Optimizing Project Implementation Time and Cost Using the Least Cost Method

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ABSTRACT

The background of this study is project delays. In the implementation of a project, projects are often found to be delayed or the implementation of the project is not in accordance with the predetermined schedule. To optimize the time and cost of implementing a late project using the Least Cost Analysis method. The Least Cost Analysis method is a method for accelerating work to obtain optimal project duration in a project by carrying out work activities simultaneously in the implementation of the project which can help complete a project efficiently and effectively. The SP. Buruan - Senganan - Pacung Provincial Road Construction Project is used as a case study which experienced a 10,61% delay in work progress in the 28th week. The application of the Least Cost Analysis method is only on work activities that are on the critical path in order to restore the project completion schedule to be completed according to schedule to avoid progress delays. The results of the application of the Least Cost Analysis method optimize the time and cost of completing the project on time, namely the time efficiency of 10,61% from the late time. In terms of cost, a cost efficiency of Rp. 328.135.246,76 or 2,52% is obtained.

Keywords: cost; time; delay; critical path; least cost analysis.

INTRODUCTION

The Public Works and Spatial Planning Agency of Bali Province is a government agency under the Bali Provincial Government that is responsible for carrying out maintenance and improving the construction of roads and bridges. The improvement of roads and bridges aims to maintain conditions so that they remain in good condition and service capacity in order to support the performance of service levels. On the provincial road section SP. Buruan - Senganan - Pacung, it is necessary to improve the performance of roads and bridges considering that the bridge has experienced a decline in condition due to several factors, including service age, weather or nature, quantity and load of vehicles, so it is necessary to improve the performance of roads and bridges.

The provincial road section SP. Buruan - Senganan - Pacung is a provincial road section on the central route of Bali Island in Tabanan Regency. On this route there is the Tukad Yeh Panahan Bridge at KM + 42 +100 with a width of 4.5 meters with a traffic lane of 3 meters. This bridge can only be passed for 1 lane so that vehicles from the opposite direction must wait for the vehicle to pass. The construction of roads and bridges will be made 2 lanes so that vehicles no longer have to wait when crossing the bridge.

In the road and bridge construction project on the provincial road section SP. Buruan – Senganan – Pacung has a width of 9.80m with a 7.00m crossing lane with a bridge span of 35 meters and a road length of 700 meters with a contract value of Rp. 14,400,000,000, - and is planned for 210 calendar days. Starting on May 19, 2023 and planned to be completed on December 14, 2023. While the realization in the field, the project was completed on December 28, 2023. When viewed from the time schedule and realization in the field, the project experienced a delay in the 28th week on November 20, 2023, the project experienced a delay or setback of 10.61%, where the cause of the delay was earthworks and geosynthetics, asphalt paving work, structural work and daily work. Therefore, it is necessary to make efforts to accelerate the project, in order to accelerate the completion time of the project so that it is on time according to the planned implementation time. There are several effective methods for carrying out a scenario of accelerating the implementation

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time due to project delays. One of them uses the Least Cost Analysis method which explains the relationship between direct costs (Direct Cost) which increase cumulatively if acceleration is carried out, for example if work acceleration is carried out then the allocation of material, labor and equipment costs will increase. When carrying out an acceleration scenario using the Least Cost Analysis Method, effective work network planning on a project can use the Precedence Diagram Method (PDM) and the Microsoft Project support program. PDM is a work network that is generally rectangular. In PDM an activity can be carried out without waiting for the predecessor activity to be 100% complete. This can be done by overlapping. In this study, an acceleration scenario will be carried out for the road and bridge construction project on the SP. Buruan - Senganan - Pacung Provincial road section using the Least Cost Analysis method with the Precedence Diagram Method (PDM) work network system. The preparation of the project activity schedule can be done by optimizing time and costs. The purpose of this study is "to determine the optimal time and costs required due to the acceleration of project implementation so that it is in accordance with the implementation time with the Least Cost Analysis method". Construction Project

A construction project is a series of activities to achieve a goal (building or construction) with certain time, cost and quality constraints. Construction projects require resources, namely man, material, machine, method, money, information, and time [1].

Construction Management

Project management is planning, organizing, leading, and controlling company resources to achieve predetermined short-term goals. PMI (Project Management Institute) states that the definition of project management is the science and art related to leading and coordinating resources consisting of humans and materials using modern management techniques to achieve predetermined goals [2].

PDM (Precedence Diagram Method)

PDM (Precedence Diagram Method) is a rectangular symbol because the location of the activity is in the node section so it is often called Activity on Node (AON). The advantages of PDM (Precedence Diagram Method) compared to Arrow Diagram are:

1. Does not require fictitious activities so that network creation becomes simpler.
2. Different overlapping relationships can be created without increasing the number of activities [2].

The following is an example of a Precedence Diagram Method (PDM) activity symbol image that can be seen in Table 1, namely as follows:

Table 1. Precedence Diagram Method activity symbol Least Cost Analysis Method [3], [6], [7]

ES LS	**Type of activity**	**EF** LF
No. Keg		Duration

The Least Cost Analysis Method is a scheduling method that determines activities and sequences in carrying out acceleration strategies by crashing in order to obtain a series of the most efficient project acceleration plans for costs. Finding the lowest cost slope value can be done after sorting the cost slope values of each activity from those on the critical path from the lowest to the highest value.

