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TIME AND COST ANALYSIS ON PROCUREMENT OF SUTET 275 KV 2CCT QUADRUPLE ZEBRA GUMAWANG - GITET LAMPUNG 1 USING TIME COST TRADE OFF METHOD

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Abstract

Indonesia as an archipelago state is still need an equality development with the intention in achieving the goals to fulfill the requirement of structure and infrastructure. The economy that has experiencing growth, it can be seen with the rising of the demand for supply of electricity power whether it is coming from domestic moreover from industrial usages. Lampung Province, as one of the regions which is in a continuation to develop, requires the support of electric power, which at its peak load reaches 1200 MW, while the capacity of the existing power plant can only produce 700 MW, therefore the construction of a 275 kV Gumawang-Lampung 1 SUTET interconnection network with a capacity of up to 2000 MW was established to meet these requirements. Based on the time schedule which noted that the duration of foundation work started with the excavation, concreting until the reaches of it's curing time in 28 days is 42 days in 2023 December 13th is on try to speed up can be curing in 2023 December 8th, so the schedule tower installation in 2023 December 9th will be on time. Due to this delay, the researcher intends to carry out an acceleration analysis starting with preparing a network diagram using the Microsoft Project software, followed by the crashing process by adding groups of workers and tools of any activities on the critical path. The next step is to calculate the crash cost and cost slope values using the time cost trade off (TCTO) method.

Keywords: *Time cost trade off, adding groups of workers and tools, SUTET 275 KV Gumawang-Lampung tower*

1. INTRODUCTION

Today the world is faced with global warming, every 1º C (one degree Celsius) increase is felt on the human body and other living things. The results of industrial and household waste processes which in the process require a lot of diesel consumption, fossil-fueled vehicle emissions which are the largest contributor to the increase in the greenhouse effect dominated by tall buildings and the contemporary style of residential homes, deforestation as the lungs of the world / deforestation, excessive use of electricity by consumers causes an increase in the capacity of power plants to fulfill it and it causes fuel consumption to produce energy to increase, methane waste from livestock and agriculture also has a share, the last rank is from the decay of wasted food will produce methane gas as well. In response to this, scientists and engineers are trying to maintain the existing natural harmony by prioritizing the principle of environmentally friendly development commonly called green building technology. This technology seeks to not overburden the environment with the concept of utilizing existing natural resources and using renewable energy. Green building technology building materials have certain requirements. This concept includes reducing electrical energy consumption by applying solar panel technology including regulating access to incoming sunlight which can reduce the use of lighting during working hours, saving water resources with vacuum toilet system installation, non-toxic materials. The building will be categorized in the green building section, if it meets 6 requirements set by the Green Building Council Indonesia / GBCI in this case as the party responsible for making administrative and operational decisions(Ratnaningsih et al., 2019). The 6 requirements include the accuracy of the building site which will discuss the availability of 30% green open space, indoor quality related to air quality from the availability of ventilation, energy efficiency, water efficiency, building management, and finally the material cycle. Another important component is documenting all building materials.(Lawi, 2018)

According to the Ministry of Environment and Forestry "Indonesia is currently lagging behind in renewable energy development because investment is considered less attractive. Based on the 2018 Renewable Energy Country Attractiveness Index, Indonesia is ranked 38th, beaten by China, India, the Philippines and Thailand".(Surya Darma, 2019) Indonesia has solar energy that has not been optimized for management. Recently, people have begun to look at Photovoltaic / PV technology. This is a technology that converts light energy into electrical energy with the help of solar cell devices or commonly called Solar Power Plants / PLTS.(Okayana, 2022)However, there are still many understandings both on a household and industrial scale that misinterpret that if you have installed solar cells, then the electricity supply can be completely fulfilled by this tool. The answer is that the electricity bill by PLN will still be received, because PV cannot completely replace the role of power plants, only reduce bills, and PV has effective working hours. The best performance is when the heat can be channeled directly to the use of equipment according to the total installed kilowatts, and when it starts in the afternoon, the power will decrease. If PV is installed on top of the roof covering, a technical study of the existing structural analysis must be carried out, including the upper and lower structures. Do not forget that there is also a heat propagation load on the PV frame which must be neutralized with an insulator so as not to burden the structure called heat propagation / heat transfer, this phenomenon will affect the existing structural connection system and also the bending of the truss rod / rafter. Installing PV cannot be as desired, the modules must be planned as well as easy to maintain as well. This is closely related to the fact that if there is a leak in the roof covering, the process of dismantling the roof covering and PV will not be difficult. PV installed anywhere will require existing structural documents (unless it is a new structure, PV loads must be included in the calculation), because the reliability and safety control factors of the structure must be analyzed in detail. What can be done in investing in PV is structural strengthening. If installed in an industry that is actively operating, it must be coordinated with the user regarding the operation schedule, the outage schedule in the hazard area, and all these schedules require the role of construction management(Soeharto, 1999).

