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Analysis of Drainage Channel Construction Work Time Using the Trade Cost Trade Off (TCTO) Acceleration Method in Ponorogo Regency

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Abstract

Drainage infrastructure development plays a crucial role in supporting urban environmental quality and preventing waterlogging and flooding. However, construction projects often experience delays that hinder infrastructure performance. In the drainage channel construction project on Letjend Suprapto Street and Menur Street, Ponorogo Regency, a progress deviation of −30.26% occurred in the eighth week, indicating the need for an effective acceleration strategy. This study aims to analyze the effect of applying the Trade-Off Cost–Time (*TCTO*) method on project time acceleration and cost changes. This research employed a quantitative approach using network planning analysis with Microsoft Project to identify the critical path, followed by crashing analysis through additional work shifts and cost slope calculations using the *TCTO* method. The findings indicate that the project duration can be reduced from 65 days to 60 days by implementing a two-shift work system. This acceleration resulted in an increase in direct costs from IDR 2,390,347,251.56 to IDR 2,411,296,170.48. The *TCTO* method is proven effective in accelerating project duration with manageable additional costs, making it a viable solution for overcoming delays in drainage construction projects.

Keywords : drainage, time, TCTO**.**

INTRODUCTION

The development of urban areas cannot be separated from the presence of adequate basic infrastructure, which serves as the foundation for supporting the social, economic, and environmental activities of the community. An ideal city is characterized by livability, productivity, and a clear identity. Within the framework of sustainable development, various major cities in Indonesia continue to undertake improvements in order to create urban environments that meet the expectations of their residents (Aisyah et al., 2024; Fatimah et al., 2020; Rachmawati et al., 2024). One of the key indicators in assessing the quality of urban life is the level of comfort experienced by the community in carrying out daily activities, which heavily depends on the availability and quality of basic facilities and infrastructure, both in terms of quantity and quality.

One of the essential infrastructures in urban areas is the drainage system, which functions to channel rainwater and prevent waterlogging and flooding (Aranda et al., 2023). A properly functioning drainage system is a critical aspect of ensuring public comfort and safety, as well as preserving the durability of roadways and buildings (Biancardo et al., 2025; Lourenço et al., 2020). Inadequacies in the drainage system can lead to physical damage, environmental degradation, and disruptions to community mobility and economic activities.

Urban areas such as Letjend Suprapto Street and Menur Street in Ponorogo Regency frequently experience waterlogging during the rainy season, with water depths reaching 0.30–0.50 meters and flood durations lasting up to eight hours. The primary causes include limited drainage capacity, blockages due to accumulated waste, and channel narrowing caused by improperly designed closures (Biancardo et al., 2025). To address these issues, the Ponorogo Regency Government, through the Emergency Budget Allocation (Belanja Tidak Terduga / BTT), initiated the construction of new drainage channels to increase capacity and reduce the risk of flooding. However, during the implementation of the drainage construction project on Letjend Suprapto and Menur Streets, delays occurred in the field. By the eighth week of implementation, a progress deviation of −30.26% was recorded, with actual work completion reaching only 52.17% compared to the target of 82.43%. To mitigate this delay, acceleration strategies are needed that do not significantly increase project costs (Ferri & Kama, 2022; Svejvig et al., 2019).

This broader context is clearly relevant to Ponorogo Regency. A recent study on Ponorogo's urban drainage system identified several flood-prone corridors, including Jaksa Agung Suprapto Street, and found that the calculated 10-year return-period discharge exceeded the capacity of existing drainage channels, indicating the need for channel improvement (Romadhon, 2020). The uploaded manuscript is consistent with this local condition, explaining that Letjend Suprapto Street and Menur Street frequently experience inundation during the rainy season and that drainage upgrading was initiated to increase capacity and reduce recurring flood risk.

The urgency of this issue is also reinforced by recent local reporting. In December 2024, flooding again affected Letjend Suprapto in Ponorogo, with residents attributing the overflow to heavy rainfall, limited drainage size, and accumulated branches and waste inside the channel. This contemporary evidence strengthens the argument that drainage intervention in the study area is not merely preventive but also responsive to a persistent public infrastructure problem that disrupts mobility and urban comfort.