Cost Slope = Acceleration Cost - Normal Cost Normal Time - Acceleration Time
From these comparison stages, it will be stopped if all activities have returned to the time schedule [2]. The following is an example of a project cost image that can be seen in Figure 1, namely, as follows:

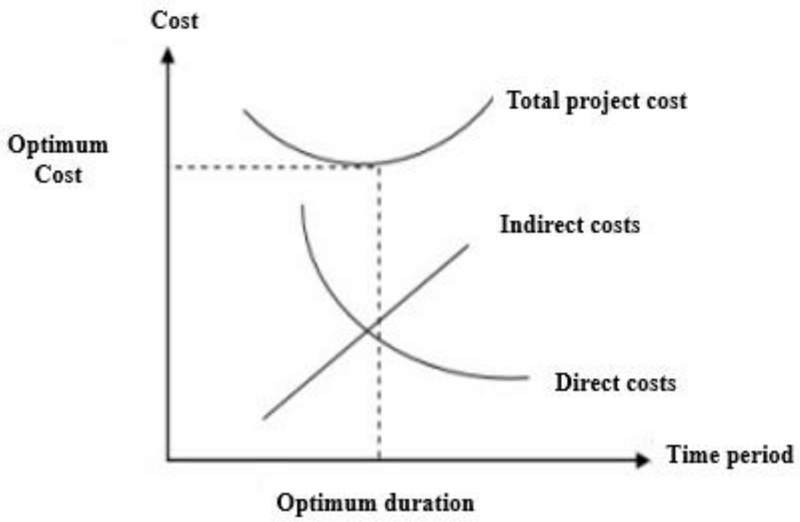

Figure 1. Project Cost Source: Soeharto in Mandiyo Priyo [4], [8]

Efficient cost management is one of the most important aspects of construction projects. The ability to minimize costs while maintaining quality and safety determines whether a project achieves its objectives successfully. In many developing regions, including Indonesia, construction often faces challenges such as budget limitations, fluctuating material prices, and resource constraints. Therefore, adopting strategies that allow the use of minimal costs without compromising project performance becomes highly relevant. The idea of minimal cost in construction does not necessarily mean reducing expenses at all costs, but rather optimizing available resources to achieve maximum results [9], [10]. It involves balancing between cost, quality, and time, known as the "triple constraint" in project management. A project that focuses solely on cutting expenses may result in structural failures, unsafe conditions, or long-term inefficiency. Thus, minimal cost must be understood as the rational allocation of funds through effective planning, material selection, and construction techniques. Construction projects, whether they involve buildings, roads, or infrastructure, typically require large financial investments. Cost overruns are common problems that can lead to delays, reduced scope, or even project abandonment [11]. By implementing cost minimization strategies, stakeholders such as contractors, project owners, and government agencies can ensure that the project remains within budget while still delivering the intended functionality. Furthermore, efficient cost use supports sustainability by reducing waste, promoting resource efficiency, and ensuring long-term value [12], [13].

Despite its advantages, achieving minimal costs is not without challenges. Unstable material prices, particularly for steel and cement, can quickly disrupt cost planning. In addition, contractors may face pressure from project owners to deliver projects at unrealistically low costs, which can compromise quality and safety. Corruption, bureaucratic inefficiencies, and lack of skilled labor are further obstacles that often inflate project expenses. Therefore, transparency, accountability, and continuous training are crucial to ensure that cost reduction does not lead to structural or operational failures [14], [15].

RESEARCH METHODS

The method used in this study is quantitative descriptive, research that describes the conditions of a particular project with analysis of existing data. Data analysis uses analytical and descriptive methods. Analytical means that existing data is processed in such a way as to produce final results that can be concluded. While descriptive is by explaining existing problems. The descriptive research method is research that is directed at providing symptoms, facts or events systematically and accurately, regarding the characteristics of a particular population or area. In descriptive research, there tends to be no need to seek or explain interrelationships and test hypotheses, this

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method is called a quantitative method because the research data is in the form of numbers and analysis using statistics.

Research Stages

This research begins with conducting a literature study, then continues with collecting project data. After that, data processing and analysis are carried out. From the results of the analysis, conclusions and suggestions are then drawn up. The following are the stages of research carried out in this study, as follows:

Preparation Stage

1. Determining the location of the study, namely the construction of roads and bridges on the SP. Buruan - Senganan - Pacung Provincial-road section.

2. Identifying problems that occur at the research location, namely delays in project implementation time.

3. Conducting a literature study by looking for theoretical references that are relevant to the cases and problems found, these references contain:

a. Construction management

b. Scheduling techniques

c. PDM (Precedence Diagram Method) network

d. Microsoft Project program

e. Analysis of the implementation cost budget

f. Least Cost Analysis Method

Data Collection Techniques

Next, data collection was carried out from the structural work of the road and bridge construction project on the SP. Buruan - Senganan Provincial road section, both primary and secondary data, namely, as follows:

1. Primary Data

2. Secondary Data

Data Analysis

Here are the analysis work steps:

1. Preparation of Network Diagram

2. Analyzing remaining work activities

Analysis is carried out on remaining work activities that are delayed.

