



Time Cost Trade-Off Analysis for Time and Cost Optimization on The Water Treatment Plant (WTP) Construction Project

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Abstract. A project is a business or activity that is complex, non-routine, limited by time, budget, resources and performance specifications designed to meet consumer needs. The Water Treatment Plant (WTP) construction project in Pulau Pinang Village, which has a capacity of 50L/SPAM, affects access under public roads. Therefore, this research was carried out to speed up project time using the Time Cost Trade-Off Analysis (TCTO) method. TCTO is an analysis method used to speed up project completion time by compressing the schedule to get a more profitable project in terms of time (duration) and cost. TCTO analysis uses the Crashing method, assisted by Microsoft Project 2016 software. The research results show that the standard time to complete a project is 180 days, and after accelerating with a Crash time, the minimum project completion time becomes 147 days; while accelerating with a Crash time, the maximum project completion becomes 140 days. Alternative improvements based on critical hotspots in this research use maximum crashing. This result is evidenced by the efficiency of reducing the total project cost by 0.36%, namely IDR 26,709,375.38 and the efficiency of reducing the total project time by 22.2%, namely 40 days.

Keywords: Construction, Crashing, TCTO, WTP.

1

Introduction

Projects generally have deadlines, meaning they must be completed before or by the specified time. Regarding project issues, timely completion is a crucial goal for project owners and contractors. During project execution, discrepancies in the schedule often occur on-site, leading to time extensions and cost overruns. Common causes of delays include design changes, weather factors, inadequate labor, materials, or equipment, planning or specification errors, and issues with leadership and management teams. Leadership is an indicator of management that involves turning planning on paper into reality. The necessary skills include converting designs into multi-story buildings with value and appeal [1]. Acceleration can be pursued not only to address delays. Project Crashing is a method to shorten the duration of project completion by reducing the processing time for activities considered critical from the previously identified time.

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That has been previously identified. This activity time reduction can be done in two ways: by adding overtime hours or workers [2].

One method to identify time and cost trade-offs in an ongoing project is Time Cost Trade-Off Analysis. The Time Cost Trade-Off Analysis method accelerates project execution by analyzing how much time can be shortened with additional costs, aiming to find the maximum acceleration and minimum cost [3]. The TCTO method can be implemented in various ways, such as changing construction methods, increasing the number of workers, introducing work shifts, using faster materials, or extending working hours or overtime. The construction project of a Water Treatment Plant (WTP) with a volume of 1.3 m³, located in Pulau Pinang, Kutai Kartanegara Regency, is chosen as the research object because the owner desires acceleration in the project execution process. The construction of the WTP 50 L/Second in Desa Pulau Pinang is selected because, during the project activities on-site, the building under the public road must be completed quickly and reopened to the public to avoid delays in execution. Therefore, this research is conducted to accelerate project execution with minimal additional costs and to analyze how much time can be shortened with minimal extra costs using the Time Cost Trade-Off (TCTO) method.

2 Material and Methods

The research is conducted on the Water Treatment Plant (WTP) construction project in Desa Pulau Pinang, Kembang Janggut District, Kutai Kartanegara Regency, East Kalimantan Province, Indonesia. The TCTO analysis uses the Crashing method with Microsoft Project 2016 software. The stages in the TCTO approach are as follows:

- Data Collection (Time and Cost Variables) was based on a questionnaire and discussion with the contractors.
- Cost Slope Analysis and Calculation Data analysis can be assisted using Microsoft Projects, Time Cost Trade-Off methods, and Microsoft Excel by inputting relevant data for analysis. The result of data input is the critical path. Once the critical path is identified, each activity on the critical path is analyzed using the time cost trade-off method, which includes optimizing overtime hours.
- Time Cost Trade-Off Calculation Analysis Result. A total cost graph is produced after performing the Time Cost Trade-Off analysis. The total project cost is the direct and indirect expenses incurred after acceleration. Direct costs will increase, while indirect costs will decrease due to the faster duration than before [4].

3 Results

3.1 Water Treatment Plant (WTP) Construction Project in Pulau Pinang Village

The project used as a case study in this research is the construction of a Water Treatment Plant (WTP) located in Desa Pulau Pinang, Kembang Janggut District, Kutai Kartanegara Regency. This WTP includes several buildings: a dosing house, a chemical

storage tank, and the central Water Treatment Plant (WTP) building. The WTP in Desa Pulau Pinang has a capacity of 50 litres per second. The Water Treatment Plant (WTP) is equipped with facilities supporting the operational unit of the WTP in Pulau Pinang, including.

