. According to Thomas (2002) in [2], every time work or working hours exceed 40 hours per week is unavoidable, forexample to catch up with schedules even though this will reduce work efficiency. In this case, a graph is made that shows productivity decreases when the number of hours per day and per week increases

2. Shift work

Shift work is a work arrangement system that provides an opportunity to utilise all available time to operate work. Shift work is a work schedule in which workers alternate shifts to ensure continuous operational activities. Shifts are related to a lackof efficient communication between workers, as well as poorhealth conditions resulting from insufficient rest hours due to irregular sleep cycle times. The division of morning, afternoon and evening work shifts has been regulated in the Law [3] concerning Manpower Article 79 paragraph 2 letter a.

The article explains that working hours within a company or other legal entity are determined in 3 (three) shifts, and the distribution for each shift is a maximum of 8 hours per day (including work breaks). When accumulated, the total work of each change may not exceed 40 hours a week. Excess working hours of employees must be known and, with an order (written) from the leadership (management) of the company, which is calculated as overtime. Meanwhile, the government allows companies to determine the number of hours worked for each shift. Companies can regulate this themselves in Work Agreements (PK), Company Regulations (PP), and Collective Labour Regulations (PKB) as long as theydo not exceed the working hours set by the Government in theLaw. The purpose of this alternative shift is to help minimise the workload received by workers and carpenters. However, to makethis alternative shift, it must be adjusted to the regulations andcosts that will be used.

Factors that affect shift work hours include the following:

1) Unsupportive environmental conditions can affect work shifts, such as noise and the awareness of workers when using PPEwhile working.
2) The rotational work system can also impact work shifts, which can lead to rhythm changes, especially for night shift workers.
3) Age (the older a person is, the higher a person's fatigue level will be).
4) Health or illness owned.
5) Gender.
6) Education.
7) Workload and length of service

C. RAB

According to Ibrahim (2003) in [4] journal, accelerated project scheduling EPCCPier C PT. Petrokimia Gresik with the fast track method, the budget plan (Bergrooting) of a building or project is the calculation of the amount of costs required for materials and wages and other expenses related to the implementation of the building or project. The budgeted cost is the price of the building, which is carefully and accurately calculated to meet the requirements.

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The budgetfor the same building will vary by region, due to differences in material prices and labour wages.

Make a Work Unit Price Analysis (AHSP): is an analysis ofthe calculation of the cost of unit price requirements for wages, materials and rental of heavy equipment to obtain a price per one unit of work volume, the AHSP itself consists ofprice descriptions, coefficients, wage unit prices, materials andtools, the product of the coefficient and the unit price. The coefficient value can be determined through national government regulations, such as SNI, or regional government regulations, and the product is then aggregated to form the unit price.

1. Direct Cost

According to Syafriandi & Luthan (2017), the book defines direct costs as those that directly affect the physical implementation of the project, which can also be referred to as labour costs. The direct costs include:

a) The cost of materials, taking into account the specifications, quality, and quantity required, can be calculated for the price of materials.
b) Labour costs, which are calculated by estimating the expertise and amount required to carry out each project activity.
c) Subcontractor costs refer to expenses incurred for specific activities performed by other parties.
d) Cost of equipment: In general, projects classify the cost of this equipment as a type of own cost, which can be a rental or equipment depreciation expense.

2. Indirect Cost

According to Syafriandi and Luthan (2017), indirect costs are expenses incurred by management to expedite project implementation. These costs include:

a) General project costs, which include these costs, for example, the cost of constructing temporary facilities, employee salaries, provision of transportation, electricity, water and others.
b) Profits, these costs are usually factored into the project bid to cover the costs of completing the project.

Indirect costs are expenses associated with supervisory, administrative, consulting, work direction, interest, and unexpected costs (overhead costs), as well as profits and cost overruns.This indirect cost does not depend on the volume of work, but rather on the duration of the project implementation period. This indirect cost will increase if the implementation time is longer. The elements contained in these costs include, for example, employee salaries, general office expenses, and costs associated with procuring public facilities.

a. Profit

For profit and overhead calculations, a maximum of 15% is commonly used, as stated in the elucidation of Presidential Regulation No. 70 of 2012, Article 66, Paragraph 8. The HSP is prepared by taking into account reasonable profits and overhead costs.

According to Nafarin (2017), in the book, Profit is defined as income with abalance of costs and expenses for a specific period. In general, profit is the total revenue minus the total costs. Profit can be defined as the excess income received in return for producing goods and services during a given period. In the world of construction projects that have a profit standard in the form of a percentage, the Indonesian government suggests that the general standard of profit from a project is 10% of the project implementation price [5]. However, this 10% profit is not a standard; it can be adjusted according to the project's contract value.

b. Overheads

Overhead, namely as an indirect cost because overhead isa cost that is taken into account in the analysis of certain unit prices, this overhead is divided into two types, goods according to Presidential Regulation No. 70 of 2012 Article 1 Paragraph 14 is every object, both tangibleand intangible, movable or immovable, which can be traded,used or utilized by the user of the goods. Overhead for goods is calculated based on a comparison of the cost components specified in the requirements with those offered by the goods market, as well as additional insurance facilities and other relevant factors.

