ANALYSIS OF THE ACCELERATION TIME AND OPTIMAL COSTS OF THE SHIPBUILDING PROJECT SPECIFIED IN THE ELECTRICAL SYSTEM WITH THE CRITICAL PATH METHOD

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ABSTRACT

PT PAL Indonesia (Persero) is one of the strategic defense industries that produces Main Weapon Systems (Alutista) especially for the Indonesian Navy, and has a strategic role in supporting the development of the national marine industry. One of the benchmarks for the success of a new shipbuilding project is the length of time to complete both the stages of the production process and the entire project in addition to cost and quality of work. Therefore, research was conducted to optimize the planning of the production process time for a new shipbuilding project by creating a project network, looking for critical activities, and calculating the project duration. The method used to analyze costs and time is the critical path method, by accelerating the duration of activities that are on the critical path, then calculating changes in project costs that occur due to acceleration. The research objective with this critical path method is to determine the time and cost of the project and what activities are included in critical activities. In addition, it is also to control and coordinate various activities so that the project can meet the right timeframe and can also help companies plan and control projects in a more efficient time and cost. From the results of the analysis of project calculations during the initial conditions with normal working days without using overtime the company spent Rp. 1,963,108,000. Critical activities in initial conditions with 870 days for completion time conditions are accelerated by 710 days (total acceleration 160 days) with 16 critical trajectories covering 34 work activities where all activities enter critical trajectories. The difference between the initial working conditions and the accelerated conditions was 160 days. The new ship building project in the electrical system can be accelerated for 160 days at an additional cost of Rp. 3,525,214,127.

Keywords: *Shipbuilding project, Critical Path Method, Acceleration of time, and costs.*

1. INTRODUCTION.

Indonesia, the largest archipelagic state in the world, consists of oceans covering two-thirds of Indonesia's territory. Also, Indonesia is one of the countries with the longest coastline in the world. As a maritime country, Indonesia's geographical position lies in the tropics, in a crossing between two continents (Asia and Australia) and two oceans (Indian and the Pacific Ocean), and it has the potential and opportunities for the development of the marine industry to become national economic strength. Indonesia as a maritime country continues to develop and upgrade the fleet sea with good additions the number and type of combat fleet as well supporting fleet. This is confirmed through Law Number 34 of 2004 about the roles and duties of the Indonesian Navy in Article 9 that the TNI has duties and responsibility to build and develop the strength of the marine dimension aims to enforce the law and maintain security and territorial sovereignty sea following national laws and laws which has been ratified.

The construction of this ship takes a long time in one part of the shipbuilding project. The difficulties are in the electrical system which was going to be combined in erections, so planning is essential to control the work so that time efficiency occurs. PT. PAL Indonesia (Persero) as an international standard shipbuilding company is required to be able to meet the effective completion time in building new ships to be able to complete the next project with better results than the previous project. Cases of project delays at

shipyard companies are usually caused by various factors, such as delays in materials, human resources, and equipment facilities. If there are material obstacles or human resources problems in the production process, each activity is less effective and it could cause delay of the completion, resulting in the emergence of a critical trajectory on the activities in the ship's electrical system. If those problems happen, there will be a lot of excess in some parts of the production. This in turn will cause an increase in production expenditures or delay in completion of production, consequently results in large losses to the shipyard industry. To support its activity, the implementation of project management is very helpful in dealing with problems that often arise in a project. Several methods have been developed to overcome this problem, including the Network Planning method.

There are two basic methods commonly used in Network Planning, namely the Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT). Scheduling is the basic technique commonly used in Network Planning is the CPM (Critical Path Method) method intended to analyze the critical path of work,. CPM or the critical path method is a project management technique that uses only one factor of time per activity and is the fastest path to working on a project. Every project included in this pathway is not given a rest period for its work, assuming that the estimated time for the project activity stages and its dependencies are logically correct. The critical path concentrates on time and cost tradeoffs. This activity is a project activity model described in the form of a network used for planning, scheduling, and controlling the project. Optimal duration in project implementation can be obtained by using a supporting application that can be used in planning and scheduling the activities of a project, all of which aim to optimize the work of a project so that there will be efficiency in terms of cost and execution time of the ship being built.

