Research Article

Analysis of Scheduling Acceleration of a Hospital Construction using the Precedence Diagram Method Combined with Fast Track and the Precedence Diagram Method Combined with Crashing Method

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Abstract.
In general, the completion of a project must be in accordance with a binding contract agreement, but in its implementation, there can be obstacles that cause delays. Project delays can affect the results of weekly progress and the final results of the project and affect the performance appraisal of project implementers. Delays can be seen through the weekly progress of the program according to the schedule. Delays can be prevented by speeding up existing scheduling. This research aimed to conduct an acceleration analysis on the schedule using the fast track method and the crashing method and critical network analysis using the Precedent Diagram (PDM), then determine which method is appropriate according to this research. In this case study, there was a delay in the 18th week where the progress of the plan of 16.60% was only at 11.21% so there was a deviation of 5.4%. This delayed the duration of project completion from 366 days to 390 days. The analysis results obtained by applying the Fast-Track method can overcome delays by returning the schedule to the original plan, without any additional costs. The results of the analysis using the PDM method combined with the crashing method can make the duration faster than the plan duration, which was 359 days or 7 working days faster and the additional cost is about 1.02%. The fast track and crashing methods can be used as scheduling acceleration tools to overcome delays, but in financing, the fast track method is more cost-effective while the crashing method has additional costs. This research provides references and descriptions about the effects of using the fast track and crashing methods on projects.

Keywords: project delays, schedule acceleration, critical network analysis

1. Introduction

Accelerating a schedule with the intention of solving the problem of delays sometimes becomes irritating because it has to meet project duration limitations and prevent large losses. Research using the accelerated method has different results depending on the conditions of the project.

Moazzami et. all. [1] research shows that the use of Fast Track can overcome delays but at the same time makes the project experience inaccurate cost estimates, damage due

to acceleration, rework occurs, and construction modifications may occur. Even though the acceleration method has a high potential for failure, the acceleration method can help reduce losses due to delays. K. Cho and M. Astak [2] the research conducted in this study using the application of the Fast Track method can produce more efficient projects, the research was carried out using 2 case studies. Where case study 1 can be reduced by 40.48% with an estimated cost reduced by 0.39% and case study 2 condensed scheduling successfully carried out by 18.59% with an estimated cost reduced by 4.48%. P. Ballesteros-Perez [3] Research conducted found that on average the use of Fast Track as an acceleration tool cannot reduce the scheduling duration of more than 25% of the total project duration. A. C. Utomo [4] The effectiveness of using Fast Track in scheduling highway projects is around 9% -12.56% and can reduce costs by as much as 6.75%. Besides the Fast Track method, there is another acceleration method, namely the Crashing method.

P. Ballesteros-Perez et. all [5] this research using the application of the Crashing method can reduce the project duration by around 26.9%. A. P. Khinasih [6] This research shows that using the Crashing method to accelerate catching up with the previous weekly presentation that is experiencing delays can reduce scheduling by as much as 9% of normal duration and save as much as 0.3% in costs. [7] In research on delays that occur in architectural work on hotel projects, the application of Crashing can return the duration according to the duration of the plan. Based on previous research, it can be said that the use of the acceleration method can be carried out depending on the conditions of the project delay and the level of complexity of the project.

This paper provides a new alternative using the Fast track and crashing method in overcoming delays in scheduling that has high complexity. the alternative consists of using the model precedence diagram method which is used to determine the critical path with the help of Ms.project. then accelerate using Fast Track and Crashing. The variables involved in this paper are duration and cost, and there can also be calculations for additional resources due to acceleration.

This alternative offers the latest references about the effect of the acceleration method on projects with high complexity. This paper will be compiled starting from the use of previous research on accelerating or reducing scheduling which is used as an illustration to researchers about the scope that will be discussed and not discussed. The material to be researched is carried out in a late project case study which has high complexity and the methods used are two types of acceleration methods, both methods address two variables, namely time and cost. After that the results will be compared between the two acceleration methods. Then the model will be realistically applied

to the case study. This paper will contribute to science and become literature for the scientific community.

2. Methods

The case study in this research was carried out on a hospital building construction project. This project has a high level of complexity. where the hospital has 5 floors + 1 basement floor and is equipped with a 2-storey parking building with a building area of $\pm$ 26,000 m2. This project has a planned completion duration of 366 working days. Based on the results of interviews with related parties at the start of the project, activities within the project environment experienced several obstacles due to restrictions on activities during the pandemic. The main cause of the delay was the delay in the construction of the Tower Crane which hampered the course of activities. This happened during the execution of substructure work. And also, the late arrival of the material. As a result of the delay, the weekly progress in the 18th week was delayed with the realization progress of 11,211% while the planned progress was 16,306%. Delays affect project performance in the following week and can also affect project results. Making the project experience a delay of 24 working days to 390 days.

