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Original Article

Time and Cost Control Analysis of the Construction of the Joyoboyo Zoo Intermodal Terminal Pedestrian Tunnel Using the Critical Path Method

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Abstract

This study aims to analyse the effectiveness of Critical Path Method (CPM) in controlling the time and cost of the Pedestrian Tunnel construction project connecting Joyoboyo Intermodal Terminal with Surabaya Zoo. This project experienced various obstacles such as social conflicts, utility handling, and cross-agency coordination, resulting in delays in implementation. The research used a qualitative approach with primary data in the form of field observations and secondary data from project documents such as schedules, weekly reports, and cost budget plans (RAB). The analysis technique involved identifying the critical path, calculating the activity time, and evaluating the impact of delays on the project schedule. The results showed that the application of CPM was able to identify the critical path that had a direct impact on the project completion time. By knowing which activities have no float time, resource management can be optimised to reduce delays. However, the change in tunnel length from 156 metres to 172 metres affected the total project cost, although the implementation cost on the critical path was maintained.

Keywords: Critical Path Method, Critical Path, Time and Cost Management, Project Control.

1. Introduction

The good impact of rapid infrastructure development is good economic development. Infrastructure development has been a catalyst for economic growth, by opening up investment opportunities, creating jobs, and increasing the competitiveness of domestic products. In addition to a better economy, better infrastructure has helped reduce the development gap between urban and rural areas, and between Java and other islands (Kusharjanto & Kim, 2011). Better access to public services such as education, health, and clean water has improved the quality of life of the people.

A common problem that is often faced in various parts of the world, including Indonesia especially in Surabaya, is the delay of construction projects. These delays can have a major impact on the contractor's reputation, project cost, and client satisfaction. Some of the main factors that often cause construction projects to be delayed include internal factors such as inadequate planning, weak project management, limited resources, financial problems, poor quality of work and for external factors weather conditions, regulatory changes, social and natural disasters. The impacts of construction project delays include cost overruns, late fees, disruption of activities for the surrounding community and increased risk of work accidents or building damage.

Surabaya City Transportation Department is the executor of authority in the field of transportation in Surabaya City as regulated in the Surabaya Mayor Regulation (Yulaicho & Hardjati, 2022). In order to support the Surabaya City Government in the implementation of its authority, especially in terms of improving accessibility services that are comfortable and safe for the community, the Surabaya City Government is currently carrying out the construction of a pedestrian tunnel as an access / connecting route between Joyoboyo Intermodal Terminal (TIJ) and Surabaya Zoo (KBS).

With the construction of the pedestrian tunnel is expected to provide convenience and safety crossing for visitors Surabaya Zoo, as well as reduce traffic congestion on the road Joyoboyo and surrounding areas.

The construction of the pedestrian tunnel from Joyoboyo Intermodal Terminal to Surabaya Zoo has been delayed due to social conflict with the community around the project site regarding the certainty of the impact of handling in the form of fence closures that result in the community being unable to carry out economic activities (unable to sell). There are several utilities that still need to be moved or diverted from the area that will be affected by the tunnel. The existence of water puddles from several PDAM pipes that were not detected during pile installation. Traffic flow diversion / traffic engineering that experienced delays in implementation because coordination with FORKOMPINDA and other related agencies was still needed. Thus we can see from the description above that there have been undetected delays in the implementation of the work that affect the schedule of activities.

As in the Pedestrian Tunnel Construction project from Joyoboyo Intermodal Terminal to Surabaya Zoo which experienced delays. This project has a planning target of 135 (one hundred thirty-five) calendar days, which started on 30 May 2024 and is planned to end on 11 October 2024 with a nominal project cost of Rp 31,996,921,529.00. The project was planned to be completed at week 20 but at week 7 when the cut-off experienced a deviation of -7.205%. At the time of writing the project is still ongoing.

Inaccurate planning of a project can affect project implementation and can cause problems on the project that affect all workers involved in the project (Bradley, 2008). Therefore, in planning a project must be appropriate and in accordance with the characteristics of the project concerned, in order to be able to deal with the uncertainty of project implementation conditions there must be scheduling planning. Problems that often arise in a project are project delays, this can lead to an extension of the project implementation period caused by setbacks in the implementation stage (Astari et al., 2022).

Therefore, project control is very important in this case the author uses the Critical Path Method (CPM) method in controlling the project. Critical Path Method (CPM) is a project management method that allows us to find the series of tasks that last the longest during the project (Aliyu, 2012). This series of tasks is called the critical path. The critical path is very important because any delays on this path will have a direct impact on the length of the project. The goal is to optimise the project completion time, prevent delays, increase the efficiency of resource use, make it easier to make decisions.