Project delays are a common problem. This delay is very detrimental to the parties involved, both the contractor and the project owner itself (Soeharto, 2010). Speeding up the time to complete the project is an attempt to complete the project earlier than the completion time in normal circumstances. There are times when the project schedule must be accelerated with various considerations from the project owner. The process of speeding up this time is called a program crash by accelerating the duration of activities located on the critical path and has the lowest cost slope, then calculating the changes in project costs that occur due to acceleration. This method is carried out continuously until the network with a critical path reaches a saturated condition, which means that it is no longer possible to reduce the implementation time (optimal point) on the critical path. Construction projects need to be carried out with proper planning and control so the acceleration of project implementation with the least additional cost could be done.

By using the Critical Path Method (CPM) the planning process all activities that must be completed in the project will be easier. CPM will include the entire list of activities required to complete the project, the time or duration required of each activity, and HR planning. From this process, the critical path from a network diagram, in which some activities can be found the manufacturing time can be shortened to obtain project work the most efficiently.

2.   MATERIAL & METHODOLOGY
2.1   Project Management

Project management determines the success of a project's work. One of the problems commonly faced in projects is the problem of delay in work. Delays in a project that can be caused due to certain reasons, such as problems with labor availability, weather problems, and other problems so that good management is needed to overcome these delays. (Soeharto, 2001).

2.2. Project Scheduling

According to (Lawrence, 2001), many project scheduling objectives are covering:

a. Determine the earliest and last schedule of start and end times for each activity leading to the earliest completion time for the entire project.

b. Calculates the likelihood that the project will be completed within a certain time frame.

c. Look for the minimum cost schedule that will complete a project by a specific date.

d. Investigate how delays for specific activities affect the overall turnaround time of the project.

e. Monitoring a project to determine whether it is running on time and within budget.

f. Look for a schedule of activities that will smooth the allocation of resources throughout the project.

2.3 Network Planning

According to (Herjanto, 2003), Network Planning is defined as a model that is widely used in project implementation, the product of which is information about the activities contained in the network diagram concerned. It can be concluded that network planning is a planning and controlling project that describes the dependency relationship between each job depicted in the network diagram.

2.4 Optimization Analysis

Optimization analysis is defined as a process of decomposing project duration to obtain the best (optimal) duration acceleration by using various alternatives in terms of cost. The process of shortening the activity time in the network to reduce the time on the critical path, so that the total completion time can be reduced is referred to as project crashing (Heizer, 2005).

2.5 CPM (Critical Path Method)

According to Schroeder in the book Project Management by Hamdan Dimyati and Kadar Nurjaman (2014:338), that is:
"Critical Path Method (CPM)" is a network-based method that uses a linear time-cost balance. Each activity can be completed faster than normal by cutting activities for a certain amount of cost. Thus, if the project completion time is not satisfactory, certain activities can be cut short to complete the project in less time ". In operation CPM (Critical Path Method) is a method using arrow diagrams to determine the critical path so it is also called the critical path method. CPM uses a certain number of estimated activity duration.

2.6 Optimum Time Analysis of Network Planning

One of the important things in project analysis is knowing when the project can be completed. To answer this, it is necessary to know in advance the time required for each activity, its relationship to other activities, and when the activity starts and ends. After these things are known, the next step is to carry out the calculations, while the calculation method that must be done consists of two ways, namely forward computation and backward computation. So that by doing the two calculations, it can be seen the critical path and also when the project or production can be completed.

a. Forward Computation

The forward calculation is the calculation of moving from the initial event to the terminal event. The point is to calculate the time that the event occurs at the earliest and when the activities start and finish at the earliest.

b. Backward Computation

In a countdown, the calculation moves from the terminal event to the initial event. The objective is to calculate the time at the latest events occurring and

the time at the latest at the start and completion of activities (TL, LS, and LF).