Secondly, there is service overhead in general, as defined by the Work Unit Price Analysis (AHSP) in the Public Works Sector, which explains that overhead is ageneral cost. Costs that are not directly incurred to supportthe realisation of the work in question, or costs that are calculated as operational costs, include expenses for office costs, management costs (such as bank interest, bank guarantees, and tenders), licensing, and medical expenses. This overhead cost is calculated based on a percentage of direct costs, the amount of which depends on the duration of the work, the prevailing interest rate, and other relevant factors.

III. METHODOLOGY AND RESULTS

This study describes the analysis of accelerated project scheduling, in which the project duration is acceleratedusing 4 hours of overtime and work shifts. The goal isto determine the change in cost and time, which will be analysed using Microsoft Project software.

A. Research Instruments

Accelerating the project duration by 4 hours through overtime and work shifts requires primary and secondary data. Primary data was obtained from further observations, interviews, and documentation. Meanwhile, secondary data for this study were obtained from previous studies. Among these are the project's general data, S-curve, RAB, BOQ, and project AHSP.

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B. Flow Chart

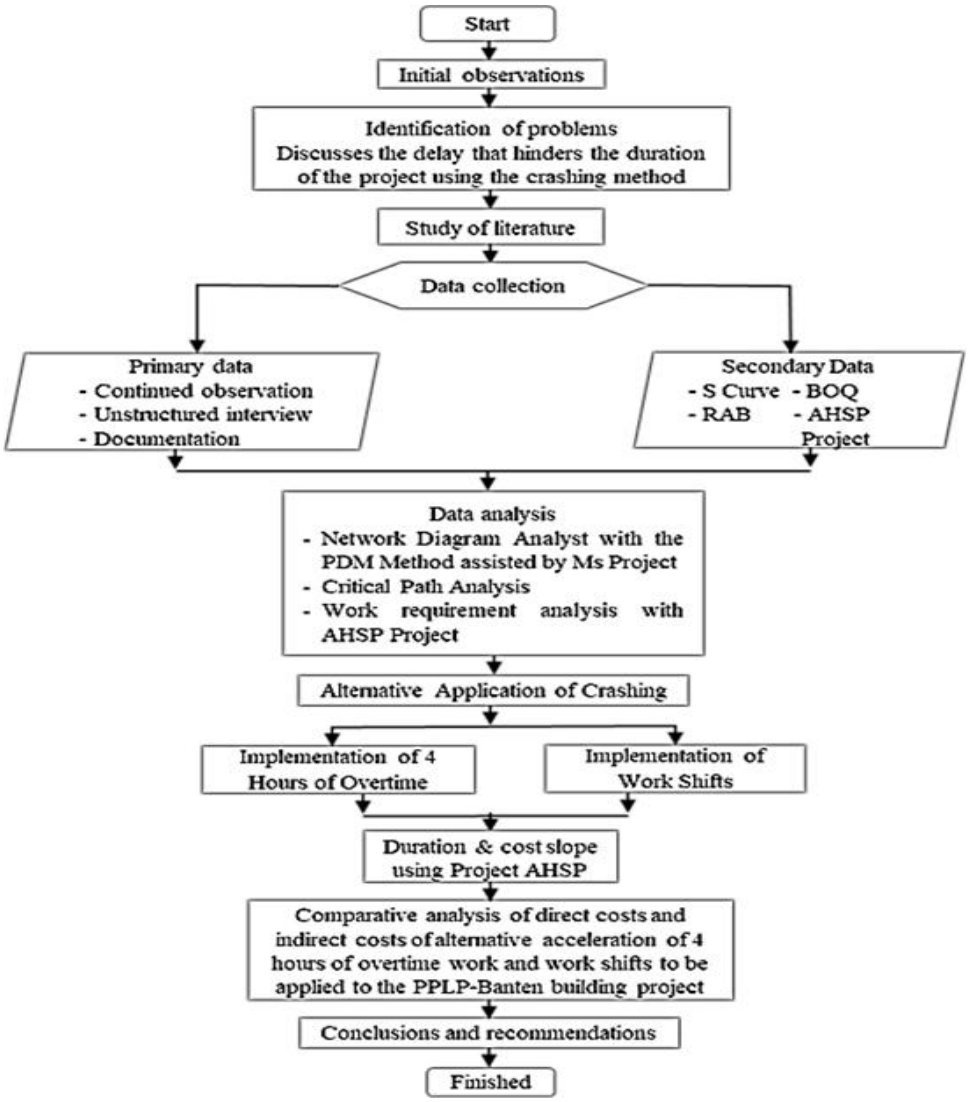

Figure 1. Flow Chart (Source: Processed Alone)

C. Normal Duration Analysis

Jobs that experience delays are heavily influenced by two factors, namely internal and external factors, including the following:

1) There is a delay in materials arriving at the project site, specifically with the piles.
2) Changes to shop drawings in the field for the bored pile foundation are being revised to accommodate pile cap foundations, which necessitate preparation for these modifications.
3) Delays in the PPLP Banten 2020 building project resulted in an additional planned time of 180 calendar days to 225 calendar days.