3. Determining the Crashing scenario

4. Calculation of labor productivity, crash costs and cost slopes.

5. Calculation of Least Cost Analysis

The stages in this study can be seen from Figure 2, namely, as follows:

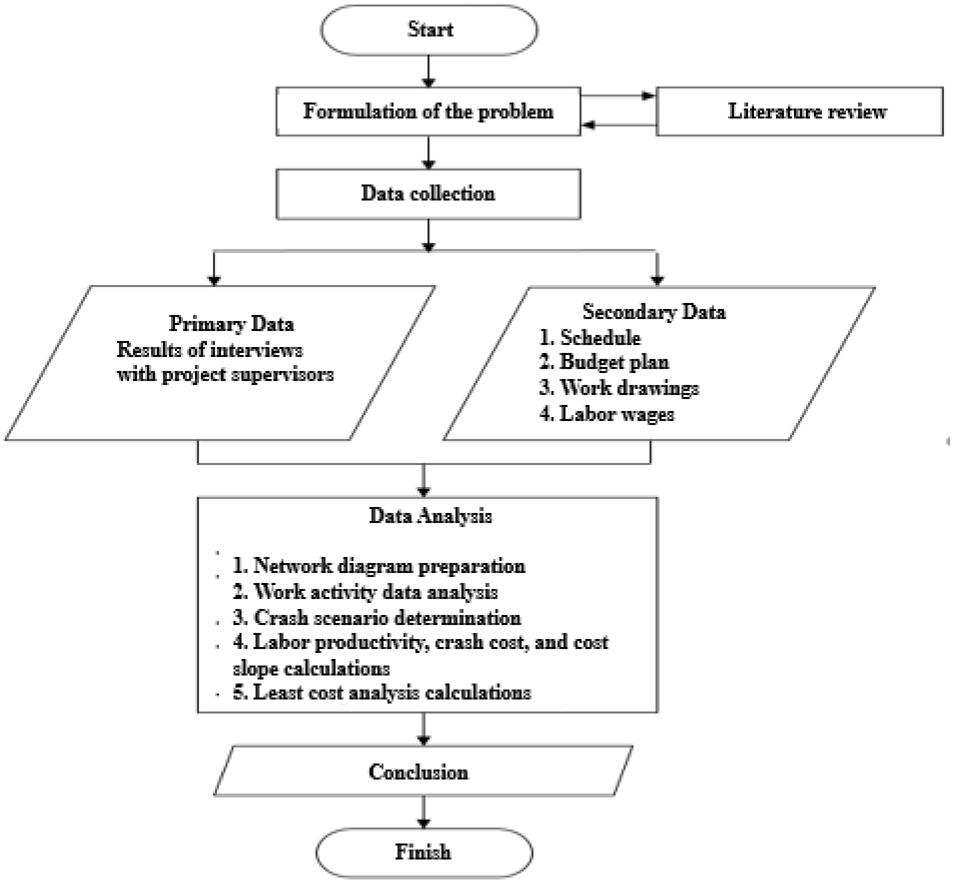

Figure 2. Research Flowchart

RESULTS AND DISCUSSION

The location of the research conducted is the Road and Bridge Construction Project on the SP. Buruan - Senganan - Pacung Provincial road section. The location of this work section is in Senganan Village (Penebel District) and Apuan Village (Baturiti District) of Tabanan Regency, Bali Province. The following location map and location points can be seen in Figure 4, namely, as follows:

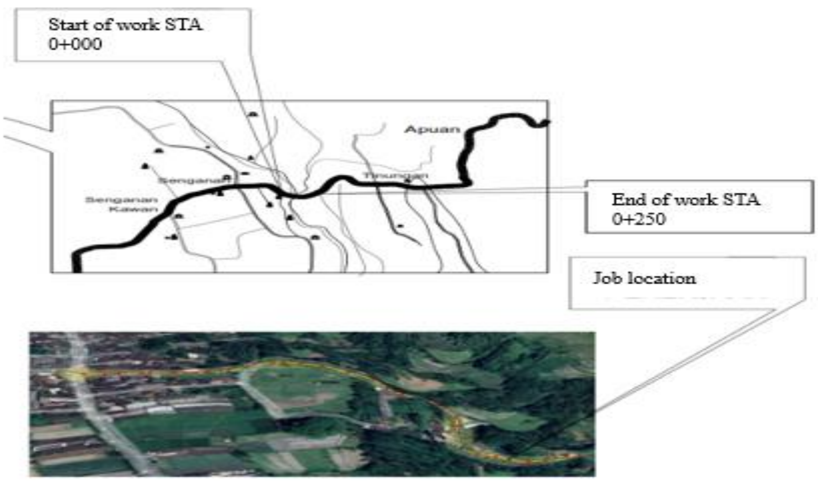

Figure 3. Research Location

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The contract value for the Road and Bridge Construction work on the SP. Buruan - Senganan - Pacung Provincial Road section is Rp. 14,400,000,000, - including 11% VAT. The selection of the implementing contractor uses a tender process and the winner of this project tender is PT. Parama Adhi Pratama as the project implementer and the supervisory consultant was won by CV. Gumi Artha Karya, PT. Ramu Prima Persada, KSO. The Road and Bridge Construction Project on the SP. Buruan - Senganan - Pacung Provincial Road section is planned for 210 calendar days starting on May 19, 2023 and completed on December 14, 2023, in the 28th week, November 20, 2023, the Road and Bridge Construction Project on the SP. Buruan - Senganan - Pacung Provincial Road section has only reached 87.547% of the planned process of 98.158% so that there is a delay in progress of 10.61%.

No	URAIAN PEKERJAAN	Bobot (%)	Bobot (%)	Bobot Rencana (%)	Bobot Realisasi (%)	Deviasi (%)
1	DIVISI 1. UMUM	Unit	4,952			
2	DIVISI 2. DRAINASE	Unit	0,790			
3	DIVISI 3. PEKERJAAN TANAH DAN GEOSINTETIK	Unit	4,079	4,079	4,009	0,070
4	DIVISI 4. PEKERJAAN PREVENTIF	Unit	-			
5	DIVISI 5. PERKERASAN BERBUTIR	Unit	2,595			
6	DIVISI 6. PERKERASAN ASPAL	Unit	11,936	11,936	7,365	4,571
7	DIVISI 7. STRUKTUR	Unit	74,852	74,852	69,253	5,599
8	DIVISI 8. REHABILITASI JEMBATAN	Unit	0,045			
9	DIVISI 9. PEKERJAAN HARIAN & PEKERJAAN LAIN-LAIN	Unit	0,549	0,549	0,179	0,370
10	DIVISI 10. PEKERJAAN PEMELIHARAAN KINERJA	Unit	0,202			
	TOTAL		100,00	98,158	87,548	10,610

Figure 4. Progress Report Data for Week 28, November 20, 2023 [5]

Compiling Network Diagram

After knowing the project work items in the RAB (Budget Plan), the next step is to compile the WBS (Work breakdown structure). In compiling the work breakdown structure, it is arranged into three levels.