2.7 Calculation of Allowance Time (Float or Slack)

Activities that can be postponed or have leeway in the process of processing can be found after doing forward and backward calculations. This slack/float can be used for scheduling without causing delays in the overall completion of the project or production. There are two types of allowance in network planning, namely total float, and free float.

According to Tjutju Tarliah Dimyati and Ahmad Dimyati (2006: 186-189): "Total float is the amount of time in which the completion time of an activity can be postponed without affecting the fastest time of completion of the overall project".

The total float is calculated by finding the difference between the slowest times starts of the activity with the earliest start of the activity. If you are going to use the equation (S = LS - ES), or it can be calculated by finding the difference between the time the activity is completed at the latest and the time the activity is completed the fastest (S = LF - EF)

Formula:

$S = LS - ES$

Where:

S = Total float

LS = when the activity starts at the latest

ES = the fastest time the activity starts

"Free float is the amount of time during which the completion of an activity can be measured without affecting the time that other activities start at the earliest or when other events occur in the network the earliest."

Meanwhile, free slack is calculated by finding the difference between the fastest time the event occurs at the end of the activity and the fastest time the activity is completed (SF = TE - E - t)

Formula:

$SF = EF - ES - t$

Where:

SF = Free Sloat

EF = The fastest time the activity is completed

ES = The fastest time to start the activity

T = the time required for an activity

An activity that has no leeway (float) is called a critical activity, in other words, a critical activity has S = SF = 0

2.8 Gantt Chart

This method was first developed by Henry L. Gantt. The principle is to describe work activities in graphical form with a time scale. Here is information about the scope of the initial task that must be completed as a condition for completing the next task.

2.9 Cost Calculation

To shorten the known critical path, there are several control methods. Especially in terms of controlling project costs which include:

a. **Manpower**: After a list of jobs and tasks for each is compiled, it can be directly drawn into a Gantt chart.

b. **Crash Program**: This program is to speed up the time of the network that has a known critical path.

After knowing the time cost elements above, you can calculate how much it costs to shorten one day using the formula:

$$\text{The slope of Costs} = \frac{\text{Shortened fees - Normal fees}}{\text{Time shortened - Normal time}}$$

c. Managing change: During project implementation, it is often necessary to adjust plans and realities.

2.10 Research Methodology

To solve problems in the observed research, steps are needed and determined to describe the approach and model of the problem. The steps taken are.
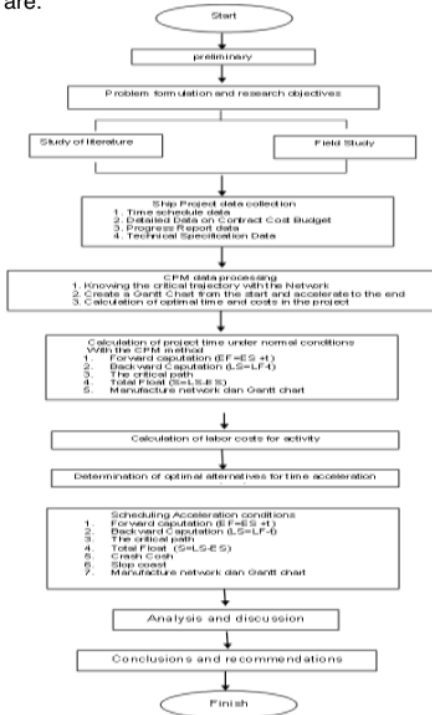

Figure 1. Research Flow Chart

3. RESULT AND DISCUSSION.

3.1 Job Description and Duration

Planning is the determination of the requirements for the project sources of the order of use in the various operations that must be carried out to achieve the desired goals. However, planning is incomplete if it is accompanied by time factors, but time should be flexible about financial, social, and other factors in planning. While the relationship between activities and duration, each activity can be seen in the tables below:

Table 1. description of activities, predecessor activities, duration of activities