Critical Path Method (CPM) revolves around finding the most important tasks in the project timeline, identifying task dependencies, and calculating task durations (Anastasiu et al., 2023). Critical Path Method (CPM) was developed in the late 1950s as a methodology to solve the problem of increasing costs due to inefficient scheduling. Since then, the Critical Path Method (CPM) has become popular for planning projects and prioritising tasks. Critical Path

Method (CPM) is able to provide valuable insights into the right way to plan projects, allocate resources, accelerate milestones, and schedule tasks (Johnson & Eniola, 2024).

The purpose of this research is to analyse the results of time control for the construction of the Pedestrian Tunnel from Joyoboyo Intermodal Terminal to Surabaya Zoo using the critical path method (CPM). In addition, this study also aims to calculate the cost required by controlling the time using the same method in the implementation of the project.

2. Methods

This research method focuses on the construction project of the Pedestrian Tunnel from Joyoboyo Intermodal Terminal to Surabaya Zoo. This research uses a qualitative approach to describe the problems and focus of the research. The qualitative method, as stated by Lexy, (2011), aims to obtain descriptive data in the form of words and pictures, not numbers, which are relevant to analyse this project.

The research data was obtained through various data collection procedures. Primary data was obtained directly from field observations made by the author at the project site. These observations provided a real picture of the tunnel construction implementation. In addition, secondary data was obtained through documents provided by the contractor, both published and unpublished. This secondary data includes the cost budget plan (RAB), project schedule, weekly project report, and price list of materials and workers' wages. Additional data such as time schedules, plan drawings, and recapitulation of project cost calculations were obtained from supervisory consultants and project implementers.

Data analysis techniques are carried out systematically and logically to understand and solve problems related to project time and cost scheduling. This analysis technique uses the critical path method (CPM) to identify the critical path in the project. The analysis steps include detailing the plan and sequence of work activities, calculating productivity and work duration to determine normal, optimistic, and pessimistic times, and scheduling planning by considering productivity efficiency. The analysis was conducted with the help of Microsoft Excel to determine critical work and evaluate weekly reports to identify potential delays in the project.

3. Results and Discussion

3.1. Determining Activity Implementation Time

In determining the implementation time of activities to simplify calculations, the following notations are used:

1) Early Start (ES) is the earliest time an activity can start after the previous activity is completed.
2) Late Start (LS) is the latest time an activity can be completed without delaying project completion.
3) Early Finish (EF) is the earliest time an activity can be completed if it is started at its earliest time and completed by its duration. If there is only one preceding activity, the EF of the preceding activity is the EF of the following activity.
4) Late Finish (LF) is the latest time an activity can be started without delaying the completion of the project. The latest time an activity can finish without delaying the completion of the project.

3.2. Forward Calculation

Forward calculation starts from the earliest event with ES = 0 to the next event, then traced forward to the right to calculate the ES of the next event. The following table shows the results of the forward calculation:

Table 1. Forward Calculation

No.	Work Items	Activity Code	Node	Duration	Early Start	Early Finish
1	Mobilisation	A1	1 - 2	7	0	7
2	Demobilisation	A2	25 - 27	7	128	135
3	Land excavation	B	6 - 7	10	37	47
4	*Urugan sirtu* elevation of building floor	C	12 - 18	4	84	88
5	Backfill soil compaction work	D	20 - 21	16	92	108
6	Soil removal	E	7 - 8	18	47	65
7	Sheet pile + Bracing	F1	4 - 6	9	28	37
8	Sheet pile + Bracing	F2	4 - 5	9	28	37
9	Removal of sheet pile + Bracing	F3	21 - 22	9	108	117
10	Sheet pile removal + Bracing	F4	21 - 23	9	108	117
11	40cm Diameter K600 Type C Piles	G	1 - 3	17	0	17
12	Pile driving including bracing	H	3 - 4	11	17	28
13	32 cm wide PVC Waterstop	I	9 - 10	4	72	76
14	Raft Foundation Concrete 60 cm fc' 35 mpa (PC 450)	J	8 - 9	7	65	72
15	Wall Concrete 40 cm thick f'c 35 Mpa (PC 450)	K	9 - 11	6	72	78
16	Concrete Plate 60 cm thick fc' 35 mpa (PC 450)	L	11 - 12	6	78	84
17	Homogeneous Tile 60x60 (Polished)	M	12 - 17	21	84	105
18	Stainless steel grill cover	N	13 - 26	2	86	88
19	Entrance cover 8 mm tempered reflective glass + spider and frame	O	14 - 27	8	105	135
20	Waterproofing Bitumen Coating (under ceramic floor)	P	12 - 20	4	84	92
21	Waterproofing bitumen membrane double sided + polymer (wall plate + top plate)	Q	12 - 19	8	84	92
22	Class C Aggregate Work	R	23 - 24	6	117	123
23	AC-WC Production and Sanding	S	24 - 25	5	123	128
24	U Ditch 80/80 G. 20 Tonne + cover and Installation	T	12 - 13	2	84	86
25	Jet Fan Cap. 3000 CMH	U	12 - 15	3	84	87
26	Fresh Air Fan (Cabinet Type)	V	12 - 16	13	84	97
27	Passenger Elevator 400 KG Capacity	W	12 - 14	21	84	105