Sustainable development in our country is fulfilled by one of them with the provision of electrification infrastructure with the declaration of the 35,000 MW program by the new government realized 8,400 MW.(Electricity Supply Business Plan, 2019) The stretches of islands that have not been electrified with all efforts are attempted to partially continue to try to meet these targets. It is necessary to fulfill the factors of financial resources, natural resources, technology transfer including human resources who master their fields to be the main element. The government is also trying to meet the main support for the veins of the generating system by adding weight to the level of domestic components / TKDN, turbines, boilers, preheaters and other important components which are then emphasized on local manufacturers to be able to contribute to this program. The value of building these facilities would be far greater if they had to be imported like their predecessors. In this case, policy makers should also make visits to the industrial locations of these manufacturers in order to ensure that this program can run as planned.

PT PLN (Persero) as one of the State-Owned Enterprises (SOEs) engaged in the field of electrical energy realized this program by making a scheme through the procurement of Engineering Procurement Construction / EPC, namely the facilities and power generated all belong to PT PLN (Persero), the contractor as a construction service provider. While in the Independent Power Producer / IPP model, the power produced all belongs to private power developers / investors, including the sale of excess power / excess power by the operating license holder to PT PLN (Persero) to buy electricity from them through a power purchase agreement (PPA) regulated in the Minister of Finance Regulation Number 77 / PMK.01 / 2011.(Guidelines for the Implementation of Business Feasibility Guarantee of PT Perusahaan Listrik Negara (Persero) for the Construction of Electric Power Plant and / or Transmission Using Renewable Energy, Coal, and Gas Conducted through Cooperation with Developers, 2011)(PLN, 2019). Until now, the electricity supply business plan (ruptl) of PT PLN (Persero) as of 2020 in megawatt scale is 43.69 MW owned, and 1.45 MW leased and 17.32 MW derived from IPP and others, and this amount is calculated since the period of 2011.(Electricity Supply Business Plan, 2019) Not only is the procurement of new units being pursued, but existing infrastructure must also receive attention. Good service by PT PLN (Persero) to the availability of disaster mitigation programs with the aim of preventive action against outages is a task that is always echoed.

The government's equitable development program through PT PLN (Persero) throughout the archipelago in an effort to meet the needs of electricity consumption runs continuously along with the demand for the supply of this energy power to customers. Sumatra Island also requires capacity expansion in addition to responding to market demand as well as preparation for infrastructure completeness to support regional development. Lampung, which continues to grow, requires the support of electricity which at peak load reaches 1200 MW while the ability of existing power plants can only produce 700 MW, with additional flow support obtained from the interconnection network so far still supplied through the 275 kV Gumawang- Lampung 1 SUTET interconnection line with a capacity of up to 2000 MW. The construction of this sutet will be located in 5 districts and pass through 13 sub-districts and 39 villages, namely: Mesuji Regency, 1 sub-district in 4 villages; West Tulang Bawang Regency, 5 sub-districts, in 13 villages; Tulang Bawang Regency, 1 sub-district in 1 village; Central Lampung Regency, 3 sub-districts, in 19 villages; Pesawaran Regency, 1 sub-district, in 2 villages.