Analyzing Remaining Work Activities

Identify the critical path in the Road and Bridge Construction project on the SP. Buruan - Senganan - Pacung Provincial Road section with the Microsoft Project scheduling program, at this work identification stage it is only carried out on remaining work or remaining work activities, critical work that has been completed is no longer included. The delay reviewed will be reviewed in the Progress in the 28th week on November 20, 2023 because the Project has only reached 87.547% of the 98.158% process plan so that there is a delay in progress of 10.61%. To overcome and restore the normal duration of project completion, crashing is carried out on selected work that is on the critical path, which is obtained from the results of network planning. The following is a list of tables that were identified as experiencing delays in project progress which reached 87.547%. shown in Figure 5, namely, as follows:

NO	ITEM PEKERJAAN
3.1.(1)	Galian Biasa
3.1.(4)	Galian Struktur dengan kedalaman 0 - 2 meter
3.1.(7)	Galian Perkerasan Beraspal dengan Cold Milling Machine
3.2.(2a)	Timbunan Pilihan dari sumber galian
3.3.(1)	Penyiapan Badan Jalan
5.1.(1)	Lapis Pondasi Agregat Kelas A
5.1.(2)	Lapis Pondasi Agregat Kelas B
6.1 (1)	Lapis Resap Pengikat - Aspal Cair/Emulsi
6.1 (2a)	Lapis Perekat - Aspal Cair/Emulsi
6.3(5a)	Laston Lapis Aus (AC-WC)
6.3(6a)	Laston Lapis Antara (AC-BC)
7.1 (5a)	Beton struktur, fc’30 Mpa (Ready Mix)
7.1 (9)	Beton Siklop, fc’15 Mpa
7.2.(12b)	Pemasangan Panel Full Depth slab
7.3 (1)	Baja Tulangan Polos-BjTP 280
7.3 (4)	Baja Tulangan Sirip BjTS 420B
7.16.(2a)	Pipa Drainase Baja diameter 150 mm
7.16.(2)	Biaya Pembongkaran gedung
8.3.(1a)	Pengecetan protektif pada elemen struktur beton, tebal 200μm
8.3.(1b)	Pengecetan protektif pada elemen struktur beton, tebal : 240μm
9.2.(1)	Marka Jalan Termoplastik
9.2(10a)	Kerb Pracetak Jenis 1 (Tegak)
9.2.(10c)	Kereb Pracetak Jenis 3 (Kursi)
9.2.(12a)	Perkerasan Blok Beton pada Trotoar dan Median
10.1.(9)	Perbaikan Campuran Aspal Panas

Figure 5. Work items identified as experiencing delays Source: Analysis Results (2024)

Determining Crashing Scenarios

Acceleration of the completion time of construction implementation is carried out by analyzing the planning using the PDM (Precedence Diagram Method) method with the help of Microsoft Project, so that the critical path can be known which is obtained from scheduling data under normal conditions. The number of critical paths obtained is 8 activities in the construction work. The following are the results of the critical path analysis shown in Figure 6, namely, as follows:

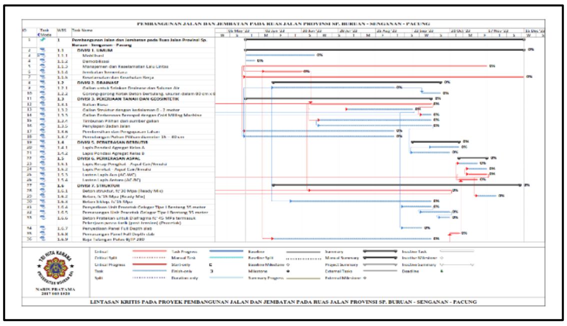

Figure 6. Critical Path Source: Analysis Results using Microsoft Project (2024)

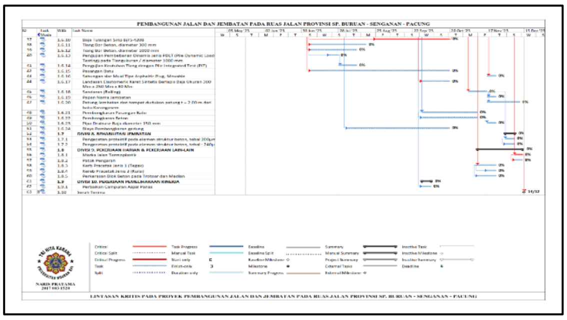

Figure 7. Critical Path Source: Analysis Results using Microsoft Project (2024)

The following are the results of the critical path analysis on the Microsoft Project shown in Figure 8, namely:

WBS ID	ITEM PEKERJAAN	SAT.	DURASI NORMAL
			(Hari)
1	**PROYEK PEMBANGUNAN JALAN DAN JEMBATAN PADA RUAS JALAN PROVINSI SP. BURUAN - SENGANAN - PACUNG**		
1.3.1	Galian Biasa	M3	91,00
1.5.3	Laston Lapis Aus (AC-WC)	TON	14,00
1.5.4	Laston Lapis Antara (AC-BC)	TON	14,00
1.6.1	Beton struktur bervolume besar fc'=30 MPa	M3	
1.6.1	Beton struktur, fc'30 Mpa (Ready Mix)	M3	105,00
1.6.8	Pemasangan Panel Full Depth slab	Buah	7,00
1.6.10	Baja Tulangan Sirip BjTS 420B	KG	56,00
1.8.1	Marka Jalan Termoplastik	M2	6,00