To address project duration issues within the available timeframe, it is necessary to expedite the implementation schedule for several critical path activities using the crashing method. After completing any work on the critical path, it will be calculated using the two alternatives selected in this study, namely, adding 4 hours of overtime work and working shifts. To help determine the total duration of crashing, project data such as normal duration and the volume of work that experiences delays on the critical path are needed.

D. Determination of Labour Needs

After analyzing the several jobs on the critical path in the network diagram, the next step is to explore the accelerationof the 18 jobs that are on the critical path. In analysing the 18 jobs, we start by calculating the number of labour requirements for the 18 jobs that are on the critical path. Whatis needed is project data to calculate labour requirements for 18 jobs on the critical path, including coefficient values and daily wages, as part of the project Unit Price Analysis using tools in Microsoft Excel. According to [6] to calculate the number of workers per day, use the following formula:

$$\text{Number of workers per day} = \frac{Volume\ x\ koefisien}{normal\ duration} \quad \text{..... (1)}$$

Table 1. Daily Labour Requirements Using The Crashing Method

No	Work	Number Of Workers Per Day (Person)				amount
		Worker	Craftsman	Foreman	Foreman	
1	Preparatory Work	1			1	2
2	Excavation Of Soil, Fill & Foundation Floor 1	16			1	17
3	Concrete Structure & Foundation Work 1st Floor	3	1	1	1	6
4	Floor Concrete Work 2	6	2	1	1	10
5	Floor Concrete Work 3	3	1	1	1	6
6	1st Floor Sill Work	1	1	1	1	4
7	1st Floor Work	13	7	1	1	22
8	1st Floor Painting Work	2	4	1	1	8
9	2nd Floor Sill Work	1	1	1	1	4
10	3rd Floor Roof & Ceiling Work	5	2	1	1	9
11	3rd Floor Painting Work	2	4	1	1	8
12	2nd Floor Sanitation Work	1	1	1	1	4
13	3rd Floor Sanitation Works	1	1	1	1	4
14	1st Floor Electrical Installation Work	2	2	1	1	6
15	2nd Floor Electrical Installation Work	3	3	1	1	8
16	3rd Floor Electrical Installation Work	2	2	1	1	6
17	Other Jobs	1			1	2
18	Install Concrete Panel Fence	2	1	1	1	5
Total						131

According to [6] to calculate labour wages using the following formula:

Wages per day of labour = *Number of workers per day x daily wages of workers*..... (2)

Total Daily Costs = *Total wages per day of labor* ..... (3)

Total Cost = *Total daily cost x Duration*..... (4)

Table 2. Daily Costs and Total Costs of Work with AHSP Projects

No	Work	Total Daily Cost	Total Cost Of Work
1	Preparatory Work	Rp 205.000	Rp 46.125.000
2	Excavation Of Soil, Fill & Foundation Floor 1	Rp 1.480.000	Rp 41.440.000
3	Concrete Structure & Foundation Work 1st Floor	Rp 585.000	Rp 32.760.000
4	Floor Concrete Work 2	Rp 940.000	Rp 46.060.000
5	Floor Concrete Work 3	Rp 585.000	Rp 36.855.000
6	1st Floor Sill Work	Rp 415.000	Rp 14.525.000
7	1st Floor Work	Rp 2.035.000	Rp 99.715.000
8	1st Floor Painting Work	Rp 800.000	Rp 28.000.000
9	2nd Floor Sill Work	Rp 415.000	Rp 14.525.000
10	3rd Floor Roof & Ceiling Work	Rp 855.000	Rp 41.895.000
11	3rd Floor Painting Work	Rp 800.000	Rp 28.000.000
12	2nd Floor Sanitation Work	Rp 415.000	Rp 15.355.000
13	3rd Floor Sanitation Works	Rp 415.000	Rp 15.355.000
14	1st Floor Electrical Installation Work	Rp 600.000	Rp 27.000.000
15	2nd Floor Electrical Installation Work	Rp 785.000	Rp 22.765.000
16	3rd Floor Electrical Installation Work	Rp 600.000	Rp 27.000.000
17	Other Jobs	Rp 205.000	Rp 9.225.000
18	Install Concrete Panel Fence	Rp 500.000	Rp 22.500.000
Total Cost		Rp 827.120.000	Rp 569.100.000

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Accelerating Crashing Using Alternative 4 Hours of Overtime