No	Type of activity	Activity Predecessor	Activity	Time (day)
	PREPARATORY WORK			
1	Drawing/Design	0	A	120 day
2	Input Material	A	B	80 day
3	Material Inspection	B	C	40 day
	FABRICATION			
4	Coming	D	E,F,G	82 day
5	Main Cable Way	E	H	8 day
6	Sub Cable Way	F	L	6 day
7	Seat Panel	G	P	12 day
	INSTALL			
	Main Cable Way			
8	a.1 Main Gladak	H	I,L,P	25 day
9	a.2 Gladak I	I	J,M,Q	36 day
10	a.3 Gladak II	J	K,N,R	33 day
11	a.4 Gladak II	K	S	17 day
	Sub Cable Way			
12	b.1 Main Gladak	L	M	18 day
13	b.2 Gladak I	M	N	10 day
14	b.3 Gladak II	N	O	12 day
15	b.4 Gladak III	O	P	17 day
16	Seat Panel	P	Q	12 day
	CABLING			
17	Cutting Cable	Q	R	18 day
18	Wiring Cabel	R	S	20 day
19	Reraplan Cabel	S	T	36 day
20	Connecting Cabel	T	U,V,W	166 day
21	Cek Line Cable	W	X	27 day
22	Merger Test	X	Y	17 day
23	Compound	Y	Z	42 day
24	Test Eunction	Z	Z1	16 day
	Amount			870 day

3.2 Project Cost

Estimated project costs play an important role [10] in the implementation of a project with the implementation of project activities starting from the planning, implementation, and control stages that will be calculated in value for money. So experience and thoroughness will be very important in preparing project forecast plans (Soeharto, 1997). There are several types of costs associated with construction project financing, namely the types of direct costs (Direct Cost) and indirect costs (Indirect Cost).

3.3 Direct Cost

Direct costs are all costs that are directly related to the implementation of construction work in the field. Direct costs can be obtained by multiplying the volume/quantity of a job by the unit cost of the work. The work unit price consists of the price of materials, labor wages, and equipment costs. In Table 2. a list of material/component prices used by the company to carry out electrical system installation work on ships

Table 2. List of Material Prices in Electrical Installations

No	Material	Harga/Unit (RP)
	POWER SUPPLY EQUIPMENT	
1	Main Switch Board :	662.500.000,00
	- Emergency switch board	Include MSB
	- Batteries	Include MSB
	- Charging and Discharging Panels for Battery	Include MSB
	- Power Supply Voltage Converter Equipment	Include MSB
2	Main Transformator	55.000.000,00
	- Distribution Panels	Include MSB
	ILLUMINATION AND NAVIGATION LIGHTING EQUIPMENT	
3	Fluorencent Lights	150.525.000,00
	- Incandescent Lights	Include above
	- Navigation light and Signal light	Include above
	COMMUNICATION,INSTRUMENTATION AND ALARM SYSTEM	
4	Ship Service Monitoring System	105.500.000,00
5	Internal Communication	8.930.712.500,00
	- Telephone Set	Include above
	- SPT System	Include above
	- PA Talk	Include above
	NAUTICAL AND RADIO EQUIPMENT	
6	Echo Sounder	3.165.608.129,00
	- Speed Log	Include above
	- ECDIS	Include above
	- GPS Receiver	Include above
	- Radar	Include above
	- EPIRB	Include above
	- Gyro & Magnetic Compass	Include above
	- Weather Facimile	Include above
	- SART	Include above
	- Radio Communication (GMDSS A-3)	Include above
7	NAUTICAL AND RADIO EQUIPMENT	3.165.608.129,00
	Echo Sounder :	Include above
	- Speed Log	Include above
	- ECDIS	Include above
	- GPS Receiver	Include above
	- Radar	Include above
	- EPIRB	Include above
	- Gyro & Magnetic Compass	Include above
	- Weather Facimile	Include above
	- SART	Include above
	- Radio Communication (GMDSS A-3)	Include above
	ELECTRICAL CABLING AND RELATED MATERIAL	
8	Cable for Power	363.784.500,00
	- Cable for Electronic	Include above
	- Cable for Control & Automation	Include above
	Tactical Communication	1.379.797.500,00
9	ELECTRICAL Outfiting	
	Raceway	376.604.980,00
10	Cable Hanger	Include above
	Cable Gland	Include above
	Terminal Lug	Include above
	Junction Box	Include above
	Cable Tie	Include above
	Amount	15.190.002.609,00

Meanwhile, direct labor costs include labor that is directly related to activities or directly working in the field. Table 3. presents a list of daily labor wages for normal hours.