Based on the variables to be examined, the initial research activities carried out direct visits to the case study locations and then conducted interviews with related parties regarding project conditions and delays. Then request data to support research. Then do the analysis and check the validation of the data.

Based on the data obtained, initially an analysis of the schedule will be carried out to find the critical path using the Precedence Diagram method, then after obtaining the results of the critical path analysis, acceleration is carried out using Fast Track and Crashing which focus on time and cost. After that the results of the two acceleration methods are compared, to find an accelerated method that can overcome delays for this case study.

3. Result and Discussion

This research began by conducting direct inspections at the research location, conducting interviews with those directly involved with the project and requesting the data that would be needed later, checking the data. Data processing is done based on the data obtained. The beginning of this research analysis simulation starts with project scheduling using S-Curve data to determine activities that will enter the critical path,

analysis is carried out using the Presedence Diagram Method (PDM) method then, after obtaining critical path activities, acceleration is carried out using the Fast Track method and the Crashing method. After that, based on the results of the analysis of the two methods, they were compared and selected the method that was appropriate and appropriate for this case study.

3.1. Identification of the critical path using the precedence diagram method

Critical path analysis was carried out on the scheduling of this case study using the Precedence Diagram Method concept with the help of the Microsoft Project project application. The analysis was carried out based on the normal duration according to the scheduling plan with a total of 74 activities. The overall duration of the project is 366 working days. Daily activities are carried out Monday to Saturday from 08.00 AM to 17.00 PM with breaks from 12.00 PM to 13.00 PM.

The analysis begins by entering data on lists of work activities into the assistance application. After that enter the duration of these activities based on the S Curve data. Then enter the Precedence Diagram Method concept into the Ms. application. Project through relationships between jobs. After that, the results of the analysis of jobs included in the critical path are as follows:

Based on the analysis results in Table 1, it can be seen that the results of the critical network analysis found that there were 24 activities included in the critical network. This activity will be the main focus of this research and will form the basis of the research foundation in conducting acceleration analysis. Acceleration of activities on the critical path using the Fast track and Crashing methods, after knowing the results of the acceleration on the Fast Track and Crashing methods a comparison will be made based on the acceleration of project completion and cost usage.

3.2. Acceleration analysis using the fast track method

Based on the results of the critical path analysis in table 1, it will be used as the basis for analysis using the fast track. Experimental simulations of applying the Fast Track method were carried out in 15 trials to find the best scheduling simulation. 15 experimental simulations were carried out on critical work by changing the schedule for carrying out the work with the help of the Ms. Project. Based on the experiments carried out, the activities that will be rescheduled for implementation are Sub Structure work, Semi

TABLE 1: The results of the critical path analysis using precedent diagram method.

No	Activity Name	Normal Duration (Days)
1	DED Development	186
2	Preparatory work	366
3	Earthwork	96
4	Retaining wall works	60
5	Spun Pile foundation work	78
6	Substructure work	126
7	Semi basement floor work	90
8	1st floor structure work	60
9	2nd floor structure work	66
10	3rd floor structure work	72
11	4th floor structure work	72
12	5th floor structure work	72
13	Semi basement wall work	72
14	1st Floor Wall Work	72
15	Semi-basement floor architectural work	78
16	Semi basement ceiling work	54
17	1st Floor ceiling work	54
18	2nd floor ceiling work	54
19	3rd floor ceiling work	54
20	Semi-basement wateIDRroofing work	30
21	1st floor wateIDRroofing work	30
22	2nd floor wateIDRroofing work	30
23	Facade work	102
24	Other jobs	102

Source: the results of the critical path analysis of the PDM network.

Basement Wall work, Facade work and Electrical Connection work. Where the Sub Structure work which was originally SS+24 was brought forward to SS+15, the Semi Basement Wall work which was originally done together with the 5th floor was brought forward together with the 4th floor, and the Facade work which was originally done together with the 2nd floor WateIDRroofing work was advanced. together with the 1st floor waterproofing work, as well as the electrical connection work from FS-89 to FS-42:

After acceleration is done on selected critical work. There was a change in the schedule which was initially delayed again according to the planned schedule. And changes that occur can result in changes to the allocation of project costs. Because of that, an analysis of changes in financing due to acceleration is carried out.