Source: Processed by the author 2024

In table 1, it can be seen that for the Mob Demob and Sheet Pile Piling and Retraction work items that were previously combined, the forward calculation table is made separate because the work is carried out on 2 different segments.

3.3. Backward Calculation

Backward calculations are used to determine when to start and complete tasks without delaying the project completion time, the results of which are obtained from forward calculations. The results of the backward calculation in the implementation of the Joyoboyo intermodal terminal pedestrian tunnel construction project to the Surabaya zoo can be seen in the table below:

Table 2. Backward Calculation

No.	Work Item	Activity Code	Node	Duration	Late	
					Start	Finish
1	Mobilisation	A1	1 - 2	7	0	17
2	Demobilisation	A2	25 - 27	7	128	135
3	Land excavation	B	6 - 7	10	37	47
4	Sirtu backfill for building floor elevation	C	12 - 18	4	84	135
5	Backfill soil compaction work	D	20 - 21	16	92	108
6	Soil removal	E	7 - 8	18	47	65
7	Sheet pile + Bracing	F1	4 - 6	9	28	37
8	Sheet pile + Bracing	F2	4 - 5	9	28	37
9	Removal of sheet pile + Bracing	F3	21 - 22	9	108	117
10	Sheet pile removal + Bracing	F4	21 - 23	9	108	117
11	40cm Diameter K600 Type C Piles	G	1 - 3	17	0	17
12	Pile driving including bracing	H	3 - 4	11	17	28
13	32 cm wide PVC Waterstop	I	9 - 10	4	72	78
14	Raft Foundation Concrete 60 cm fc' 35 mpa (PC 450)	J	8 - 9	7	65	72
15	Wall Concrete 40 cm thick f'c 35 Mpa (PC 450)	K	9 - 11	6	72	78
16	Concrete Plate 60 cm thick fc' 35 mpa (PC 450)	L	11 - 12	6	78	84
17	Homogeneous Tile 60x60 (Polished)	M	12 - 17	21	84	135
18	Stainless steel grill cover	N	13 - 26	2	133	135
19	Entrance cover 8 mm tempered reflective glass + spider and frame	O	14 - 27	8	127	135
20	Waterproofing Bitumen Coating (under ceramic floor)	P	12 - 20	4	82	92
21	Waterproofing bitumen membrane double sided + polymer (wall plate + top plate)	Q	12 - 19	8	84	92
22	Class C Aggregate Work	R	23 - 24	6	117	123
23	AC-WC Production and Sanding	S	24 - 25	5	123	128
24	U Ditch 80/80 G. 20 Tonne + cover and Installation	T	12 - 13	2	84	133
25	Jet Fan Cap. 3000 CMH	U	12 - 15	3	84	135
26	Fresh Air Fan (Cabinet Type)	V	12 - 16	13	84	135
27	Passenger Elevator 400 KG Capacity	W	12 - 14	21	84	127

Source: Processed by the author 2024

Likewise, in the table above, it can be seen that for the Mob Demob and Sheet Pile Piling and Retraction work items that were previously combined, the backward calculation table is made separate because the work is carried out in 2 different segments.

3.4. Calculating Total Float

Calculating total float. Before determining the critical path, we must identify the total float of each activity. Total float is an activity that has a time gap. Calculation of total float can be done by reducing LS with ES or LF with EF. This calculation can be seen in table below:

Table 3. Calculation of Total Float and Free Float

No.	Activity Code	Node	Duration	Total Float	Free Float
1	A1	1 - 2	7	10	0
2	A2	25 - 27	7	0	0
3	B	6 - 7	10	0	0
4	C	12 - 18	4	47	0
5	D	20 - 21	16	0	0
6	E	7 - 8	18	0	0
7	F1	4 - 6	9	0	0
8	F2	4 - 5	9	0	0
9	F3	21 - 22	9	0	0
10	F4	21 - 23	9	0	0
11	G	1 - 3	17	0	0
12	H	3 - 4	11	0	0
13	I	9 - 10	4	2	0
14	J	8 - 9	7	0	0
15	K	9 - 11	6	0	0
16	L	11 - 12	6	0	0
17	M	12 - 17	21	30	0
18	N	13 - 26	2	47	0
19	O	14 - 27	8	22	22
20	P	12 - 20	4	4	4
21	Q	12 - 19	8	0	0
22	R	23 - 24	6	0	0
23	S	24 - 25	5	0	0
24	T	12 - 13	2	47	0
25	U	12 - 15	3	48	0
26	V	12 - 16	13	38	0
27	W	12 - 14	21	22	0

Source: Processed by the author 2024

From the table above, it can be seen the calculation of determining Total Float and Free Float using the following formula:

Total Float = Late Finish – Early Start – Duration

Free Float = Early Finish – Early Start – Duration

3.5. Network Drawing

To make it easier to identify critical path activities with forward calculations and backward calculations, it can be done by drawing a network first.