Table 3. Wages / Salary of Labor / Day

No	Type of Worker	Work unit	Unit price (Rp)
1	Head of the workshop	Day	375.000,00
2	Group Leader	Day	275.000,00
3	Technician	Day	275.000,00
4	Repairman	Day	185.000,00

Overtime wages are calculated per working day which is adjusted to the job title of each worker. Overtime work can be held at any time if it is necessary, such as to catch up on a project completion time in case of a setback. Overtime is done 2 hours a day after normal working hours. The following Table 4. provides the cost of overtime pay per day for each employee position:

In a day there are 8 normal working hours, namely 08.00-12.00 WIB, 13.00-17.00 WIB, and 1 hour of rest. If there is a maximum of 3 hours of overtime a day, starting from 17.00-20.00 WIB. In 1 week there are 5 working days, Saturday and Sunday holidays, for overtime payment calculation 1/173 x Basic Salary = Tariff, this is by the Decree of the Minister of Manpower Number KEP.102 / MEN / VI / 2004 article 11, if any employees who enter that day are declared overtime for 6 hours starting from the first hour, except for employees who are all-in.

3.4 Indirect Costs

Indirect costs can be expressed as related to activities including the exploitation of equipment and machines, expenses for supervisors, field administration, supervision costs, and others. (Soeharto; 1997) costs that include indirect costs are:

a. Costs included in overhead are a component of costs including company operating expenses that are charged to the project.

b.	Contingencies. The contingency is the cost reserve of an estimated cost or budget to be allocated to items that have not been determined, which according to experience and statistics show that it is always needed. The farther the project goes, the more data and information is input, so there will be many uncertain problems, as well as contingencies. In general, this cost is required between 0.5% -5% of the total project.

## 3.5	Calculation of Project Time with CPM

In CPM scheduling, the activities in the project are classified into critical activities and non-critical activities. In the arrangement of scheduling in project activities, there are a number of activities that must be done as soon as possible, because these activities have the longest processing time sequence. These activities are called critical activities and the path through which they are passed is the critical path or critical path. To determine the critical trajectory is calculated using forward and backward calculations.

Table 5. Foward Computation Initial Conditions

Activities	Node Start	Node Finish	Duration	ES	EF = ES + t
1	0	1	160	0	160
2	1	2	120	160	280
3	2	3	80	280	360
4	3	4	12	360	372
5	4	6	16	372	388
6	4	5	38	372	410
7	4	7	37	372	409
8	5	8	6	410	416
9	6	12	4	388	392

Table 6. Backward Computation Initial Conditions

Activities	Node Start	Node Finish	Duration	LF	LS = LF - t
1	0	1	160	160	0
2	1	2	120	280	160
3	2	3	80	360	280
4	3	4	12	372	360
5	4	6	16	430	414
6	4	5	38	410	372
7	4	7	37	463	426
8	5	8	6	416	410
9	6	12	4	434	430
10	7	16	10	473	463
11	8	12	4	434	430
12	8	9	8	424	416
13	12	13	6	440	434
14	9	13	16	440	424
15	9	10	12	440	428
16	13	14	8	448	440
17	10	14	8	448	440
18	10	11	14	501	487
19	14	15	10	458	448
20	15	16	15	473	458
21	8	16	10	473	463
22	9	17	10	483	473
23	10	18	15	498	483
24	11	19	15	516	501
25	16	17	10	483	473
26	17	18	15	498	483
27	18	19	18	516	498
28	19	20	32	548	516
29	20	21	55	683	628
30	20	22	55	683	628
31	20	23	55	603	548
32	23	24	24	617	603
33	24	25	14	631	617
34	25	26	39	670	631
35	26	27	13	683	670