The Work Order for this project is dated December 22, 2017 with an implementation period of 540 calendar days with a total plan of 61 sets of SUTET towers and to date has completed 3 towers, so it can be said to be a multi-year contract. The main things that cause this delay are non-technical factors in the form of land acquisition by the project owner, changes in transmission routes, while other non-technical disturbances that often occur in the field are not mentioned in this study. This means that not all project delays are caused by contractors and consultants, in this case the management and users of electrification services also have an important role in supporting its smooth running(Prateapusanond, 2003). Meanwhile, the causes of technical factors at this project location vary, including the presence of residential areas that limit the need for tower foundation footprints, requiring negotiations for land acquisition, sometimes the tower plan is located in valleys and mountains. The road to the location cannot be passed by heavy equipment, so the work is carried out using manual drilling, and cast using manual molen / site mix. From each tower construction plan, the tower installation/erection schedule is also targeted, which depends on achieving a concrete age of 28 days.

In this regard, the researcher intends to conduct a cost and time analysis to simulate the acceleration of implementation using the Time Cost Trade Off method following the use of the Microsoft Project auxiliary program on tower no. 397 which is experiencing delays in the tower installation schedule because the new concrete age is reached on December 13, 2023, while the tower installation schedule is December 9, 2023, then the concrete age reaches 98% compressive strength must be achieved on December 8, 2023.(Rosyid et al., 2020)

Based on the background accompanied by an explanation of the existing conditions, to make it easier for researchers to carry out the analysis, the purpose of this study is to analyze the magnitude of changes in project implementation time and analyze the magnitude of changes in project implementation costs(Saputra & Angreni, 2021).

2. RESEARCH METHODS

Secondary data obtained from the contractor, one of which is a Microsoft project that already contains job descriptions and scheduling along with the duration, and the stages of analysis that will be carried out are as follows;

1. Identify the critical path by :
   a. Calculate the normal duration according to the existing number of workers and tools.(Rizal Rosyid, Gede Sarya, Michella Beatrix & Manyar-surabaya, 2020)
   b. Using the Microsoft Project auxiliary program, enter the normal duration of the stage 1 calculation results and adjust the date to the actual field conditions.
   c. After all the activity descriptions are filled in according to the results of the normal duration calculation until the final date of plan implementation is obtained, then identify the critical path using the Microsoft Project program.
2. Method of acceleration by way of :

In accelerating the project duration, there are several alternatives that can be used such as increasing working hours, adding work groups, and increasing the capacity of work tools, changing work methods, using construction materials that are more effective, in the sense that they do not require a lot of tools and labor in installing or working on them. The results of the acceleration duration calculation are then inputted in the Microsoft Project model to obtain a new critical path that may still be present in other activity descriptions, or even there is no new critical path, which means that the acceleration duration calculation process is optimal. Acceleration is only applied to components that are on the critical path, as well as to other components that support acceleration. By sorting and prioritizing work that becomes a priority scale using the Microsoft Project assistance program. (Yaqin et al., 2023)

The normal duration calculation analysis is obtained from the work network diagram by taking into account the time required to complete all remaining work. The normal duration of 1 reinforced concrete foundation tower type 2AA Quadruple Zebra +3, no. 397 is excluding the installation of tower steel structure and all cables including accessories.

a. Normal cost
b. Acceleration Alternative
c. Crash Duration and Crash Cost
    1. Crash Duration
    2. Crash Cost
d. Cost Slope

The location of this research is the transmission route through Mesuji, Tulang Bawang, West Tulang Bawang, Central Lampung and Pesawaran districts in South Lampung. Some of the instruments used in this research consist of:

a. Hardware in the form of laptops and printers are useful in processing all work programming commands during the analysis process until they become a form of research report.
b. Microsoft Project assisted the research in the process of detailing the preparation of work duration, critical trajectory.
c. Microsoft Excel as an auxiliary program in the calculation of concrete volume, formwork area and tonnage of formwork used in the calculation of work quantity/bill of quantity. and Microsoft Word helps in the process of all calculation needs including volumetric and editorial reports.
d. Field documentation that provides an overview of field conditions is used as a basis for considering the selection of acceleration alternatives and document/softcopy files in the form of cost budget plans and S curves that are used as material for further analysis.

3. RESULTS AND DISCUSSION

3.1. Cost Budget Plan

The results contain answers to research problems quantitatively and/or qualitatively in a clear, precise and complete manner that can use actual information in the form of pictures/graphs/tables/descriptions.