1. Productivity 4 Hours of Overtime According to[6]

Productivity per day = $\frac{Volume}{normal\ duration}$ ..... (5)

Workforce Productivity = $\frac{Productivity\ per\ day}{number\ of\ workers}$ ..... (6)

Normal Productivity Per hour = $\frac{Prod.Labor}{Normal\ working\ hours\ per\ day}$ ..... (7)

Normal productivity 4 Hours = *Productivity. Normal Hourly x Additional Hours Duration (4 Hours)* $\frac{Normal\ Product}{1,1}$ ……(8)

Prod. 1st Hour Overtime = $\frac{Normal\ Product}{1,2}$ ……(9)

Prod. 2nd Hour Overtime = $\frac{Normal\ Product}{1,3}$ ……(10)

Prod. 3rd Hour Overtime = $\frac{Normal\ Product}{1,4}$ ……(11)

Prod. 4th Hour Overtime = ……(12)

Total Overtime Productivity 4 Hours

= *First Hour + Second Hour + Third Hour*

+ Fourth Hour .....(13)

Labour Efficiency = $\frac{Total\ Prod.4\ hours}{Normal\ Prod.4\ hours}$ *x 100%*.....(14)

Productivity Decline

= *1 – labour effectiveness* .....(15)

2. Alternative Crash Duration 4 Hours Overtime

To get the crash duration for the alternative of 4 hours of overtime, according to [6] to calculate labour wages using the following formula.

Crash duration = $\frac{(Dn\ x\ h)}{(h+(ho\ x\ e))}$ ..... (16)

note:

Dn = normal duration, ho = total number of overtime hours,h = Number of normal working hours, e = labour efficiency

Table 3. Summary of Alternative Crash Duration: 4 Hours of Overtime Work

No	Work	Normal Duration	CrashDuration
1	Preparatory Work	225	161
2	Excavation Of Soil, Fill & Foundation Floor 1	28	20
3	Concrete Structure & Foundation Work 1st Floor	56	40
4	Floor Concrete Work 2	49	35
5	Floor Concrete Work 3	63	45
6	1st Floor Sill Work	35	25
7	1st Floor Work	49	35
8	1st Floor Painting Work	35	25
9	2nd Floor Sill Work	35	25
10	3rd Floor Roof & Ceiling Work	49	35
11	3rd Floor Painting Work	35	25
12	2nd Floor Sanitation Work	37	27
13	3rd Floor Sanitation Works	37	27
14	1st Floor Electrical Installation Work	45	33
15	2nd Floor Electrical Installation Work	29	21
16	3rd Floor Electrical Installation Work	45	33
17	Other Jobs	45	33
18	Install Concrete Panel Fence	45	33
Total		942	678

3. Alternative Crash Costs: 4 Hours of Overtime

Government Regulation Number 35 of 2021 Article 26 Paragraph 1[7[Note: 4 hours of overtime is only allowed up to a maximum of 4 hours in a single day.] Then,in the calculation of overtime hours, wages are entered into the formula as follows:

– First overtime hour wage
= 1.5 x normal hourly wage..... (17)

- Second overtime hour wage
= 2 x normal wage per hour ..... (18)

- Third overtime hour wage
= 2 x normal wage per hour ..... (19)

- Fourth overtime hour wage
= 2 x normal wage per hour..... (20)

- Total overtime pay per day
= Total first overtime pay + Second overtime amount +Third overtime amount + Total fourth overtime (21)

- Daily wages = Total labor wages per day x Number of workers (22)

According to [6]

Crash Cost = *Total labour wage per day x crash duration* (23)

Table 4. Crash Cost Alternative 4 Hours of Overtime using ProjectAHSP

No	Work	Normal Cost	Crash Cost
1	Preparatory Work	Rp 46.125.000	Rp 247.537.500
2	Excavation Of Soil, Fill & Foundation Floor 1	Rp 41.440.000	Rp 222.000.000
3	Concrete Structure & Foundation Work 1st Floor	Rp 32.760.000	Rp 175.500.000
4	Floor Concrete Work 2	Rp 46.060.000	Rp 246.750.000
5	Floor Concrete Work 3	Rp 36.855.000	Rp 197.437.500
6	1st Floor Sill Work	Rp 14.525.000	Rp 77.812.500
7	1st Floor Work	Rp 99.715.000	Rp 534.187.500
8	1st Floor Painting Work	Rp 28.000.000	Rp 150.000.000
9	2nd Floor Sill Work	Rp 14.525.000	Rp 77.812.500
10	3rd Floor Roof & Ceiling Work	Rp 41.895.000	Rp 224.437.500
11	3rd Floor Painting Work	Rp 28.000.000	Rp 150.000.000
12	2nd Floor Sanitation Work	Rp 15.355.000	Rp 84.037.500
13	3rd Floor Sanitation Works	Rp 15.355.000	Rp 84.037.500
14	1st Floor Electrical Installation Work	Rp 27.000.000	Rp 148.500.000
15	2nd Floor Electrical Installation Work	Rp 22.765.000	Rp 123.637.500
16	3rd Floor Electrical Installation Work	Rp 27.000.000	Rp 148.500.000
17	Other Jobs	Rp 9.225.000	Rp 50.737.500
18	Install Concrete Panel Fence	Rp 22.500.000	Rp 123.750.000
Total		**Rp 569.100.000**	**Rp 3.066.675.000**