## 3.6	Determination of the Critical Path

Total Float: calculated by finding the difference between the time the activity starts at the latest and the time at the earliest to start the activity is calculated by the equation:

Rumus :

S = LS – ES   (2.12)

Dimana :

S   = Total float

LS = When the activity starts at the latest

ES = The fastest time the activity starts

Table 7. Initial Total Float Calculation

Activities	Node Start	Node Finish	Duration	ES	S = LS - ES
1	0	1	0	0	0
2	1	2	160	160	0
3	2	3	280	280	0
4	3	4	360	360	0
5	4	6	414	372	42
6	4	5	372	372	0
7	4	7	426	372	54
8	5	8	410	410	0
9	6	12	430	388	42
10	7	16	463	409	54
11	8	12	430	416	14
12	8	9	416	416	0
13	12	13	434	420	14
14	9	13	424	424	0
15	9	10	428	424	4
16	13	14	440	440	0
17	10	14	440	436	4
18	10	11	487	436	51
19	14	15	448	448	0
20	15	16	458	458	0
21	8	16	463	416	47
22	9	17	473	424	49
23	10	18	483	436	47
24	11	19	501	450	51
25	16	17	473	473	0
26	17	18	483	483	0
27	18	19	498	498	0
28	19	20	516	516	0
29	20	21	628	548	80
30	20	22	628	548	80
31	20	23	548	548	0
32	23	24	603	603	0
33	24	25	617	617	0

3.7 Labor Costs for Activities

Carrying out the calculation of labor costs requires data such as duration of activities, wages of labor per day, number and allocation of labor for activities or activities. In calculating the cost of labor in this init Duration of Activities (days) x Wages or Salary of Workers x Number of Workers

Table 8. Labor Costs for Activities in Initial Conditions

No	Tipe of activity	Duration (day)	Head of the workshop	Group Leader	Technician	Repairman	labor costs (Rp)
	PREPARATORY WORK						
1	Drawing Design	120	1	1	2		246.720.000
2	Material Input	80	1		2		108.960.000
3	Inspeksi Material	40	1	1	2		94.560.000
	FABRICATION						
4	Coming	82	1	1	1	5	165.873.000
5	Main Cable Way	8		1	2	9	14.814.000
6	Sub Cable Way	6		1	1	2	3.656.000
7	Seat Panel	12			1	7	15.550.000
	INSTALL						
	Main Cable Way	112		1	3	12	368.704.000
8	a.1 Gladak Utama	25					Include Above
9	a.2 Gladal I	35					Include Above
10	a.3 Gladak II	33					Include Above
11	a.4. Gladak III	17					Include Above
	Sub Cable Way	46		1	1	4	58.880.000
12	b.1 Gladak Utama	18					Include Above
13	b.2 Gladak I	10					Include Above
14	b.3 Gladak II	12					Include Above
15	b.4 Gladak II	17					Include Above
16	Seat Panel	12		1	7		15.550.000
	CABLING						
17	Cutting Cable	18		1	1	3	16.455.000
18	Wiring Cable	20		1	3	20	85.608.000
19	Heat Cabel	36		1	2	9	79.008.000
20	Connecting Cable	168		1	2	15	588.555.000
21	Cek Line Cable	27		1	1	5	35.112.000
22	Mergger Test	17	1	1	1	1	15.274.000
23	Compound	42		1	1	2	35.646.000
24	Test Fundion	15	1	1	1	1	14.183.000
	total cost						1-963.108.000

3.8 Scheduling of Proposed Conditions or Acceleration

The initial condition of the project can be completed within 870 days at a cost of Rp. 1,963,108,000, - In this proposed condition a crash program will be used to speed up the project implementation time. The crash program in this study was carried out by imposing overtime hours, while the crash program used was a crash program with a maximum time limit, namely the completion of the project with a maximum time limit set by the project owner.