3.2.1. Changes in cost due to fast track method

Based on research data obtained in the construction project for the new building of D Hospital at East Java, it cost IDR. 170,454,272,727. After a delay in financing experienced swelling.

After the acceleration of the scheduling in terms of financing will experience changes. So it will be analyzed on the financing. The analysis was carried out on 2 types of financing, namely direct costs and indirect costs. Direct costs are costs used for carrying out work and can be seen in the Budget Plan. Costs and indirect costs are costs for supporting activities in the project area, such as employee costs and operational costs. And for indirect costs have the following calculations:

TABLE 2: Overhead cost.

No	Types of Fees	Per Month	Per day
1	Staff Salary Fee	IDR 140,000,000	IDR 5,833,333
2	Operating costs	IDR 60,000,000	IDR 2,500,000
	Total cost	IDR 20,000,000	IDR 8,333,333

Based on table 2 the calculation of indirect costs is divided into 2 types, namely employee salaries and operational costs which are sorted by costs for a day and a month. the use of table 2 will be a comparison of financing before and after using Fast Track.

Indonesia has regulations governing project contracts starting from the beginning of the process to completion of the project contract. And if the project is delayed beyond the contract agreement bound for late fees set forth in PUPR Ministerial Regulation Number 1 of 2020 Article 44 Paragraph 2 it says that a provider who is late in completing work within the timeframe stipulated in the contract due to the provider's error, is subject to a late fee of 1/ 1000 of the contract price for each day of delay.

If based on the regulation on fines for delays in the project, the project suffers a significant loss due to a delay of 24 days. However, in this project the executors were not subject to fines because during the implementation of the project a pandemic occurred which hampered the routine activities of the project and then they received relief and did not need to pay fines. The following is an analysis of project financing before, experiencing delays and after the Fast Track.

In table 3 the results of a comparative analysis before and after using fast Track based on direct costs, indirect costs, and late costs. The value of direct costs is based on the budget plan, indirect costs are based on interviews with the implementing agency, and late fees are based on binding regulations. At the time of financing before the fast

TABLE 3: The difference in costs before and after fast track.

No	Description	Initial Plan Cost	Cost Before Fast Track
1	Direct cost	IDR 170,454,272,727	IDR 170,454,272,727
2	Overhead cost	IDR 8,333,333	IDR 11,350,000
3	Delay		
	Total cost	IDR 170,462,606,061	IDR 170,465,622,727

Track costs experienced additional costs in operational costs due to a delay of 24 days. Overall, the results obtained using the Fast Track method in terms of costs can restore financing that has experienced swelling to return according to the planned cost.

3.3. Acceleration analysis using the crashing method

Analysis of the Crashing Method is carried out by reducing the duration of a job to speed up the duration of work completion by adding working hours. The analysis is carried out on activities that are included in the critical path. In conducting the crashing analysis, 3 trials were carried out with the addition of different working hours.

The analysis is carried out only on critical path activities because activities on this path can affect the final project outcome. Project activities are carried out from Monday to Saturday with normal activity duration from 08.00 to 17.00 and breaks from 12.00 to 13.00. Three types of work hours are added, namely 2 hours overtime (18.30-20.30), 3 hours overtime (19.00-22.00) and 4 hours overtime (19.00-23.00). Overtime pay is 1.5 times the normal hourly rate.

With the addition of working hours, there is a decrease in productivity. In direct proportion, the higher the overtime hours, the higher the decrease in productivity. Analysis The decrease in productivity for 2-hour overtime decreased by 13%, for 3-hour overtime it decreased by 16% and for 4-hour overtime it decreased by 19%. After knowing the value of the decline in each hour of overtime, an analysis of daily productivity is carried out on critical path activities.

The calculation focuses on sub structure work because this work is experiencing delays due to the late completion of the previous work.

   i. Before crashing

     Daily productivity

$$(1) = \frac{work\,weight\,value}{normal\,duration} \tag{1}$$

Hourly productivity

$$(2) = \frac{Daily\,productivity}{working\,hours\,a\,day} \tag{2}$$

ii. After crashing

Productivity after adding 4 hours of overtime

Daily productivity

$$(3) = (normal\,duration\,x\,(2)) + (overtime\,duration\,x\,productivity\,decline\,x\,(2)) \tag{3}$$

Job duration after crashing

$$(4) = \frac{work\,weight\,value}{(3)} \tag{4}$$

iii. Duration difference

$$(5) = Plan\,duration - crashing\,duration\,(5) \tag{5}$$

For acceleration results on other critical path work can be seen in Table 4 following:

TABLE 4: Result of crash cost in crashing method.