Water Treatment Plant (WTP): The WTP is a system or facility used to process water from contaminated raw water (influent) to achieve the desired water quality standards or make it suitable for consumption. This construction involves five processes: coagulation, flocculation, sedimentation, filtration, and disinfection [5].

Chemical Addition House: In the WTP coagulation-flocculation process, colloidal particles destabilize because the raw water source is typically in colloidal form with various colloids present [6]. The general description of the WTP construction project in Pulau Pinang Village is as follows.

3.2 Normal Project Execution Stages

The details of the work stages and regular durations can be seen in Table 1.

Table 1. Population Growth Rate

No	Activity
I	Water Treatment Plant (WTP)
1.1	Drainage
1.2	WTP 50 l/s
II	Mechanical, Electrical, and Plumbing
III	Dosing house
3.1	Preparation stage
3.2	Foundation
3.3	Structure
3.3.1	Sloof 15/20 cm
3.3.2	Column 20/20 cm
3.3.3	Column 15/25 cm
3.3.4	Ring Balk 15/25 cm
3.3.5	Chemical tub work
3.3.6	inspection of roads and stairs
3.3.7	Wall and floor
3.3.8	Roof and Ceiling
3.3.9	electrical installation
3.3.10	Finishing
IV	Others work
	Duration 180 days

3.3 Project Costs for the WTP Construction in Pulau Pinang

The project costs used in the Water Treatment Plant (WTP) construction in Pulau Pinang village are the actual costs obtained from the project consultant, CV. XYZ. This result is the breakdown cost for the Water Treatment Plant (WTP) construction project in Pulau Pinang Village, as shown in Table 2.

Table 2. Project Cost Breakdown for PDAM in Pulau Pinang

Direct cost	Rp	6,747,472,621.62
PPN 11%	Rp	742,221,988
Amount	Rp	7,489,694,609.62

3.4 Developing the Network Diagram

After determining the dependencies between activities and the duration of each activity, a network diagram can be prepared using Microsoft Office Project 2016 software to perform forward and backward calculations. The critical path and critical activities can be identified by examining the precedence diagram of each activity, as shown in Table 3.

Table 3. Critical Path of the WTP Project

No	Activity
I	Water Treatment Plant Project
1.1	Drainage
1.1.1	Excavation of 1m ³ of ordinary soil 0 to 1 m deep
1.1.2	Pair 1m ³ of stone mountain foundation 1:5
1.1.3	Making 1m ³ Concrete Quality f _c = 7.4 Mpa
II	Mechanical-Electrical Work
III	Dossing House Construction Work
3.1	Preliminary Work
3.1.1	Bouwplank Measurement and Installation
3.2	Excavation & Foundation Work
3.2.1	1 m Ulin 10/10 (Local) Pile
3.2.2	Installing 5x10 Ulin Wood Sunduk Kalang
3.2.3	Excavation of 1 m ³ of ordinary soil 0 to 1 m deep
3.2.4	Backfill 1 m ³ Excavated Soil
3.2.5	Pair 1 m ³ Stone Mountain Foundation 1:5
3.3	Structure Work
3.3.1	Sloft work 15/20 cm
3.3.1.1	Making 1 m ³ of concrete quality f _c = 19.3 MPa
3.3.1.2	Reinforcement of 1 Kg with plain iron or threaded iron
3.3.1.3	Installation of 1m ² of sloof formwork
3.3.2	Column work 20/20 cm
3.3.2.1	Make 1 m ³ of concrete quality f _c = 19.3 MPa
3.3.2.2	1 Kg reinforcement with plain iron or screw iron
3.3.2.3	Installation of 1m ² column formwork
3.3.3	Column Work 15/25 cm
3.3.3.1	Making 1 m ³ of concrete quality f _c = 19.3 MPa
3.3.3.2	Reinforcement of 1 Kg with plain iron or threaded iron
3.3.3.3	Installation of 1m ² column formwork
3.3.4	Ring Balk Column Work
3.3.4.1	Making 1 m ³ of concrete quality f _c = 19.3 MPa
3.3.4.2	1 Kg reinforcement with plain iron or screw iron
3.3.4.3	Installation of 1m ² beam formwork
3.3.5	Chemical Tub Work
3.3.5.1	Making 1 m ³ of concrete quality f _c = 19.3 MPa