In construction management terms, however, solving drainage problems requires not only appropriate design but also timely project delivery. The manuscript shows that by the eighth week of implementation, the drainage project experienced a progress deviation of −30.26%, with actual realization at 52.17% compared with the planned 82.43%. Such a delay is critical because the benefits of drainage infrastructure cannot be realized when construction completion falls behind schedule, particularly in flood-prone corridors where delays directly prolong exposure to hazards.

Previous studies have shown that schedule acceleration methods can help address construction delays. Thoengsal and Tumpu reported that in drainage work, adding labor reduced project duration from 30 to 25 working days and was more economical than adding overtime hours. Other Trade-Off Cost-Time (TCTO)-based studies in Indonesian construction contexts have similarly demonstrated that project acceleration can shorten completion time through overtime, shift work, or labor adjustment, while requiring careful evaluation of additional costs and productivity changes (Antoro et al., 2024; Azmia & Rohman, 2023; Erfaliani et al., 2024; Himawan et al., 2023; Iryansyah, 2024; Mardiana et al., 2022; Muin et al., 2023; Nabila, 2023; Oetomo & Wulandari, 2023; Paramitha & Dibiantara, 2023). These findings confirm that time–cost optimization is a practical approach in delayed construction environments.

Even so, an important research gap remains. Much of the existing literature applies crashing or time–cost trade-off (TCTO) analysis to buildings, roads, bridges, toll roads, or generalized construction cases (Himawan et al., 2023; Iryansyah, 2024; Mardiana et al., 2022; Muin et al., 2023; Paramitha & Dibiantara, 2023), while fewer studies focus specifically on emergency or urban drainage projects with local flooding implications and critical-path acceleration based on actual field deviation (Oetomo & Wulandari, 2023). The uploaded manuscript contributes to this underexplored area by examining a real drainage construction case in Ponorogo and by linking schedule recovery directly to critical activities such as excavation, U-ditch installation, box culvert installation, river stone masonry, and finishing works.

The novelty of this research therefore lies in its application of the Trade Cost Trade-Off (TCTO) method to a flood-mitigation drainage project in a specific local context where infrastructure urgency and schedule delays intersect. Unlike studies that discuss acceleration in generic construction settings, this research positions TCTO as a decision-support tool for restoring implementation performance in a drainage corridor that has direct consequences for urban flood control. It also offers a practical comparison between normal and accelerated conditions using critical-path analysis and shift-based crashing scenarios, making the study operationally relevant for local public works planning.

Based on that background, this research is intended to analyze how the application of the Trade Cost Trade-Off (TCTO) Acceleration Method in Ponorogo Regency affects project duration and cost in the drainage channel construction work on Letjend Suprapto Street and Menur Street, Ponorogo Regency. The study seeks to identify the critical activities suitable for acceleration, estimate the time reduction achievable through shift addition, and evaluate the cost consequences of that decision. The expected contribution is both theoretical and practical: theoretically, it enriches construction management discussions on time–cost optimization in drainage infrastructure; practically, it provides a reference for contractors and local governments in handling delayed infrastructure projects more efficiently without losing control over budget decisions and implementation priorities.

RESEARCH METHOD

This research began with a literature review based on books and previous research journals, serving as the theoretical foundation for the study. Primary and secondary data were then collected as the basis for calculations. A scheduling analysis was conducted using network planning, followed by analysis with Microsoft Project to identify the critical path of project activities. The activities located on the critical path were then subjected to acceleration or crashing to determine the Crash Duration, Crash Cost, and Cost Slope resulting from the addition of work shifts. Subsequently, a Time Cost Trade Off (TCTO) analysis was conducted to evaluate the accelerated schedule duration and the associated additional costs.