Figure 8. List of critical path results on the Microsoft Project Source: Analysis Results (2024)

Calculation of Labor Productivity, Crash Cost and Cost Slope

Labor productivity affects project costs. One approach to try to measure labor efficiency is to use the productivity index parameter. In the cost slope calculation, the analysis list provided and used by the contractor is used. Calculation of duration to speed up work on the critical path obtained from Microsoft Project output. The supporting data when making calculations, namely the RAB, direct costs and indirect costs, the author obtained from the RAB data of PT. Parama Adhi Pratama, there is a Road and Bridge Construction project on the SP Provincial Road. Buruan - Senganan - Pacung. Here we present it in the form of Figure 9 and Figure 10, namely as follows:

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NO	URAIAN PEKERJAAN	SAT.	BIAYA LANGSUNG *DIRECT COST* (Rp)	
a	b	c	d	
	RENCANA ANGGARAN BIAYA PROYEK PEMBANGUNAN JALAN DAN JEMBATAN PADA RUAS JALAN PROVINSI SP. BURUAN - SENGANAN -			
1	DIVISI 1. UMUM	Unit	Rp	578.154.960,00
2	DIVISI 2. DRAINASE	Unit	Rp	92.215.969,40
3	DIVISI 3. PEKERJAAN TANAH DAN GEOSINTETIK	Unit	Rp	476.298.131,51
4	DIVISI 4. PEKERJAAN PREVENTIF	Unit		-
5	DIVISI 5. PERKERASAN BERBUTIR	Unit	Rp	303.011.550,91
6	DIVISI 6. PERKERASAN ASPAL	Unit	Rp	1.393.595.768,77
7	DIVISI 7. STRUKTUR	Unit	Rp	8.739.534.722,02
8	DIVISI 8. REHABILITASI JEMBATAN	Unit	Rp	5.224.807,07
9	DIVISI 9. PEKERJAAN HARIAN & PEKERJAAN LAIN-LAIN	Unit	Rp	64.049.315,02
10	DIVISI 10. PEKERJAAN PEMELIHARAAN KINERJA	Unit	Rp	23.590.450,97
		TOTAL	Rp	11.675.675.675,67

Figure 9. Direct Costs Source: PT. Parama Adhi Pratama (2023)

NO	URAIAN PEKERJAAN	SAT.	VOLUME	HARGA SATUAN (Rp)	JUMLAH HARGA (Rp)	BIAYA TIDAK LANGSUNG *INDIRECT COST* (Rp)	
a	b	c	d	e	f	d	
	RENCANA ANGGARAN BIAYA PROYEK PEMBANGUNAN JALAN DAN JEMBATAN PADA RUAS JALAN PROVINSI SP. BURUAN - SENGANAN - PACUNG						
1	BIAYA OPRASIONAL LAPANGAN					Rp	604.200.000,00
	a. Administrasi dan Pelaporan		1,00	105.000.000,00	105.000.000,00		
	b. PM		1,00	87.500.000,00	87.500.000,00		
	c. SM		1,00	75.000.000,00	75.000.000,00		
	d Pelaksana		2,00	57.500.000,00	115.000.000,00		
	e. Surveyor		2,00	60.000.000,00	120.000.000,00		
	f Logistik		2,00	30.875.000,00	61.750.000,00		
	g Biaya Mob Demob Pekerja dan Material		1,00	25.000.000,00	25.000.000,00		
	h Biaya Adminstrasi Pekerja (kipem)		1,00	1.950.000,00	1.950.000,00		
	i Kendaraan Proyek		2,00	6.500.000,00	13.000.000,00		
2	SEWA MESS PEKERJA DAN LITRIK					Rp	44.448.648,65
	a. Sewa Mess Pekerja		1,00	13.500.000,00	13.500.000,00		
	b. Sewa listrik		1,00	30.948.648,65	30.948.648,65		
A	BIAYA *OVERHEAD*				648.648.648,65	Rp	648.648.648,65
B	BIAYA *PROFIT*				648.648.648,65	Rp	648.648.648,65
C	TOTAL BIAYA TIDAK LANGSUNG (*INDIRECT COST*)				1.297.297.297,30	Rp	1.297.297.297,30

Figure 10. Direct costs Source: PT. Parama Adhi Pratama (2023)

Calculation of Labor Productivity

Labor productivity affects project costs. One approach to try to measure labor efficiency is to use the productivity index parameter. Productivity decreases when the number of hours per day and days per week increases. Example of Calculation of Division 7. Structural work, namely Structural Concrete Work fc'=30 MPa (Ready Mix), as follows:

Normal time is daytime with a total working hours of 8 hours, starting at 08:00 to 17:00.

1. Calculation of the number of workers

   Number of Workers = Labor coefficient x Volume of work
   a. Workers = 0.8032x1,097.86=882 people
   b. Craftsmen = 1.1044x1,097.86=1212 people
   c. Foreman = 0.35x1,097.86= 384 people

2. Calculation of the number of workers against the duration

   = Number of workers / Duration
   Where the normal duration is: 105 days
   a. Workers = 882 / 105 = 9 people / day
   b. Craftsmen = 1,212 / 105 = 12 people / day
   c. Foreman = 384 / 105 = 4 people / day

3. Volume productivity per day

   Daily productivity = Volume / Normal Duration
   = 1,097.86 m3 / 105 days
   = 10.45 m3 per day

4. Volume productivity per hour

   Hourly productivity = Daily productivity / Working hours per day (8 hours)
   = 10.45 m3 per day / 8 hours
   = 1.3 m3 per hour

Overtime productivity total time 4 hours, starting at 18:00 to 22:00.