No	Activity
3.3.5.2	Formwork 1 Kg with plain iron or threaded iron
3.3.5.3	Installation of 1 m ² wall formwork
3.3.6	Inspection Road and Stairs Work
3.3.6.1	Making 1 m ³ f concrete quality f _c = 7.4 MPa
3.3.6.2	1 Kg reinforcement with plain iron or screw iron
3.3.6.3	Installation of 1 m ² floor formwork
3.3.7	Wall & Floor Work
3.3.7.1	Wall Laying Red Brick ½ Brick 1:5
3.3.7.2	Plastering 1 m ² 1sp:5pp 2 cm
3.3.7.3	Instalation of 1 m ² acian
3.3.7.4	Ceramic Floor Work 40x40
3.3.7.5	1 m ² Fitting, Ceramic Wall 40x40 cm SNI 7395: 2008
3.3.8	Roof & Ceiling Work
3.3.8.1	Light Steel Frame/m ² Installed
3.3.8.2	Installation of 1 m ² Zinalum Roof
3.3.8.3	Installation of 1 m Clasiboard Plank List
3.3.8.4	Metal Ceiling Frame Furimng/m2 Installed
3.3.9	Electrical Installation Work
3.3.9.1	Electrical Installation
3.3.9.2	7 watt LED lamp + fittings
3.3.9.3	Double Switch
3.3.9.4	1 Phase Contact Stop
3.3.10	Paint Work
3.3.10.1	Painting 1 m ² of New Wall / Ceiling
3.3.10.2	Painting 1 m ² Wood Surface with Oil Paint 3 times
IV	Other Works
4.1	Pair 1 m ³ of Stone Mountain Foundation 1:5
4.2	Making of 1 m ³ Concrete Quality f _c = 19.3 Mpa
4.3	Laying 1m ² Foundation Formwork

Based on the preparation for each work item listed in Table 3, which represents the critical path of the WTP construction project in Pulau Pinang Village, there are four categories of work with 43 crucial items. These items include excavation work from 0 to 1 meter deep, mountain stone foundation placement, making concrete with a compressive strength of f_c = 7.4 MPa, and others.

3.5 Alternative Project Acceleration

In this study, the method used to accelerate the project is by adding optimum overtime hours. According to the Decree of the Minister of Manpower and Transmigration of the Republic of Indonesia, No. Kep 102/MEN/VI/2004, Articles 3 and 11 regarding overtime wages and work hours: Overtime work can only be performed for a maximum of 3 hours per day and 14 hours per week. The first hour of overtime must be paid 1.5 times the hourly wage. Each subsequent hour of overtime must be paid twice the hourly wage.

1. Determining Crash Duration

Crash duration is required to complete the work after adding optimum overtime hours. Before calculating crash duration, daily productivity, productivity per hour, and daily productivity after crashing (acceleration) must be determined.

2. Determining Crash Cost

The crash is the total direct cost incurred to complete the work after acceleration. This cost includes direct costs and total overtime wages for workers. With acceleration, the direct costs for each work item will be higher compared to previous direct costs.

3. Determining Cost Slope

The cost slope represents the increase in direct costs to accelerate an activity per unit of time. The increase in cost is directly proportional to the crash cost. The higher the crash cost, the higher the cost slope, and vice versa. The planned duration also affects the magnitude of the acceleration cost.

$$\text{Cost Slope/Day} = (\text{Crash Cost} - \text{Normal Cost}) / \text{Crashing} \quad (1)$$

3.6 Time Cost Trade-Off Analysis (TCTO)

Once each activity's cost slope (increase in cost due to acceleration) is determined, the next step is to perform a Time Cost Trade-Off Analysis. This analysis involves compressing (shortening) activities on the critical path. The compression process will reveal a new critical path, meaning that compression should continue until the project duration is shortened to the point with the lowest cost slope. In the WTP construction project in Pulau Pinang Village, the hill at the lowest cost is for the mountain stone foundation installation.