The cost slope for the alternative of 4 hours of overtime according to [8] uses the formula

Cost slope =.. $\frac{crash\ cost - normal\ cost}{durasi\ normal - durasi\ crash}$ ..... (24)

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Table 5. Recapitulation of Alternative 4-Hour Overtime Cost Slope Using Project AHSP

No	Work	*Cost slope*
1	Preparatory Work	Rp 3.115.087,60
2	Excavation Of Soil, Fill & Foundation Floor 1	Rp 22.440.362,91
3	Concrete Structure & Foundation Work 1st Floor	Rp 8.870.008,31
4	Floor Concrete Work 2	Rp 14.252.662,93
5	Floor Concrete Work 3	Rp 8.870.008,31
6	1st Floor Sill Work	Rp 6.292.399,06
7	1st Floor Work	Rp 30.855.499
8	1st Floor Painting Work	Rp 12.129.925,90
9	2nd Floor Sill Work	Rp 6.292.399,06
10	3rd Floor Roof & Ceiling Work	Rp 12.963.858,30
11	3rd Floor Painting Work	Rp 12.129.925,90
12	2nd Floor Sanitation Work	Rp 6.459.675,95
13	3rd Floor Sanitation Works	Rp 6.459.675,95
14	1st Floor Electrical Installation Work	Rp 9.395.721,29
15	2nd Floor Electrical Installation Work	Rp 12.104.340,94
16	3rd Floor Electrical Installation Work	Rp 9.395.721,29
17	Other Jobs	Rp 3.210.204,77
18	Install Concrete Panel Fence	Rp 7.829.767,74
Total		Rp 193.067.245,23

E. Accelerating Crashing Using Alternative Shift Work

1. Productivity of Morning And Evening Work Shifts According to [6]

- Morning shift productivity = $\frac{Volume}{normal\ duration}$ ..... (25)
- Night shift productivity = *(100% - Productivity Decline) x Morning shift Productivity*..... (26)
- Total productivity per day = *Morning productivity + Evening Productivity*..... (27)

2. Work Shift Alternate Crash Duration

- Crash shift duration[6]

$$= \frac{Volume}{total\ productivity\ per\ day} \quad \text{..... (28)}$$

Table 6. Summary of Alternative Crash Duration of Work Shifts

No	Work	Normal Duration	Crash Duration
1	Preparatory Work	225	125
2	Excavation Of Soil, Fill & Foundation Floor 1	28	16
3	Concrete Structure & Foundation Work 1st Floor	56	31
4	Floor Concrete Work 2	49	28
5	Floor Concrete Work 3	63	35
6	1st Floor Sill Work	35	20
7	1st Floor Work	49	28
8	1st Floor Painting Work	35	20
9	2nd Floor Sill Work	35	20
10	3rd Floor Roof & Ceiling Work	49	28
11	3rd Floor Painting Work	35	20
12	2nd Floor Sanitation Work	37	21
13	3rd Floor Sanitation Works	37	21
14	1st Floor Electrical Installation Work	45	25
15	2nd Floor Electrical Installation Work	29	17
16	3rd Floor Electrical Installation Work	45	25
17	Other Jobs	45	25
18	Install Concrete Panel Fence	45	25
Total		942	530

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3. Alternative Crash Costs of Work Shifts According to [8]

- Morning shift wages
  = *normal day wages* ..... (29)
- Night shift wages = *wages/day + (wages/day x 15%)* ..... (30)

[8] uses the formula

Cost slope = $\frac{crash\ cost - normal\ cost}{duration\ normal - duration\ crash}$ ..... (24)

Table 8. Alternative Crash Cost Shift Work Using AHSP Project

No	Work	*Cost slope*
1	Preparatory Work	Rp 530.437,50
2	Excavation Of Soil, Fill & Foundation Floor 1	Rp 3.971.333,33
3	Concrete Structure & Foundation Work 1st Floor	Rp 1.506.960
4	Floor Concrete Work 2	Rp 2.522.333,33
5	Floor Concrete Work 3	Rp 1.513.687,50
6	1st Floor Sill Work	Rp 1.113.583,33
7	1st Floor Work	Rp 5.460.583,33
8	1st Floor Painting Work	Rp 2.146.666,67
9	2nd Floor Sill Work	Rp 1.113.583,33
10	3rd Floor Roof & Ceiling Work	Rp 2.294.250
11	3rd Floor Painting Work	Rp 2.146.666,67
12	2nd Floor Sanitation Work	Rp 1.103.640,63
13	3rd Floor Sanitation Works	Rp 1.103.640,63
14	1st Floor Electrical Installation Work	Rp 1.552.500
15	2nd Floor Electrical Installation Work	Rp 2.181.645,83
16	3rd Floor Electrical Installation Work	Rp 1.552.500
17	Other Jobs	Rp 530.437,50
18	Install Concrete Panel Fence	Rp 1.293.750
Total		**Rp 33.638.199,58**