Table 1. Civil RAB of SUTET tower T.397

NO	URAIAN PEKERJAAN	VOLUME	SATUAN	HARGA SATUAN	JUMLAH HARGA
1	2	3	4	5	6 = 3x5
A.	PEKERJAAN PERSIAPAN				
	1 Mobilisasi tenaga kerja dan peralatan	1.00	ls	85,000,000.00	85,000,000.00
				Sub Total A	85,000,000.00
B.	PEKERJAAN PONDASI				
	1 Pengukuran bouwplank (berikut stub setting)	1.00	twr	2,700,000.00	2,700,000.00
	2 Pekerjaan galian tanah biasa	664.37	m³	224,600.00	149,217,951.20
	3 Urugan pasir, t = 10 cm	8.84	m³	220,000.00	1,943,920.00
	4 Lantai kerja, beton camp. 1 : 3 : 5, t = 5 cm	4.42	m³	882,530.38	3,899,019.20
	5 Baja tulangan ulir BJTD 32	4,703.26	kg	26,000.00	122,284,739.96
	6 Bekisting	101.60	m²	577,800.00	58,704,480.00
	7 Pekerjaan beton K225 (pad and chimney)	43.37	m³	2,002,900.00	86,873,784.60
	8 Bongkar bekisting	101.60	m²	4,000.00	406,400.00
	9 Urug kembali dan perataan tanah sisa galian	607.74	m³	224,600.00	136,499,302.40
	10 Patok beton batas tanah	4.00	bh	276,800.00	1,107,200.00
	11 Transport material pondasi ke lokasi tower	56.63	m³	650,000.00	36,808,200.00
	12 Test kubus beton/silinder beton	12.00	bh	90,100.00	1,081,200.00
	13 Pembuatan kontur tapak tower	1.00	twr	526,200.00	526,200.00
	14 Dewatering	1.00	twr	1,500,000.00	1,500,000.00
	15 Finishing dan pembersihan	1.00	twr	300,000.00	300,000.00
				Sub Total C	603,852,397.36
C.	TOWER TIPE 2AA (QUAD ZEBRA)+3				
	1 Pekerjaan pengadaan tower 275 kv 4x450	1.00	set	576,819,750.00	576,819,750.00
	2 Pekerjaan pengadaan stub tower	1.00	set	28,900,613.00	28,900,613.00
	3 Pekerjaan langsir dan erection tower	1.00	set	87,207,500.00	87,207,500.00
	4 Pengelasan baut tower sampai bottom cross arm	1.00	set	9,000,000.00	9,000,000.00
	5 Pekerjaan pengangkutan, asuransi serta sortir tower dan accessories (tower 275kv 4x450,	1.00	set	51,710,000.00	51,710,000.00
	6 Pekerjaan transport stub tower	1.00	set	2,009,378.06	2,009,378.06
	7 Pekerjaan lansir stub tower	1.00	set	805,592.00	805,592.00
	8 Pemasangan anti climbing device, danger plate, number plate dan penomoran number	1.00	twr	250,000.00	250,000.00
	9 Sewa gudang temporary dan pengamanan untuk material	1.00	Ls	175,000,000.00	175,000,000.00
				Sub Total D	931,702,833.06
				Total biaya 1 tower hingga erection	1,620,555,230.42
				PPN 11%	178,261,075.35
				Total biaya termasuk PPN	1,798,816,305.76
				Dibulatkan	1,798,816,000.00

Sidoarjo, 10 Nopember 2023
KSO. PT. HASTA PRAJATAMA - PT. SEJAHTERA INTERCON

CATATAN :
RAB ini belum termasuk pengadaan konduktor, isolator, asesoris termasuk stringing, saging dan lain lain.

SINGGIH HARTOYO, ST.
Project Manager PT. HASTA PRAJATAMA

Source: Secondary data, 2023

RAB Description:

The total cost to install/erect the SUTET T.397 lattice tower structure is Rp. 1,620,555,230.42, while the preparation and reinforced concrete foundation activities are Rp. 688,852,397.36.

The foundation is a typical 4-foot, K225 reinforced concrete slab that was constructed using manual labor. The foundation work scheme includes excavation, sand layer, working floor, concreting, formwork, concrete curing, formwork dismantling, and backfill.