1. Project Time and Cost Efficiency

- Maximum Crashing

$$\begin{aligned} \text{Project Time Efficiency} &= \frac{(\text{Normal Duration} - \text{Acceleration Duration})}{\text{Acceleration Duration}} \times 100\% \\ &= (180 - 140) / 180 \times 100\% \\ &= 22.2\% \end{aligned}$$

$$\begin{aligned} \text{Project Cost} &= \frac{\text{Normal Cost} - \text{Acceleration Cost}}{\text{Normal Cost}} \times 100\% \\ &= \frac{\text{Rp. 7, 624, 644, 062} - \text{Rp. 7, 651, 834, 687.43}}{\text{Rp. 7, 624, 644, 062}} \\ &= 0.36\% \end{aligned}$$

- Minimum Crashing

$$\begin{aligned} \text{Project Time Efficiency} &= \frac{(\text{Normal Duration} - \text{Acceleration Duration})}{\text{Acceleration Duration}} \times 100\% \\ &= (180 - 147) / 180 \times 100\% \\ &= 18.3\% \end{aligned}$$

$$\begin{aligned} \text{Project Cost} &= \frac{\text{Normal Cost} - \text{Acceleration Cost}}{\text{Normal Cost}} \times 100\% \\ &= \frac{\text{Rp. 7, 624, 644, 062} - \text{Rp. 7, 651, 834, 687. 43}}{\text{Rp. 7, 624, 644, 062}} \\ &= 0.36\% \end{aligned}$$

4 Conclusions

After conducting this study using the Time Cost Trade-Off Analysis method, the following time accelerations were achieved: The Maximum crashing resulted in a project duration of 140 days, and the Minimum crashing resulted in a project duration of 147 days. Thus, applying this method can successfully accelerate the project completion time. The research conducted on the WTP Development project in Pulau Pinang Village has yielded several conclusions. Firstly, the standard completion time for the project is 180 days. Still, after accelerating it with the addition of optimum overtime working hours and minimum crashing time, the project completion time decreases to 147 days. Moreover, if the project is further accelerated with the addition of optimum working hours and maximum crashing time, the completion time can be reduced to 140 days. Thus, the maximum crashing acceleration alternative is considered the most optimal, resulting in a time efficiency of 22.2%.

Additionally, the calculation of this alternative shows that it incurs an additional total cost of 0.36% or Rp 27,190,625.43. The original total cost of the project ranged from Rp 7,624,644,062.00 to Rp 7,651,834,687.43. The alternative efficiency in terms of time and cost is achieved at a project age of 140 working days, with a total project cost of Rp 7,651,834,687.43, a project time efficiency of 40 days (22.2%), and an additional cost efficiency of Rp 27,190,625.43 (0.36%).

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

References

1. Sari, D. P., Purwanto, H., Purnama, H., Hidayat, A., Iskandar, A. A., Isdyanto, A.: Manajemen Proyek Infrastruktur. Tohar Media, Makassar (2024).

2. Brando, R., Walangitan, P.D.R.O., Tjakra, J.: Sistem Pengendalian Waktu dengan Critical Path Method (CPM) pada Proyek Konstruksi (Studi Kasus: Menara Alfa Omega Tomohon). *J. Sipil Statik* 5, 363–371 (2017).
3. Vebiola, N.E., Waskito, J.P.H.: Analisis Optimasi Waktu dan Biaya dengan Metode Time Cost Trade Off (Studi Kasus: Proyek Pembangunan Basement Kawasan Balai Pemuda). *Axial J. Rekayasa Dan Manaj. Konstr.* 8, 113 (2020).
4. Gunawan, S., Handayani, F.S., Setiono, S.: Analisis Optimasi Waktu dan Biaya pada Proyek JDU SPAM Regional Wosusokas Segmen 3 dengan Metode Time Cost Trade Off menggunakan Software Primavera 6.0. *Sustain. Civ. Build. Manag. Eng.* 1, 8 (2024).
5. Rachmawati, F., Marsono, B.D.: Evaluasi Teknis Instalasi Pengolahan Air Unit Ultrafiltrasi pada Instalasi Pengolahan Air (IPA) Siwalanpanji PDAM Sidoarjo. *J. Tek. ITS* 10, (2021).
6. Utami, R.P., Radityaningrum, A.D.: Kinerja Sistem Pengolahan Air Bersih Di Instalasi Pengolahan Air Ii Ngares, Kabupaten Trenggalek. *Environ. Eng. J. ITATS* 1, 35–43 (2021).

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