Calculation with 4 hours of overtime

1. Work Performance
   = 0.1 x 4 hours = 0.4 per hour
2. Work Performance Percentage
   = 0.4 x 100% = 40%
3. Percentage coefficient of productivity decrease due to 4 hours of overtime
   = 100% - 40% = 60% = 0.6
4. Normal Duration
   = 105 days
5. Activity Volume
   = 1,097.86 m3
6. Daily Productivity
   = 10.45 m3/day
7. Hourly Productivity
   = 1.3 m3/hour
8. Productivity due to 4 hours of overtime
   = (a x b x hourly productivity)
   = (4 x 0.6 x 1.3)
   = 3.12 m3 per 4 hours
9. Daily productivity after crash = (hours worked per day x hourly productivity + (a x b x hourly productivity) hours)
   = (8 hours x 1.3 m3 per hour) + (4 hours x 0.6 x 1.3 m3 per hour)
   = 13.52 m3 per day

Calculation of Crash Cost, Crash Duration and Cost Slope

In this analysis, the acceleration of duration is done by adding 4 hours of work. Example of calculating the crash cost of workers for the Concrete structure work fc'=30 MPa with 4 hours of overtime. The cost of accelerated time wages (overtime) for the Concrete structure work fc'=30 MPa if accelerated for 1 day, there is an increase due to the price of overtime wages per hour, the cost of lighting working at night and the addition of consumption costs outside of workers' wages. So it can be calculated as follows:

Normal Time is daytime time with a total working hours of 8 hours, starting at 08:00 to 17:00.

1. Normal duration labor wage costs (Wages are obtained from the contractor)

Labor wage costs = Daily wages x Number of workers

a. Workers = 135,000 x 9 people
   = Rp.1,215,000.00
b. Craftsmen = 162,000 x 12 people
   = Rp.1,944,000.00
c. Foreman = 175,500 x 4 people
   = Rp.702,000.00

Total = Rp.3,861,000

2. Calculation of additional working hours (overtime) for 4 hours (Hourly wages are obtained from the contractor).

Overtime labor cost for 4 hours (6:00 p.m. to 10:00 p.m.)
= (first overtime hour × 1.5 × one-hour wage) + (next overtime hour × 2 × one-hour wage)

a.. Worker = (1 x 1.5 x 19,396.68) + (3 x 2 x 19,396.68)
= Rp. 145,475.10

b. Craftsman = (1 x 1.5 x 23,227.01) + (3 x 2 x 23,227.01)
= Rp. 174,202.50

c. Foreman = (1 x 1.5 x 25,155.58) + (3 x 2 x 25,155.58)
= Rp. 188,660.85

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3. Labor wage cost for Accelerated overtime duration for 4 hours.

Labor wage cost = Wages per day x Number of workers
a.. Workers = Rp. 145,475.10 x 9 people
= Rp. 1,309,275.90
b. Craftsmen = Rp. 174,202.50 x 12 people
= Rp. 2,090,430.90
c. Foreman = Rp. 188,660.85 x 4 people
= Rp. 754,643.40
Total Rp. Rp. 4,154,374.20
d. Additional costs during overtime
Rp. 800,000.00.
= Rp. 4,154,374.20 + Rp.
800,000.00
= Rp. 4,954,374.20

4. Crash Cost of Workers Per Day

Normal cost of workers per day + overtime cost per day
= Rp. 3,861,000.00 + Rp.
4,954,374.20
=Rp. 8,815,374.20
Crash Duration
= Crash duration
Volume/(Daily productivity after crash)
= 1,097.86 m^3
13.52 m3
= 81.2 days ~ 81 days

5. Cost Slope

= Acceleration Cost – Normal Cost
Normal Time – Acceleration Time
= Rp. 4,954,374.20 - Rp. 3,861,000.00
105 days – 104 days
= Rp. 1,093,374.20

With the help of Microsoft Excel, the same calculation is carried out as the example of the cost slope calculation description, on all jobs that are on the critical path / which are crashed with the addition of 4 hours of work, the results of the cost slope calculation will be displayed in the form of Figure 11, namely, as follows:

NO	ITEM PEKERJAAN	DURASI NORMAL	DURASI DIPERCEPAT	BIAYA NORMAL	BIAYA DIPERCEPAT	COST SLOPE	DURASI PERCEPATAN
		(Hari)	(Hari)	(Rp)	(Rp)	(Rp)	(Hari)
1	**PROYEK PEMBANGUNAN JALAN DAN JEMBATAN PADA RUAS JALAN PROVINSI SP. BURUAN - SENGANAN - PACUNG**						
1	Galian Biasa	91	91,00	11.102.445,21	11.132.946,43	30.501,22	1
2	Marka Jalan Termoplastik	6	6,00	755.172,21	786.637,72	31.465,51	1
3	Laston Lapis Antara (AC-BC)	14	14,00	1.979.246,58	2.014.590,26	35.343,69	1
4	Laston Lapis Aus (AC-WC)	14	14,00	15.736.000,00	16.017.000,00	281.000,00	1
5	Pemasangan Panel Full Depth slab	7	7,00	23.220.335,62	24.049.633,32	829.297,70	1
6	Baja Tulangan Sirip BjTS 420B	56	55,00	200.925.095,89	201.822.082,93	896.987,04	1
7	Beton struktur, fc'30 Mpa (Ready Mix)	105	104,00	405.405.000,00	406.498.374,20	1.093.374,20	1
	TOTAL BIAYA PERCEPATAN					**3.197.969,36**	