3.2. Normal Cost and Duration Calculation

3.2.1. Calculate normal duration and normal cost

In calculating normal cost, data on the volume of work, coefficient of labor or tools, effective working hours, unit price of labor, materials, tool rental are required(INDONESIA, n.d.). The following is the calculation of normal cost and duration for activities included in the critical path.

1. Land excavation

Table 2. Digging with an excavator

No.	Explanation	Unit	Coefficient	Unit Price
Labor Wages				
1	Worker	Hours	0.0414	85,000.00
2	Foreman	Hours	0.0041	150,000.00

Equipment Rent				
1	Excavator	Hours	0.0231	168,000.00

a. Calculating duration and cost by labor;

Production per day = $\frac{1}{(0.0414+0.0041)} \times 7 \times 2 = 43.956\ m^3/\text{day}$

Duration = $\frac{664.372/4}{43.956} = 3.779 \approx 4\ \text{days}$

Wages = $664.372/4 \times (0.0414 \times 85{,}000 + 0.0041 \times 150{,}000) \times 7 \times 4 = \text{Rp. } 19{,}225{,}596.94$

b. Calculating duration and cost by tool rental;

Vis bucket capacity = 1.50 m^3 → secondary field data

F_b is bucket factor = 1 → table 2.3

F_a is the tool efficiency factor = 0.83 → table 2.4

F_k is the soil development factor $\frac{\gamma_{sat}}{\gamma_d}$ → taken 1.1

T_1 is the time of digging, loading, etc. = 7 minutes → table 2.5

T_2 is *round/swing* back and others = 4 minutes → table 2.6

T_s is the cycle time, $T_s = 7 + 4 = 11$ menit

60 is the multiplication of 1 hour to minutes

So the production capacity of 1 excavator per day =

$$Q = \frac{1.50 \times 1 \times 0.83 \times 60}{11 \times 1.1} = 6.17\ m^3/\text{hours}$$

Production per day $= 6.17 \times 7 = 43.215\ m^3/\ \text{day}$

Duration = $\frac{664.372/4}{43.215} = 3.843 \approx 4\ \text{days}$

Rent $= 664.372/4 \times (0.0231 \times 168{,}000) \times 7 \times 4 = \text{Rp. } 18{,}079{,}456.51$

b. Sand backfill

a. Calculating duration and cost by labor;

Table 3. Sand backfill as fill material (1 m³)

No.	Explanation	Unit	Coeffisient	Unit Price
Labor Wages				
1	Worker	OH	0.4000	85,000.00
2	Foreman	OH	0.0400	150,000.00
Material				
1	Sand	m^3	1.2000	150,000.00

Production per day = $\frac{1}{(0.40+0.04)} \times 2 = 4.545\ m^3/\ \text{day}$

Durtion = $\frac{8.836/4}{4.545} = 0.486 \approx 1\ \text{days}$

Wages = $8.836/4 \times (0.400 \times 85{,}000 + 0.040 \times 150{,}000) \times 1 = \text{Rp. } 88{,}360$

b. Calculating cost by material ;

$$\text{Maetrial} = 8.836/4 \times (1.200 \times 150{,}000) = \text{Rp. } 397{,}620$$

c. Work floor

a. Calculating duration and cost by labor;

Table 4. 1 m³ of concrete for working floor (bedding)

No.	Explanation	Unit	Coeffisient	Unit Price
Labor Wages				
1	Worker	OH	1.3200	85,000.00
2	Mason	OH	0.2200	100,000.00
3	Chief Mason	OH	0.0220	125,000.00
4	Foreman	OH	0.1320	150,000.00
Bahan				
1	Portland cement	kg	247.0000	1,300.00
2	Concrete Sand	m³	0.6210	175,000.00
3	Gravel	m³	0.7400	400,000.00
4	Water	L	215.0000	25.00

$$\text{Production per day} = \frac{1}{(1.320 + 0.220 + 0.022 + 0.132)} \times 4 = 2.361 \text{ m}^3/\text{day}$$

$$\text{Duration} = \frac{4.418/4}{2.361} = 0.468 \approx 1 \text{ days}$$

$$\text{Wages} = 4.418/4 \times \begin{pmatrix} 1.320 \times 85{,}000 + 0.220 \times 100{,}000 + \\ 0.022 \times 125{,}000 + 0.132 \times 150{,}000 \end{pmatrix} \times 1 = \text{Rp. } 173{,}130.38$$

b. Calculating cost by material;

$$\text{Material} = 4.418/4 \times \begin{pmatrix} 247 \times 1{,}300 + 0.621 \times 175{,}000 + \\ 0.740 \times 400{,}000 + 215 \times 25 \end{pmatrix} = \text{Rp. } 801{,}624.42$$

d. Fixing

a. a.Calculating duration and cost by labor;