RESULTS AND DISCUSSION

Network Planning Analysis using Microsoft Project

In this study, network planning was developed using Microsoft Project based on the S-Curve of the drainage construction plan on Letjend Suprapto and Menur Streets, Ponorogo Regency. This planning identified several critical activities essential for time acceleration analysis (crashing) within the TCTO method. The resulting S-Curve provides information on the activity sequence and overall project duration. The list of critical activities is presented in the following table:

Table 1. Work Items on the Critical Path

No.	Activity Description	Activity Code	Predecessor	Duration (days)	Critical Activity
A	DRAINAGE WORK	1	-	-	-
I	Preparatory Work (Layout and Project Signboard)	2	-	3	-
II	Mobilization and Demobilization of Heavy Equipment	3	2	3	-
III	SMKK Implementation (Safety Docs, PPE, BPJS)	4	2SS	60	-
IV	Excavation Work Using Heavy Equipment	5	3	20	CRITICAL
V	Install 1 m U-Ditch 120x120x120 cm (5 Ton Axle Load)	6	5FS-1 day	20	CRITICAL
VI	Install 1 m U-Ditch Cover (Type LD) 120x120x120 cm	7	6FF+1 day	20	-
VII	Install 1 m U-Ditch 100x120x120 cm (5 Ton Axle Load)	8	6SS+2 days	20	CRITICAL
VIII	Install 1 m U-Ditch Cover (Type LD) 100x120x120 cm	9	8FF+1 day	20	-
IX	Install 1 m Box Culvert 100x100x120 cm (20 Ton)	10	8SS	20	CRITICAL
X	1 m² Plastering (1:3 Mortar, 15 mm Thick)	11	10FF	6	-
XI	Manual Rebar Installation (<12 mm)	12	10	2	-
XII	Formwork Installation (4x Reuse)	13	12	2	-
XIII	Low-Quality Concrete (f'c 15 MPa, Slump 100±25 mm)	14	6SS-2 days	3	-
XIV	Ready-Mix Concrete (f'c 20 MPa)	15	13	3	-

No.	Activity Description	Activity Code	Predecessor	Duration (days)	Critical Activity
XV	Aggregate Base Course Layer Class A	16	15	2	-
XVI	Prime Coat – Liquid Asphalt / Emulsion	17	16SS	4	-
XVII	Asphalt Concrete – Wearing Course (AC-WC)	18	17SS	4	-
XVIII	Wiremesh M10 Installation	19	10	8	-
XIX	River Stone Masonry	20	10FS-2 days	14	CRITICAL
XX	Finishing works of river stone masonry	21	20	4	CRITICAL
XXI	Sluice Gate Installation	22	20FF	4	-
XXII	Trash Filter Installation	23	22FF	1	-

Source: Analysis Results, 2025

Based on Table 1, the critical activities selected for analysis using the Trade Cost Trade Off (TCTO) method include:

1. Excavation using heavy equipment/excavator
2. Installation of 1 meter U-Ditch 120x120x120 cm (5-ton axle load)
3. Installation of 1 meter U-Ditch 100x120x120 cm (5-ton axle load)
4. Installation of 1 meter Box Culvert 100x100x120 cm (20-ton axle load)
5. River stone masonry work
6. Finishing works of river stone masonry

Calculation of Direct and Indirect Costs

Direct costs refer to expenses incurred for the actual execution of construction work on-site, which include labor wages and material costs. Meanwhile, indirect costs are expenditures not directly used in field operations, comprising profit margin and overhead costs.

The determination of direct and indirect costs can be calculated using the following formulas:

$$Indirect\ Cost = 10\% \times Direct\ Cost \tag{1.1}$$

$$Direct\ Cost = Normal\ Cost - Indirect\ Cost \tag{1.2}$$

The summary of direct and indirect cost calculations can be seen in the following table:

Table 2. Calculation of Direct and Indirect Costs

No	Work Description	Unit	Vol.	Unit Price (IDR)	Indirect Cost (IDR)	Direct Cost (IDR)
A	DRAINAGE WORK					
I	Preparatory Work (Layout and Project Signboard)	Ls	1,00	1.500.000,00	150.000,00	1.350.000,00