G. Comparison Results of the Application of the Crashing Method with Alternatives for the Addition of 4 Hours of Overtime and Work Shifts

- Total labour wages
  = *(morning shift wages + night shift wages) x duration of work x number of workers* ..... (31)

Table 7. Alternative Crash Cost Shift Work Using AHSP Project

No	Work	Normal Cost	Crash Cost
1	Preparatory Work	Rp 46.125.000	Rp 99.168.750
2	Excavation Of Soil, Fill & Foundation Floor 1	Rp 41.440.000	Rp 89.096.000
3	Concrete Structure & Foundation Work 1st Floor	Rp 32.760.000	Rp 70.434.000
4	Floor Concrete Work 2	Rp 46.060.000	Rp 99.029.000
5	Floor Concrete Work 3	Rp 36.855.000	Rp 79.238.250
6	1st Floor Sill Work	Rp 14.525.000	Rp 31.228.750
7	1st Floor Work	Rp 99.715.000	Rp 214.387.250
8	1st Floor Painting Work	Rp 28.000.000	Rp 60.200.000
9	2nd Floor Sill Work	Rp 14.525.000	Rp 31.228.750
10	3rd Floor Roof & Ceiling Work	Rp 41.895.000	Rp 90.074.250
11	3rd Floor Painting Work	Rp 28.000.000	Rp 60.200.000
12	2nd Floor Sanitation Work	Rp 15.355.000	Rp 33.013.250
13	3rd Floor Sanitation Works	Rp 15.355.000	Rp 33.013.250
14	1st Floor Electrical Installation Work	Rp 27.000.000	Rp 58.050.000
15	2nd Floor Electrical Installation Work	Rp 22.765.000	Rp 48.944.750
16	3rd Floor Electrical Installation Work	Rp 27.000.000	Rp 58.050.000
17	Other Jobs	Rp 9.225.000	Rp 19.833.750
18	Install Concrete Panel Fence	Rp 22.500.000	Rp 48.375.000
Total		Rp 569.100.000	Rp 1.223.565.000

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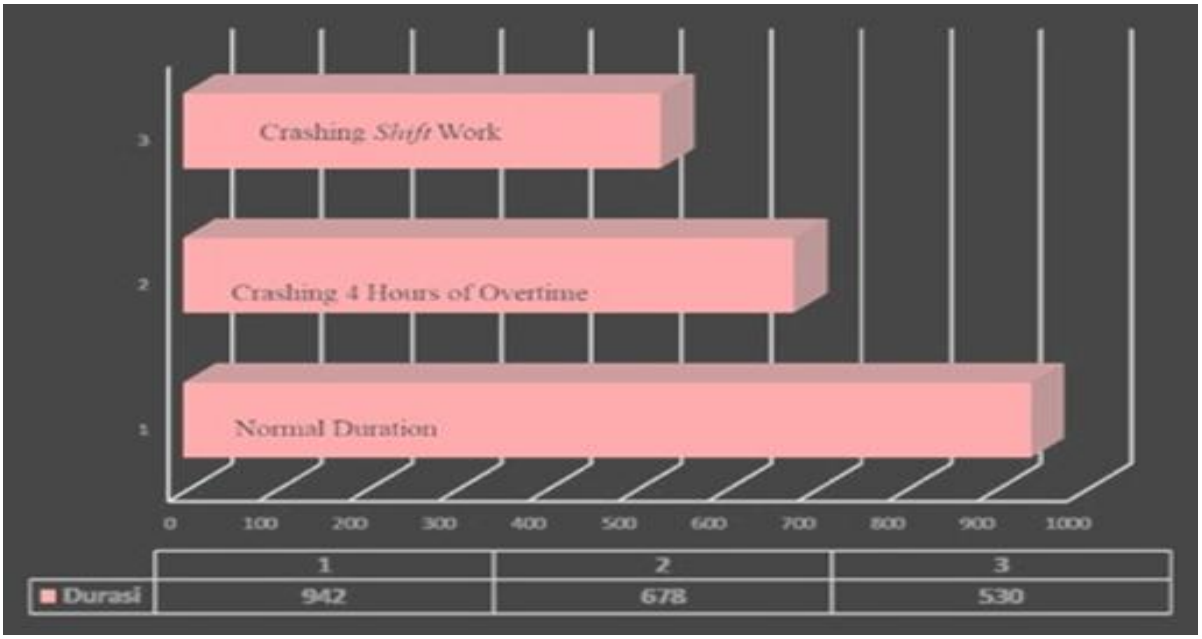