Table 5. 100 kg of plain iron and threaded stee

No.	Explanation	Unit	Coeffiient	Unit Price
Labor Wages				
1	Worker	OH	0.7000	85,000.00
2	Ironworker	OH	0.7000	125,000.00
3	Head Ironmonger	OH	0.0700	125,000.00
4	Foreman	OH	0.0700	150,000.00
Material				
1	Concrete Iron (plain/engraving)	kg	105.0000	15,000.00
2	Tie Wire	kg	1.5000	21,000.00

$$\text{Production per day} = \frac{1}{(0.700 + 0.700 + 0.070 + 0.070)} \times 4 \times 100 = 259.740 \text{ kg/hari}$$

$$\text{Duration} = \frac{(4{,}549.125 + 154.134)/4}{259.740} = 4.527 \approx 5 \text{ days}$$

$$\text{Wages} = (4{,}549.125 + 154.134)/4 \times \frac{\begin{pmatrix} 0.700 \times 85{,}000 + 0.700 \times 125{,}000 + \\ 0.070 \times 125{,}000 + 0.070 \times 150{,}000 \end{pmatrix}}{100} \times 5 = \text{Rp. } 9{,}773{,}960.59$$

b. Calculating cost by material;

$$\text{Material} = \frac{(4{,}549.125 + 154.134)/4 \times (105 \times 15{,}000 + 1.5 \times 21{,}000)}{100} = \text{Rp. } 18{,}889{,}464.88$$

e. Formwork

a. Calculating duration and cost by labor;

Table 6. 1 m² formwork for exposed concrete surfaces with 12 mm or 18mm multiflex - 5/7 cm rafters (without scaffolding).

No.	Explanation	Unit	Coefficient	Unit Price
Labor Weges				
1	Worker	OH	0.5600	85,000.00
2	Carpenter	OH	0.2500	100,000.00
3	Head Fitter	OH	0.0250	125,000.00
4	Foreman	OH	0.0500	150,000.00
Material				
1	Multiflex 18 mm	lbr	0.2450	300,000.00
2	Kaso 5/7	m^3	0.0135	31,000.00
3	Nails 5 cm dan 7 cm	kg	0.2500	17,000.00
4	Formwork Oil	L	0.2000	1,200.00

$$\text{Production per day} = \frac{1}{(0.500 + 0.250 + 0.025 + 0.05)} \times 4 = 4.520 \text{ m}^2/\text{day}$$

$$\text{Duration} = \frac{101.600/4}{4.520} = 5.620 \approx 6 \text{ days}$$

$$\text{Wages} = \frac{101.600/4}{4.520} \times \begin{pmatrix} 0.560 \times 85{,}000 + 0.250 \times 100{,}000 + \\ 0.0250 \times 125{,}000 + 0.050 \times 150{,}000 \end{pmatrix} \times 6 = \text{Rp. } 12{,}683{,}490$$

b. Calculating cost by material;

$$\text{Material} = 101.600/4 \times \begin{pmatrix} 0.245 \times 300{,}000 + 0.0135 \times 31{,}000 + \\ 0.245 \times 17{,}000 + 0.200 \times 1{,}200 \end{pmatrix} = \text{Rp. } 1{,}991{,}575.9$$

f. Cast reinforced concrete

a. Calculating duration and cost by labor;

Table 7. 1 m³ Concrete grade, f'c = 19.3 MPa (K225)

No.	Explanation	Unit	Coefficient	Unit Price
Labor Wages				
1	Worker	OH	1.6500	85,000.00
2	Mason	OH	0.2750	100,000.00
3	Head Fitter	OH	0.0280	125,000.00
4	Foreman	OH	0.1650	150,000.00
Bahan				
1	Portland cement	kg	371	1,300.00
2	Concrete Sand	kg	698	150.00
3	Gravel	kg	1,047	160.00
4	Water	L	215	3.00
Sewa peralatan				
1	Manual Molen	Hari	0.1434	250,000.00