Figure 11. Cost Slope Calculation due to the addition of 4 hours of work and acceleration duration
Source: Analysis Results (2024)

Least Cost Analysis Calculation

After obtaining the cost slope value for each critical activity, it is continued by finding the lowest cost slope value. Then, compression is carried out on the work with the lowest cost slope value, namely ordinary excavation work. In accelerating the completion of a project by compressing the duration, it is attempted to minimize the addition in terms of costs. Cost control is carried out on direct costs because these costs will increase if the duration is reduced (accelerated) until it reaches the duration according to the contract. The calculations in the compression stage are as follows:

TAHAP	WAKTU	WAKTU KONTRAK	TOTAL WAKTU
WAKTU TERLAMBAT	10,61%	210 HARI	232 HARI
WAKTU *LEAST COST ANALYSIS*	-	210 HARI	210 HARI

Figure 12. Results of Acceleration of Road and Bridge Construction Projects on the SP. Buruan - Senganan - Pacung Provincial Road Section Source: Analysis results (2024)

Normal Stage

1. Project Duration = 210 days

2. Remaining Direct Costs

= Cumulative Remaining Normal Duration x Direct Costs
= 1.843% x Rp. 11,675,675,675.67
= Rp. 215,182,702.70

3. Indirect Costs

= Overhead Costs + Profit Costs
= Rp. 648,648,648.65 + Rp.
648,648,648.65
= Rp. 1,297,297,297.30

4. Overhead Costs per Day of Normal Time

= Total Overhead Costs / Normal Duration Time
= Rp. 648,648,648.65 / 210 days
= Rp. 3,088,803.08
Delay Stage (analysis results using the lowest cost slope, namely regular excavation work)

1. Crash Duration = 683.25 m3 / 9.84 m3 = 69 days

= 91 days – 69 days = 22 days

2. Direct Delay Cost

= Rp. 11,675,675,675.67

3. Overhead Cost due to delay

= Duration of the project is late x Overhead Cost per day
= 22 days x Rp. 3,088,803.09
= Rp. 67,953,667.95

4. Total Overhead Cost

= Total normal Overhead Cost + Overhead Cost due to delay
= Rp. 648,648,648.65 + Rp.
67,953,667.95
= Rp. 716,602,316.60

5. Total Cost according to project duration due to delay

= Total Direct Cost + Total
Overhead Cost due to delay
= Rp. 11,675,675,675.67 + Rp.
716,602,316.60
= Rp. 12,392,277,992.28
Compression Stage 1

1. Work = Regular excavation

2. Cost Slope per day = Rp. 30,501.22 per day

3. Total Delay Time = 232 days

4. Acceleration Time = 7 days

5. Remaining Delay Time = 225 days

6. Additional Cost

= Cost Slope x Acceleration Time
= Rp. 30,501.22 x 7 days
= Rp. 213,508.56

7. Additional Overtime Cost

a. Workers = Rp. 145,475.10 x 5 people
= Rp. 727,325.50
b. Foreman = Rp. 188,660.85 x 1 person
= Rp. 188,660.85
Total Rp. 916,036.35
c. Additional cost during overtime
Rp. 250,000.00
= Rp. 916,036.35 + Rp. 250,000.00
= Rp. 1,116,036.35
Overtime wage cost per 4 hours x acceleration time
= Rp. 1,116,036.35 x 7 days
= Rp. 7,812,254.45

8. Direct Cost

= Total Direct Cost + Additional
Cost + Additional Overtime Cost
= Rp. 11,675,675,675.67 + Rp. 213,508.56 + Rp. 7,812,254.45
= Rp. 11,683,701,438.68

9. Indirect Cost (Overhead Cost)

= (Overhead Cost per day x remaining time)
= (Rp. 3,088,803.08 x 225 days)
= Rp. 694,980,694.98

10. Total Cost

= Direct Cost + Indirect Cost
= Rp. 11,683,701,438.68 + Rp.
694,980,694.98
= Rp. 12,378,682,133.66
Compression Stage 2

1. Work = Regular excavation

2. Cost Slope per day = Rp. 30,501.22 per day

3. Total Late Time = 225 days

4. Acceleration Time = 5 days

5. Remaining Late Time = 220 days

6. Additional Cost

= Cost Slope x Acceleration Time

= Rp. 30,501.22 x 5 days
= Rp. 152,506.12

7. Additional Overtime Cost

a. Workers = Rp. 145,475.10 x 5 people
= Rp. 727,325.50
b. Foreman = Rp. 188,660.85 x 1 person
= Rp. 188,660.85
Total Rp. 916,036.35
c. Additional cost during overtime
Rp. 250,000.00
= Rp. 916,036.35 + Rp.250,000.00
= Rp. 1,116,036.35
Overtime wage cost per 4 hours x acceleration time
= Rp. 1,116,036.35 x 5 days
= Rp. 5,580,181.75

8. Direct Cost

= Total Direct Cost Result
Compression 1 + Additional Cost +
Additional Overtime Cost
= Rp. 11,683,701,438.68 + Rp.
152,506.12 + Rp. 5,580,181.75
= Rp. 11,689,434,126.55

9. Indirect Cost (Overhead Cost)

= (Overhead Cost per day x remaining time)
= (Rp. 3,088,803.08 x 220 days)
= Rp. 679,536,679.54

10. Total Cost

= Direct Cost + Indirect Cost
= Rp. 11,689,434,126.55 + Rp.
679,536,679.54
= Rp. 12,368,970,806.08

After calculating Direct Cost and Indirect Cost by accelerating 7 days, 12 days, 17 days, 21 days and 22 days by adding 4 hours of overtime work each day, the optimal acceleration of project completion will be selected.