No	Work Description	Unit	Vol.	Unit Price (IDR)	Indirect Cost (IDR)	Direct Cost (IDR)
II	Mobilization and Demobilization of Heavy Equipment	Ls	1,00	1.600.000,00	1.160.000,00	10.440.000,00
III	SMKK Implementation (Safety Docs, PPE, BPJS)	Ls	1,00	5.039.021,62	503.902,16	4.535.119,46
IV	Excavation Work Using Heavy Equipment	m^3	1.554,58	51.418,66	7.993.442,50	71.940.982,54
V	Install 1 m U-Ditch 120x120x120 cm (5 Ton Axle Load)	m	177,60	2.232.868,10	39.655.737,41	356.901.636,73
VI	Install 1 m U-Ditch Cover (Type LD) 120x120x120 cm	m	178,80	924.389,01	16.528.075,57	148.752.680,17
VII	Install 1 m U-Ditch 100x120x120 cm (5 Ton Axle Load)	m	264,00	2.086.362,77	55.079.977,17	495.719.794,52
VIII	Install 1 m U-Ditch Cover (Type LD) 100x120x120 cm	m	266,40	720.375,85	19.190.812,54	172.717.312,90
IX	Install 1 m Box Culvert 100x100x120 cm (20 Ton)	m	82,80	4.395.304,72	36.393.123,05	327.538.107,44
X	1 m² Plastering (1:3 Mortar, 15 mm Thick)	m^2	217,06	57.053,92	1.238.412,39	11.145.711,49
XI	Manual Rebar Installation (<12 mm)	kg	2.692,95	17.272,20	4.651.317,10	41.861.853,89
XII	Formwork Installation (4x Reuse)	m^2	62,58	126.368,00	790.810,94	7.117.298,50
XIII	Low-Quality Concrete (f'c 15 MPa, Slump 100±25 mm)	m^3	16,28	1.224.575,70	1.993.609,25	17.942.483,22
XIV	Ready-Mix Concrete (f'c 20 MPa)	m^3	166,40	1.247.829,00	20.763.874,56	186.874.871,04
XV	Aggregate Base Course Layer Class A	m^3	32,34	552.438,16	1.786.585,01	16.079.265,09
XVI	Prime Coat – Liquid Asphalt / Emulsion	liter	872,31	15.085,43	1.315.917,42	11.843.256,80

No	Work Description	Unit	Vol.	Unit Price (IDR)	Indirect Cost (IDR)	Direct Cost (IDR)
XVII	Asphalt Concrete – Wearing Course (AC-WC)	ton	189,49	1.620.547,99	30.707.763,90	276.369.875,11
XVIII	Wiremesh M10 Installation	m^2	215,63	131.903,56	2.844.236,42	25.598.127,74
XIX	River Stone Masonry	m^3	144,48	1.101.897,50	15.920.215,08	143.281.935,72
XX	Finishing works of river stone masonry	m^2	224,70	59.026,55	1.326.326,58	11.936.939,21
XXI	Sluice Gate Installation	unit	2,00	27.500.000,00	5.500.000,00	49.500.000,00
XXII	Trash Filter Installation	unit	1,00	1.000.000,00	100.000,00	900.000,00
GRAND TOTAL					**265.594.139,06**	**2.390.347.251,56**

Source: Analysis Results, 2025

From Table 2, the total normal indirect cost is IDR 265.594.139,06, while the total direct cost amounts to IDR 2.390.347.251,56.

Crashing Schedule Analysis by Implementing Additional Work Shifts

In this alternative, a two-shift work system is implemented. The first shift operates from 08:00 to 16:00, while the second shift operates from 16:00 to 00:00. The labor force assigned to the morning and evening shifts consists of different groups, with the productivity of the night shift workers assumed to be 85% of the productivity of the day shift workers. The following is an example of a work shift calculation for the drainage construction project on Letjend Suprapto street and Menur street, Ponorogo Regency:

1) River Stone Masonry

Given:

Volume : 144,48 m^3
Duration : 14 days
Number of Shifts : 2 shifts per day
Normal Direct Cost : 143.281.935,72

a) Calculation of normal productivity

Productivity = Volume / Duration
= 144,48 m^3 / 14 days
= 10,32 m^3 / day

b) Calculation of crash duration

Crash duration = Volume / (Prod. Morning shift + Prod. Night shift)
= 144,48 m^3 / (10,32 m^3 /day + 8,77 m^3 /day)
= 8 hari

c) Calculation of crash cost

The first step in determining the crash cost is to calculate the normal daily labor cost. This calculation is presented in the table below:

Table 3. Calculation of Labor Costs for Morning and Night Shifts

Labor Type	Quantiy (Person)	Cost/hour (IDR)	Total Hours	Cost/day (IDR)	Total Cost (IDR)
Worker	16	14.286	7	100.000	1.600.000
Mason	6	16.429	7	115.000	690.000
Foreman	2	21.429	7	150.000	300.000
Total				365.000	2.590.000

Source: Analysis Results, 2025

As shown in the table above, the normal daily labor cost required to perform the respective work item amounts to IDR 2.590.000

Wage Cost = Daily Labor Cost x Normal Duration

= 2.590.000,00 × 14

= 36.260.000,00

Material Cost = Direct Cost – Wage Cost

= 143.281.935,72 - 36.260.000,00

= 107.021.935,72

Crash Cost = Material Cost + (Wage Cost × Number of Shifts × Crash Duration)

= 107.021.935,72 + (2.590.000 × 2 × 8)

= 146.221.936

d) Cost slope calculation

$$\text{Cost Slope} = \frac{Crash\ Cost - Normal\ Direct\ Cost}{Normal\ Duration - Crash\ Duratiom}$$

$$= \frac{146.221.935{,}72\ -\ 143.281.935{,}72}{14\ day\ -\ 8\ day}$$

= 457.058,82 /day

For a more detailed explanation of the cost slope calculation, refer to the following table:

Table 4. Crashing Analysis through the Addition of Work Shifts

No	Work Description	Normal Cost		Cost after Crashing (Work Shift)		
		Normal Duration (Dn)	Total Direct Cost	Crashing Duration (Dc)	Total Direct Cost (IDR)	Cost Slope (IDR)
A	DRAINAGE WORK					
I	Excavation Work Using	20	71.940.982,54	20	71.940.982,54	511.764,71

No	Work Description	Normal Cost		Cost after Crashing (Work Shift)		
		Normal Duration (Dn)	Total Direct Cost	Crashing Duration (Dc)	Total Direct Cost (IDR)	Cost Slope (IDR)
	Heavy Equipment					
II	Install 1 m U-Ditch 120x120x120 cm (5 Ton Axle Load)	20	356.901.636,73	11	357.655.690,79	82.058,82
III	Install 1 m U-Ditch 100x120x120 cm (5 Ton Axle Load)	20	495.719.794,52	11	496.473.848,58	82.058,82
IV	Install 1 m Box Culvert 100x100x120 cm (20 Ton)	20	327.538.107,44	11	328.129.999,33	64.411,76
V	River Stone Masonry	14	143.281.935,72	8	146.221.935,72	457.058,82
VI	Finishing works of river stone masonry	4	11.936.939,21	2	12.955.317,58	554.117,65

Source: Analysis Results, 2025

Table 4 presents the results of the crashing analysis by adding work shifts to the activities located on the critical path.

Time and Cost Comparison Analysis Between Normal Conditions and Accelerated Schedule

Table 5. Time and cost comparison between normal conditions and accelerated schedule using the TCTO method

NO	Work Description	Normal Cost		Cost after Crashing (Work Shift)		
		Normal Duration (Dn)	Total Direct Cost	Crashing Duration (Dc)	Total Direct Cost (IDR)	Cost Slope (IDR)
A	DRAINAGE WORK					
I	Preparatory Work (Layout and Project Signboard)	3	1.350.000,00	-	1.350.000,00	-
II	Mobilization and	3	10.440.000,00	-	10.440.000,00	-