No	Overtime	Normal Duration (Days)	Job load (1)	Productivity		Crashing	
				Day	Hour	Productivity	Final Duration
				(1)	(2)	(3)	(4)
1	2 Hours	126	4.059	0.0322	0.00402669	0.0332604	122
2	3 Hours	126	4.059	0.0322	0.00402669	0.0335020	121
3	4 Hours	126	4.059	0.0322	0.00402669	0.00337436	120

Based on the results of the analysis in Table 4, it can be seen that the addition of 2 hours of overtime can shorten the duration by 4 days. For 3 hours overtime can shorten as much as 5 days while with 4 hours overtime can shorten as much as 6 days. When viewed as a whole the results of acceleration with variations in the addition of working hours only experience a difference of 1 day.

3.3.1. Crash cost due to acceleration

After carrying out an acceleration analysis on the duration of the scheduling, it will definitely incur additional costs. The analysis is called Crash Cost. The formula to be used in this analysis contains costs at normal duration and normal costs plus overtime costs. The normal fee is based on the normal duration of 8 hours of work and the overtime fee is based on variations in hours studied. The following formulas are used:

Number 6. Substructure Works

i. Wages for work with normal daily duration

$$(6) = \frac{laborwageprices}{normalduration} \tag{6}$$

ii. Hourly work wages normal duration

$$(7) = \frac{laborwageprices}{normaldurationinaday} \tag{7}$$

iii. Daily overtime pay

$$(8) = 4 \times (1.5 \times 1hourwages) \tag{8}$$

iv. Crash Cost of workers per day

$$(9) Hourlyworkwagesnormaduration) + Dailyovertimepay) \tag{9}$$

v. Total Crash Cost

$$(10) = Crashcostofworkersperday \times crashingduration \tag{10}$$

For acceleration results on other critical path work can be seen in Table 4 following:

Substructure work has a design cost of IDR 720,090,000. Based on Table 5, it can be seen that the additional cost due to the additional 2 hours working hours is 1.33%. 1.5% additional 3-hour working hours and 1.67% additional 4-hour working hours. Overall, the higher the overtime hours, the higher the additional costs. Furthermore, a comparative analysis of additional costs by accelerating the final duration of the project is carried out from the results of the Crash Cost analysis.

TABLE 5: Result of crash cost in crashing method.

No	Overtime	Labor Wage Normal Duration		Overtime Pay		Crashing
		Day	Hour	Day	Productivity	Final Duration
		(6) (IDR)	(7) (IDR)	(8) (IDR)	(9) (IDR)	(10) (IDR)
1	2 Hours	5,715,000	714,375	2,143,125	7,858,125	958,957,627
2	3 Hours	5,715,000	714,375	3,214,688	8,929,688	1,081,865,986
3	4 Hours	5,715,000	714,375	4,286,250	10,001,250	1,203,014,320

3.3.2. Cost slope calculation in crashing method

Cost slope analysis is carried out after the crash cost value is obtained. The analysis describes the comparison of costs and time at the normal duration and the accelerated duration. Following are the results of the Cost Slope analysis on the variation of overtime hours.

TABLE 6: Result of cost slope in crashing method.

No	Overtime	Normal Duration (Days)	Crashing duration	Normal Fee	Crashing Fee	Cost Slope
		Day	Hour	Day	Productivity	Final Duration
		(a)	(b)	(c) (IDR)	(d) (IDR)	(d-c)/(a-b) (IDR)
				Sub Structure Work		
1	2 Hours	5,715,000	714,375	2,143,125	7,858,125	958,957,627
2	3 Hours	5,715,000	714,375	3,214,688	8,929,688	1,081,865,986
3	4 Hours	5,715,000	714,375	4,286,250	10,001,250	1,203,014,320

Based on Table 6 it can be said that the work of the lower structure added to the variation of overtime hours has different acceleration results in terms of time and cost. Selection in the use of the best additional working hours on the additional working hours of 3 hours. Because this variation is in the middle of the position of using 2 hours and 4 hours of overtime. For a comparison of the overall duration can be seen in Table 7.

TABLE 7: The difference in overall duration in the crashing method.