Figure 2. Bar Comparison of Normal Duration, Alternative 4 Hours of Overtime Work & Work Shifts

Based on Figure 2, which shows the normal duration and duration after acceleration using the crashing method, with the addition of 4 hours of overtime work and work shifts. The normal duration is 942 days for 18 jobs that are late. If an additional alternative with 4 hours of overtime work is considered, the resulting crash duration is 678 days, resulting in a 264-day difference. The percentage difference is 28% of the normal duration, and the alternative work shift is 530 days in length. The difference is, for example, 412 days ago; the percentage difference was 44% at that time. Then the alternative of 4 hours of overtime is delayed compared to the accelerated work shift. However, these 4 hours of overtime work cannot be applied to other options that will be used in accelerated conditions for the PPLP Banten project. Therefore, the alternative duration of work shifts can be applied to other options that will be used in accelerated conditions for the Banten PPLP project, as it is more efficient. Next is a picture comparing the cost slope for alternative 4 hours of overtime work and shift work using the AHSP project, which is as follows.

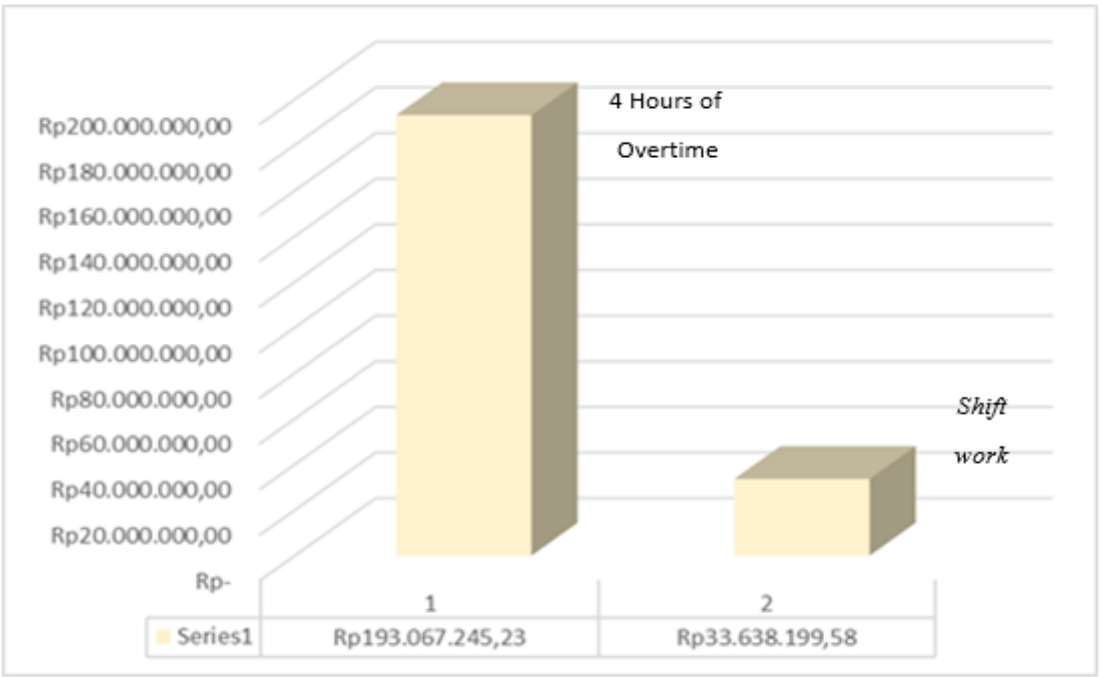

Figure 3. Cost Slope Comparison Column on 4-Hour Overtime Alternatives and Working Shifts Using Project AHSP

Based on Figure 3, it is explained that the cost slope (additional costs) using the AHSP project resulted in an alternative of 4 hours of overtime worth Rp. 193,067,245.23 and an alternative to the work shift system, Rp. 33,638,199.58 using the AHSP project.

H. Analysis of Direct Costs and Indirect Costs

1. Comparison of Direct Costs and Indirect Costs [1]

$$\text{Material Coefficient} = \frac{\text{Material Cost}}{\text{Wage and Material Cost}} \quad \ldots\ldots\ldots\ldots \quad (25)$$

$$\text{Wage Coefficient} = \frac{\text{Wage Cost}}{\text{Material Cost and wage}} \quad \ldots\ldots\ldots\ldots \quad (26)$$

$$\text{Direct cost weight} = \frac{\text{Material and labor costs}}{\text{HSP value}} \quad \ldots\ldots\ldots\ldots \quad (27)$$

Indirect cost weight = *100% - direct cost weight*... (28)