Table 9. Work Duration of Acceleration

No	Tipe of activity	Predecessor Activities	Activity	time (day)	time Accelarated
	PREPARATORY WORK				
1	Drawing/Design	0	A	120	60
2	Material Input	A	B	80	80
3	Inspeksi Material	B	C	40	40
	FABRICATION				
4	Coming	D	E,F,G	82	82
5	Main Cable Way	E	H	8	6
6	Sub Cable Way	F	L	6	4
7	Seat Panel	G	P	12	10
	INSTALL				
	Main Cable Way				
8	a.1 Gladak Utama	H	I,L,P	25	25
9	a.2 Gladak I	I	J,M,Q	35	25
10	a.3 Gladak II	J	K,N,R	33	33
11	a.4 Gladak II	K	S	17	17
	Sub Cable Way				
12	b.1 Gladak Utama	L	M	18	18
13	b.2 Gladak I	M	N	10	10
14	b.3 Gladak II	N	O	12	12
15	b.4 Gladak III	O	P	17	17
16	Seat Panel	P	Q	12	12
	CABLING				
17	Cutting Cable	Q	R	18	18
18	Wiring Cabel	R	S	20	20
19	Perapian Cabel	S	T	36	36
20	Connecting Cabel	T	U,V,W	168	90
21	Cek Line Cable	W	X	27	24
22	Merger Test	X	Y	17	17
23	Compound	Y	Z	42	39
24	Test Funtction	Z	Z1	15	15
	Total days accelerated			870	710

3.9 Calculation of the Critical Path for Acceleration Conditions

In determining the critical path after applying overtime, forward and backward calculations are used.

Table 10. Foward Computation in Accelerated Condition

Activities	Node start	Node finish	Duration	ES	EF = ES + t
1	0	1	100	0	100
2	1	2	80	100	180
3	2	3	50	180	230
4	3	4	12	230	242
5	4	6	16	242	258
6	4	5	38	242	280
7	4	7	37	242	279
8	5	8	6	280	286
9	6	12	4	258	262
10	7	16	10	279	289
11	8	12	4	286	290
12	8	9	8	286	294
13	12	13	6	290	296
14	9	13	16	294	310
15	9	10	12	294	306
16	13	14	8	310	318
17	10	14	8	306	314
18	10	11	14	306	320
19	14	15	10	318	328
20	15	16	15	328	343
21	8	16	10	286	296
22	9	17	10	294	304
23	10	18	15	306	321
24	11	19	15	320	335
25	16	17	10	343	353
26	17	18	15	353	368
27	18	19	18	368	386
28	19	20	32	386	418
29	20	21	30	418	473
30	20	22	30	418	473
31	20	23	30	418	473
32	23	24	20	473	493
33	24	25	14	493	507
34	25	26	30	507	537
35	26	27	13	537	550

Table 11. Backward Computation in Accelerated Conditions.

Activities	Node Start	Node Finish	Duration	LF	LS = LF - t
1	0	1	100	100	0
2	1	2	80	180	100
3	2	3	50	230	180
4	3	4	12	242	230
5	4	6	16	300	284
6	4	5	38	280	242
7	4	7	37	333	296
8	5	8	6	286	280
9	6	12	4	304	300
10	7	16	10	343	333
11	8	12	4	304	300
12	8	9	8	294	286
13	12	13	6	310	304
14	9	13	16	310	294
15	9	10	12	310	298
16	13	14	8	318	310
17	10	14	8	318	310
18	10	11	14	371	357
19	14	15	10	328	318
20	15	16	15	343	328
21	8	16	10	343	333
22	9	17	10	353	343
23	10	18	15	368	353
24	11	19	15	386	371
25	16	17	10	353	343
26	17	18	15	368	353
27	18	19	18	386	368
28	19	20	32	418	386
29	20	21	30	550	495
30	20	22	30	550	495
31	20	23	30	473	418
32	23	24	20	493	473
33	24	25	14	507	493
34	25	26	30	537	507
35	26	27	13	550	537