No	Overtime	Total Project Duration	Job Duration	Crash duration	Difference Duration	Total After Crash
		(a)	(b)	(c)	(b-c)	A x (b-c)
				Sub Structure Work		
1	2 Hours	390	126	122	4	386
2	3 Hours	390	126	121	5	385
3	4 Hours	390	126	120	6	384

Based on Table 7 it can be seen that in terms of time with the addition of variations in working hours it cannot reverse delays, it can only speed up work in a few working days. Then if the results of the acceleration duration are known, an analysis of the effect of applying the Crashing method on direct and indirect costs can be carried out.

3.3.3. Direct cost and indirect cost analysis

Based on the previous stages, after implementing crashing on the critical path, an analysis of the changes in costs that occur is carried out. There are 3 types of costs to be analyzed namely direct costs, indirect costs and total costs. According to the data obtained by the Budget Plan, it has IDR 170,465,622,727 is a direct cost and for indirect costs the operational costs of project implementers amounting to IDR 8,333,333 (CS) per day. Following are the results of the analysis of additional costs by direct costs and indirect costs:

TABLE 8: Direct cost and indirect cost analysis in crashing method.

No	Overtime	Duration Crashing	Extra Cost (IDR)	Direct Cost (IDR)	Indirect Cost (IDR)	Total Cost (IDR)
		(a)	(b)=CSx(a)	(c)=RAB+(b)	(d)=(a)xOC	(e)=(c)+(d)
			Sub Structure Work			
1	2 Hours	386	238,867,627	170,693,140,354	3,216,949,153	173,910,089,507
2	3 Hours	385	361,775,986	170,816,048,713	3,209,615,385	174,025,664,097
3	4 Hours	384	482,924,320	170,937,197,047	3,202,386,635	174,139,583,682

Based on table 8, it can be seen that the use of the Crashing method as a whole cannot overcome the delays that have occurred and causes significant additional costs. This makes the application of the crashing method on projects that have high complexity less precise, because it will make the executor's expenses higher and can make the decline in labor productivity even higher.

3.4. Comparison of acceleration analysis using fast track method and crashing method

In the new building construction project at Hospital D in East Java, which had a planned duration of 366 days and experienced a delay of 24 working days, it became 390 days. Based on the time aspect, the use of the Fast-track method can return the duration of project completion back according to plan, namely 366 days. While the use of the Crashing method can only speed up the duration of 5 days faster than the delay, which is 385 days.

In terms of costs, the use of the Fast-Track method has a more economical cost than the Crashing method. Because basically the fast track method can make refinancing in accordance with the budget plan that is bound in the contract document because this method uses good management while the Crashing method due to additional working hours (overtime) results in additional costs. The use of the Crashing method is inappropriate as the main choice in overcoming delays on projects that have high complexity. The following is a comparison table between the Fast Track and Crashing methods in Table 9.

TABLE 9: Differences in the results of the analysis of the Fast Track method and the Crashing Method.

		Duration			Fee (IDR)		
No	Method	Plan	Delay	Acceleration	Plan	Acceleration	Difference
1	Fast Track	366	390	366	170,465,622,727	170,462,606,061	3,016,667
2	Crashing	366	390	385	170,465,622,727	174,025,664,097	3,560,041,370

4. Conclusion

The use of the Fast Track method can be seen based on time and cost. The results of the analysis based on the time of application of the Fast Track method can return the duration of project completion which was initially late to the duration of completion according to the plan where the duration of the delay of 390 working days is returned according to plan to 366 working days by advancing and moving the time for doing substructure work, wall work , façade work and power connection work. And the results of the analysis based on costs after implementing fast track there is a cost savings of 0.9%.

The results of the analysis using the Crashing method based on time can overcome delays where the duration of the delay is 390 days to 385 days. The results of applying the Crashing method can only make the duration 5 days faster than the duration of the delay. And the results of the analysis based on the cost after the implementation of crashing there is an additional cost of 1.5%.

Based on the time, the use of the Fast Track method is better because it can return the duration according to the duration of the plan, whereas the application of the Crashing method can only return the duration of completion 5 days faster than the duration of the delay according to the duration of the plan. And based on the cost of implementing costs after the Fast Track is more efficient, while the Crashing method there is an additional cost.

The Fast Track method can be one of the main choices in dealing with delays in high complexity projects, while the crashing method can only be done if circumstances are urgent. This is because the use of the Fast Track method uses good management and Crashing uses overtime hours. But in the end the use of the Fast Track method has a fairly high risk because it must have good management and the more work on the critical path the higher the risk of using this method, while the Crashing method has no risk because it is done overtime but makes additional costs unavoidable and there may be a decrease in the productivity of the workforce.

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