NO	Work Description	Normal Cost		Cost after Crashing (Work Shift)		
		Normal Duration (Dn)	Total Direct Cost	Crashing Duration (Dc)	Total Direct Cost (IDR)	Cost Slope (IDR)
	Demobilization of Heavy Equipment					
III	SMKK Implementation (Safety Docs, PPE, BPJS)	60	4.535.119,46	-	4.535.119,46	-
IV	Excavation Work Using Heavy Equipment	20	71.940.982,54	11	78.995.036,60	767.647,06
V	Install 1 m U-Ditch 120x120x120 cm (5 Ton Axle Load)	20	356.901.636,73	11	360.538.123,22	395.735,29
VI	Install 1 m U-Ditch Cover (Type LD) 120x120x120 cm	20	148.752.680,17	-	148.752.680,17	-
VII	Install 1 m U-Ditch 100x120x120 cm (5 Ton Axle Load)	20	495.719.794,52	11	500.365.740,47	505.588,24
VIII	Install 1 m U-Ditch Cover (Type LD) 100x120x120 cm	20	172.717.312,90	-	172.717.312,90	-
IX	Install 1 m Box Culvert 100x100x120 cm (20 Ton)	20	327.538.107,44	11	329.192.161,49	180.000,00
X	1 m² Plastering (1:3 Mortar, 15 mm Thick)	6	11.145.711,49	-	11.145.711,49	-
XI	Manual Rebar Installation (<12 mm)	2	41.861.853,89	-	41.861.853,89	-
XII	Formwork Installation (4x Reuse)	2	7.117.298,50	-	7.117.298,50	-

NO	Work Description	Normal Cost		Cost after Crashing (Work Shift)		
		Normal Duration (Dn)	Total Direct Cost	Crashing Duration (Dc)	Total Direct Cost (IDR)	Cost Slope (IDR)
XIII	Low-Quality Concrete (f'c 15 MPa, Slump 100±25 mm)	3	17.942.483,22	-	17.942.483,22	-
XIV	Ready-Mix Concrete (f'c 20 MPa)	3	186.874.871,04	-	186.874.871,04	-
XV	Aggregate Base Course Layer Class A	2	16.079.265,09	-	16.079.265,09	-
XVI	Prime Coat – Liquid Asphalt / Emulsion	4	11.843.256,80	-	11.843.256,80	-
XVII	Asphalt Concrete – Wearing Course (AC-WC)	4	276.369.875,11	-	276.369.875,11	-
XVIII	Wiremesh M10 Installation	8	25.598.127,74	-	25.598.127,74	-
XIX	River Stone Masonry	14	143.281.935,72	8	146.221.935,72	457.058,82
XX	Finishing works of river stone masonry	4	11.936.939,21	2	12.955.317,58	554.117,65
XXI	Sluice Gate Installation	4	49.500.000,00	-	49.500.000,00	
XXII	Trash Filter Installation	1	900.000,00	-	900.000,00	
	TOTAL	**65**	**2.390.347.251,56**	**60**	**2.411.296.170,48**	**2.860.147**

Source: Analysis Results, 2025

As shown in Table 5, a comparative analysis between the normal execution condition and the accelerated scenario demonstrates that the initial project duration of 65 calendar days was reduced to 60 calendar days through the application of the Trade Cost Trade Off (TCTO) method. This schedule compression was achieved with an increase in direct construction costs, reaching IDR 2,411,296,170.48

CONCLUSION

This study analyzed the application of the Trade Cost Trade Off (TCTO) method to accelerate the drainage construction project on Letjend Suprapto street and Menur street, Ponorogo Regency. By implementing a two-shift work system and identifying critical path activities, the project duration was successfully reduced from 65 days to 60 days. The direct cost after acceleration was IDR 2.411.296.170.48. These results indicate that the TCTO method can be an effective approach to reducing project time with manageable additional costs. While time and cost efficiency are achieved through project acceleration, it is important to ensure that quality standards are not compromised. Therefore, it is strongly recommended to integrate a quality control management system during accelerated project execution. Future studies may also explore the impact of acceleration strategies on worker safety, equipment performance, and long-term maintenance outcomes to ensure a more comprehensive project evaluation.

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