[8] Profit = *Total project cost x 10%* ..... (29)

Overhead cost = *Total project cost x 3%* ..... (30)

$$\text{Overhead per day} = \frac{\text{Overhead Cost}}{\text{Normal Duration}} \quad \ldots\ldots\ldots\ldots \quad (31)$$

Direct cost = *Total direct cost weight x Total project cost* (32)

Indirect cost = *Profit + Overhead costs*..... (33)

Total costs = *Direct costs + Indirect costs* ..... (34)

Material cost = Direct cost x material coefficient... (34)

Cost of wages = *Direct cost x coefficient of wages* (35)

a) Direct costs

-Crashing alternative: 4 hours of overtime work

= *normal cost + total cost slope of 4 hours overtime* (36)

Crashing alternative work shifts

= *normal direct costs + total alternative shift cost slope* …. (37)

b) Indirect costs

-Crashing alternative: 4 hours of overtime work

= *Crashing duration x overhead per day) + profit* (38)

-Crashing alternative work shifts

= *Crashing duration x overhead per day) + profit* (39)

c) Total project cost after crashing

-Crashing alternative: 4 hours of overtime work

= *direct costs + indirect costs* ..... (40)

-Crashing alternative work shifts

= *direct costs + indirect costs* ..... (41)

2. Comparison of Project Costs Using AHSP Projects

Table 9. Comparison of Duration and Cost Using AHSP Projects

	Duration	Direct Cost	Indirect Cost	Amount
Normal Condition Project	942	Rp 9.479.093.787	Rp 1.416.416.313	Rp 10.895.510.100
Crashing 4 Hours of Overtime	678	Rp 9.672.161.032,23	Rp 1.322.728.805.77	Rp 10.994.889.838
Crashing Shift Work	530	Rp 9.512.731.986,58	Rp 1.273.456.116,78	Rp 10.786.188.103,37

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Based on Table 9, it is obtained under normal project conditions, namely Rp. 10,895,510,100, with a normal duration of 942 days, as per the contract. Suppose you use the accelerated alternative of 4 hours of overtime. In that case, you will receive Rp. 10,994,889,838. You will experience a swelling of Rp: 99,379,738, or 0.91%. However, 4 hours of overtime will result in a faster completion, namely 264 days, or 28% of the normal duration. In contrast, if you use acceleration, an alternative work shift results in Rp. 10,786,188,103.37, resulting in cost savings of Rp. 109,321,996.63, or 1%, with a shorter duration of 412 days, or 44% compared to normal conditions. Can prove that the comparison of the results of calculating direct costs and indirect costs after crashing with the results of alternative calculations of 4 hours of overtime work with direct costs of Rp.9,672,161,032.23 and indirect costs of Rp.1,322,728,805.77 and alternative work shifts with costs direct costs of Rp.9,512,731,986.58 and indirect costs of Rp.1,273,456,116.78 which produce the minimum and can be applied to the Banten PPLP project are alternative work shifts. Because the work shift alternative is a better option, with the most economical additional cost results, and can be applied to the Banten PPLP project compared to the 4-hour overtime alternative.

IV. CONCLUSION

1. In jobs that experience delays, 18 out of 43 jobs are affected. Then the work that experienced delays included preparatory work, excavation work, fill & foundation 1st floor, concrete structure & foundation 1st floor, concrete work 2nd floor, concrete work lt. 3, sill work lt.1, floor work lt.1, painting work lt.1, sill work lt.2, roof & ceiling work lt.3, painting work lt.3, sanitation work lt.2, sanitation work lt. 3, electrical installation work on the 1st floor, electrical installation work on the 2nd floor, electrical installation work on the 3rd floor, other work and installation of concrete panel fences.
2. The total normal duration and cost of 18 jobs that are on the critical path with a normal duration of 942 days is Rp.569,100,000 using AHSP, the total duration of alternative crashing is 4 hours of overtime work, which is 678 days, while in the work shift, the total crash duration is 530 days. In the AHSP project, the resulting total alternative crash cost for 4 hours of overtime is Rp. 3,066,675,000, and a work shift with a crash cost of Rp. 1,223,565,000.
3. The results of the cost slope comparison using the AHSP project are the calculations of the additional cost of 4 hours of overtime, using the AHSP project, which amounts to Rp. 193,067,245.23 for the extra cost of work shift, using the AHSP project of Rp. 33,638,199.58.
4. The results of direct and indirect costs are as follows: 4 hours of overtime work, with direct costs of Rp. 9,672,161,032.23 and indirect costs of Rp. 1,322,728,805.77. In contrast, when using accelerated work shifts, the direct costs are Rp. 9,512,731,986. 58 and the indirect costs of Rp. 1,273,456,116.78. So the alternative acceleration of work shifts at direct and indirect costs is more economical and was chosen to be applied to the PPLP-Banten building project.

DECLARATION

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Authors Contributions	All authors have equal contributions to this article.

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