From the results of the compression calculation using the Least Cost Analysis method in Table 8, a graph of the relationship between direct costs, indirect costs, and total costs with the project duration is obtained, as seen in Figure 13, Figure 14 and Figure 15, namely, as follows:

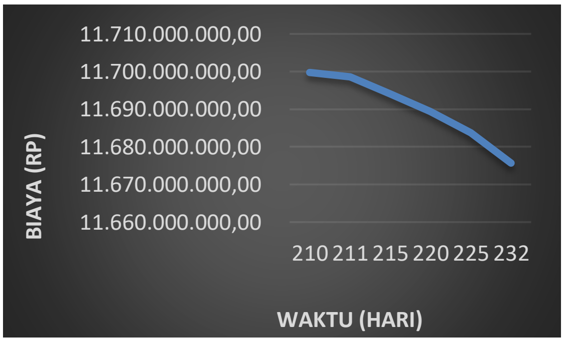

Figure 13. Graph of the relationship between direct costs and project duration due to the addition of 4 hours of working time per day Source: Results (2024)

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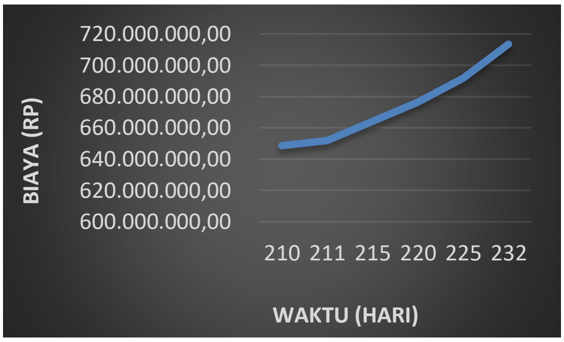

Figure 14. Graph of the relationship between indirect costs and project duration due to the addition of 4 hours of working time per day Source: Analysis Results (2024)

Figure 15. Graph of the relationship between direct and indirect costs with project duration due to the addition of 4 hours of working time per day Source: Analysis Results (2024)

After the compression stage was carried out on activities on the critical path using the Least Cost Analysis method and starting from the job with the lowest cost slope value, the changes in time and costs that occurred due to the addition of 4 hours of working time (overtime) per day can be seen. When reaching the contract time of 210 days (232 days of available time) according to the calculation figure 15 which is marked in blue, it is an acceleration until the 5th compression, the total project cost was obtained at Rp. 12,349,548,150.93. The results of the calculation of the compression stage using the Least Cost Analysis method, obtained the amount of the fine due to the delay of 22 days with the following calculation:

1. Fine Per Day

= Duration of Delay x Fine per
day x Project Contract Cost excluding VAT
= 22 days x (1/1000) x Rp. 12,972,972,972.97
= Rp. 285,405,405.41 per 22 days
= Rp.12,972,972.97 per day

2. And the fine must not be greater than 5% of the total project contract

= 5% x Total Project Contract Cost before VAT.
= 5% x Rp. 12,972,972.97
= Rp. 648,648,648.65

3. Total late fine ≤ 5% of the total project contract cost

Rp.285,405,405.41 ≤ Rp.648,648,648.65

Then the total fine that must be paid if the project is delayed by 22 days is Rp. 285,405,405.41 and Rp. 12,972,972.97 per day, this fine does not include VAT. The results of the recapitulation of the comparison of duration and costs between normal or late time projects and after being accelerated can be seen in figure 16, namely, as follows:

NO	PEKERJAAN	DURASI	BIAYA LANGSUNG *(DIRECT COST)*	BIAYA TIDAK LANGSUNG / BIAYA *OVERHEAD (INDIRECT COST)*	BIAYA TIDAK LANGSUNG / BIAYA PROFIT *(INDIRECT COST)*	DENDA KETERLAMBATAN 22 HARI	TOTAL BIAYA
		(hari)	*(Rp)*	*(Rp)*	*(Rp)*	*(Rp)*	*(Rp)*
1	Proyek Waktu Normal	210 hari	11.675.675.675,67	648.648.648,65	648.648.648,65		12.972.972.972,97
2	Proyek Waktu terlambat 232 hari	232 hari	11.675.675.675,67	716.602.316,60	648.648.648,65	285.405.405,41	13.326.332.046,34
3	Proyek dipercepat 22 hari	210 hari	11.700.899.502,28	648.648.648,65	648.648.648,65		12.998.196.799,58

Figure 16. Recapitulation of the comparison of project acceleration costs Source: Analysis results (2024)

CONCLUSION

Based on the results of the analysis using the Least Cost Analysis method on the Construction of Roads and Bridges on the SP. Buruan - Senganan - Pacung Provincial Road section, from a delay time of 232 days, an acceleration of 22 days was carried out so that it became 210 days or in accordance with the project contract and an acceleration time efficiency of 10.61% was obtained. Based on the results of the analysis using the Least Cost Analysis method on the Construction of Roads and Bridges on the SP. Buruan - Senganan - Pacung Provincial Road section, to be able to restore the duration of the 22-day delay in the progress of the work plan, it can be done by adding 4 hours of work on the jobs that are on the critical path. After the acceleration was carried out, a total cost of Rp. 12,349,548,150.93 was obtained, a cost efficiency of Rp. 328,135,246.76 or 2.52% of the total cost of the delay was obtained.

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