3.6. Determining the Critical Path

The next stage identifies the critical path in project activities by looking at table 4.7, by looking at the Total Float (FF) and Free Float (FF) values which are worth 0. Activities on the critical path are presented in table below:

Table 4. Critical Path

No.	Work Item	Activity Code	Duration	Total Float	Free Froat
1	Mobilisation	A1	7	10	0
2	Demobilisation	A2	7	0	0
3	Land excavation	B	10	0	0
4	Sirtu backfill for building floor elevation	C	4	47	0
5	Backfill soil compaction work	D	16	0	0
6	Soil removal	E	18	0	0
7	Construction of sheet pile + bracing	F1	9	0	0
8	Construction of sheet pile + bracing	F2	9	0	0
9	Removal of sheet pile + Bracing	F3	9	0	0
10	Sheet pile removal + Bracing	F4	9	0	0
11	40cm Diameter K600 Type C Piles	G	17	0	0
12	Pile driving including bracing	H	11	0	0
13	32 cm wide PVC Waterstop	I	4	2	0
14	Raft Foundation Concrete 60 cm fc' 35 mpa (PC 450)	J	7	0	0
15	Wall Concrete 40 cm thick f'c 35 Mpa (PC 450)	K	6	0	0
16	Concrete Plate 60 cm thick fc' 35 mpa (PC 450)	L	6	0	0
17	Homogeneous Tile 60x60 (Polished)	M	21	30	0
18	Stenlish steel grill cover	N	2	47	0
19	Entrance cover 8 mm tempered reflective glass + spider and frame	O	8	22	22
20	Waterproofing Bitumen Coating (under the floor tiles)	P	4	4	4
21	Waterproofing bitumen membrane double sided + polymer (wall plate + top plate)	Q	8	0	0
22	Class C Aggregate Work	R	6	0	0
23	AC-WC Production and Sanding	S	5	0	0
24	U Ditch 80/80 G. 20 Tonne + cover and Installation	T	2	47	0
25	Jet Fan Cap. 3000 CMH	U	3	48	0
26	Fresh Air Fan (Cabinet Type)	V	13	38	0
27	Passenger Elevator 400 KG Capacity	W	21	22	0

Source: Processed by the author 2024

From the table above, it can be seen the critical path of each work item by looking at activities where Total Float = Free Float = 0. This means that the path where each activity has no time leeway, either Total Float or Free Float. From the table above, it can be seen that almost all work items are critical paths, because these work items are major work items for the construction of a pedestrian tunnel from the Joyoboyo intermodal terminal to the Surabaya zoo.

From the analysis carried out on the project control of the construction of the Joyoboyo intermodal terminal pedestrian tunnel to the Surabaya zoo using the critical path method (CPM) can be described as follows:

1) Work starts at the earliest from node 1, namely from the receipt of the Work Start Order (SPMK).
2) The work is planned to be completed in 135 days which is the critical time of the Joyoboyo intermodal terminal pedestrian tunnel construction project activities to the Surabaya zoo so that delays from one activity node to another activity node on one critical path will affect the completion time of the work.
3) The Total Float and Free Float of the work on the critical path is equal to zero (0) meaning that there is no free time that can be used to delay an activity, while some activities that are not on the critical path still have free time to carry out the work.

4. Conclusion

By applying the critical path method (CPM) in the construction project of the Joyoboyo intermodal terminal pedestrian tunnel to the Surabaya zoo, it can be known early the effect of delays in one activity on other activities due to the dependence of each job. For example, a delay in the procurement of 40cm diameter piles will affect the delay of other work, so it is necessary to manage existing resources to accelerate other work.

Meanwhile, the use of a time schedule in the form of a flowchart with an S curve made by the implementing contractor cannot provide information on the relationship from the delay of one job to another because it does not provide critical path information. With project control using the critical path method (CPM) on the Joyoboyo intermodal terminal pedestrian tunnel construction project to the Surabaya zoo there is no change in the cost of implementing the work. The price change occurred due to a change in the length of the tunnel work from 156 meters to 172 meters.

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