Table 12. Calculation of Total Float in Accelerated Condition

| Activities	Node start	Node finish	LS	ES	S = LS − ES
1	0	1	0	0	0
2	1	2	100	100	0
3	2	3	180	180	0
4	3	4	230	230	0
5	4	6	284	242	42
6	4	5	242	242	0
7	4	7	296	242	54
8	5	8	280	280	0
9	6	12	300	258	42
10	7	16	333	279	54
11	8	12	300	286	14
12	8	9	286	286	0
13	12	13	304	290	14
14	9	13	294	294	0
15	9	10	298	294	4
16	13	14	310	310	0
17	10	14	310	306	4
18	10	11	357	306	51
19	14	15	318	318	0
20	15	16	328	328	47
21	8	16	333	286	49
22	9	17	343	294	47
23	10	18	353	306	51
24	11	19	371	320	0
25	16	17	343	343	0
26	17	18	353	353	0
27	18	19	368	368	0
28	19	20	386	386	77
29	20	21	495	418	77
30	20	22	495	418	0
31	20	23	418	418	0
32	23	24	473	473	0
33	24	25	493	493	0
34	25	26	507	507	0
35	26	27	537	537	0
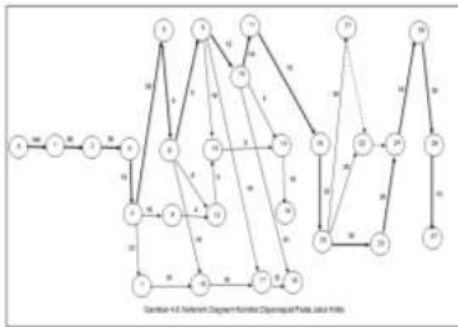
Figure 1. Network Diagram of Accelerated Conditions on a Critical Path
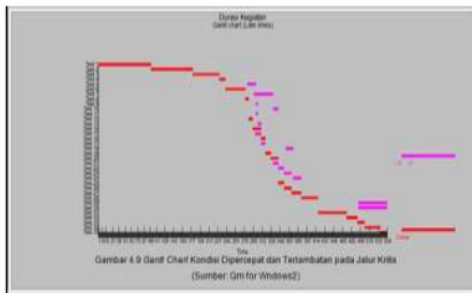

Figure 2. Gantt Chart Accelerated and Delayed Conditions on Critical Pathways

3.8 Labor Costs After Acceleration Conditions

The results of the calculation of labor costs for accelerated activities can be found activity slope which is useful for knowing the comparison to choose which critical activity will be shortened, the smaller the cost to shorten the time period of the activity, and vice versa.

Table 13. Tambulation of Normal, Accelerated and Cost Slopes

Activities	Normal Time	Normal Fee	Crash Time	Crash Fee	Slope of Costs
Drawing/Design	120	189.120.000	100	237.207.720	801.462
Material Input	80	108.960.000	80	115.080.000	153.000
Inspeksi Material	40	94.560.000	50	100.603.860	201.462
CABLING					
Conneting Cable	168	588.555.000	90	637.852.950	657.306
Cek Line Cable	27	35.112.000	20	36.182.256	267.564
Compound	42	35.646.000	30	37.132.620	164.180

4. CONCLUSIONS

After carrying out the research process, from the processing results data and calculations that have been done it can summed up as follows:

a. Critical activity in initial conditions with 870 days for an accelerated condition of completion time for 710 days (a total acceleration of 160 days) with 16 critical trajectories covering 34 work activities where all activities enter critical trajectories.

b. The difference in processing time during the initial condition and acceleration condition is 160 days.

c. Alternate acceleration applied to reduce consequences of delay, among others:

    1) Additional working hours, and

    2) Increase in the number of workers

d. The Shipbuilding project on the electrical system can be accelerated for 160 days at a cost an additional amount of Rp. 3.525.214.127.

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