Production per day = $\frac{1}{(1.650+0.275+0.025+0.165)}\times 4 = 1.889$

Duration = $\frac{43.374/4}{1.889} = 5.742 \approx 6$ days

Wages = $43.374/4 \times \begin{pmatrix} 1.650\times 85{,}000 + 0.275\times 100{,}000 + \\ 0.028\times 125{,}000 + 0.165\times 150{,}000 \end{pmatrix}\times 6$

$= \text{Rp. } 12{,}751{,}956$

b. Calculating duration and cost by tool rental;

Kapasitas produksi beton/jam, $Q = \frac{V\times F_a\times 60}{1000\times T_s} \rightarrow m^3/\text{hour}$

By:

V is the capacity of the mixing tank, taken as 350 liters.

Fa is the tool efficiency factor, taken as 0.83

V1 is the average speed of the contents, 15 km/hour

V2 is the average empty speed, 25 km/hour

T1 is the length of charging time, taken as 0.50 minutes

T2 is the length of mixing time, taken as 1.00 minutes

T3 is the length of spilling time, taken 0.30 minutes

T4 is the waiting time etc., taken as 0.2 minutes.

Ts is the cycle time, Ts = 0.50 +1.00 + 0.30 + 0.20 = 2 menit

60 is the multiplication of 1 hour to minutes

So that the production capacity of 1 manual molen per day =

$Q = \frac{(15+25)\times 0.83\times 60}{1000\times 2} = 0.996\ m^3/\text{jam} = 0.996\times 7 = 6.972\ m^3/\text{ hour}$

Duration = $\frac{43.374/4}{6.972} = 1.555 \approx 2$ hours

Rent $= 43.374/4 \times (0.1434 \times 250{,}000) \times 2 = \text{Rp. } 777{,}646.30$

g. Dismantle formwork

a. Calculating duration and cost by labor;

Table 8. Unload 1 M² Of Formwork In The Usual Way (And Clear The Debris)

No.	Explanation	Unit	Coefficient	Unit Price
Labor Wages				
1	Worker	OH	0.0400	85,000.00
4	Foreman	OH	0.0040	150,000.00

Formwork dismantling and debris hearth in units of days, and no tools are required.

Production per day = $\frac{1}{(0.04 + 0.004)} \times 2 = 45.455\ m^2/\ day$

Duration = $\frac{101.600/4}{45.455} = 0.559 \approx 1$ days

Wages =101.600/4 x (0.040 x 85,000 x 0.004 x 150,000) x 1 = Rp. 101,600

h. Backfill soil

a. Calculating duration and cost by labor;

Production per day = $\frac{1}{(0.0414 + 0.004)} \times 2 = 43.956\ m^3/\ day$

Duration = $\frac{607.744/4}{43.956} = 3.457 \approx 4$ days

Wages = $607.744/4 \times (0.0414 \times 85{,}000 + 0.004 \times 150{,}000) \times 7 \times 4 =$ $\text{Rp. } 17{,}586{,}895\ .87$

b. Calculating duration and cost by tool rental;

So the production capacity of 1 excavator per day =

$$Q = \frac{1.50 \times 1 \times 0.83 \times 60}{11 \times 1.1} = 6.17\ m^3/\ hours$$

Production per day = 6.17 x 7 = 43.215 m3/day

Duration = $\frac{664.372/4}{43.215} = 3.843 \approx 4$ days

Rent = 664.372/4 x (0.0231 x 168,000) x 7 x 4 = Rp. 18,079,456 .51

The results of this normal duration analysis are used as input duration in the Microsoft Project auxiliary program model according to the sequence of work, and the critical trajectory is obtained as in Appendix 4. Critical trajectory analysis by Microsoft

Project based on RAB activity description, concrete curing must be accelerated , as well as Appendix 5, 6 Network planning normal duration and critical trajectory.

3.2.2. Calculate crash duration and crash cost

In calculating crash cost, data on work volume, coefficient of labor or tools, effective working hours, unit price of labor, materials, tool rental are required. The following is an example of calculating normal costs for activities that are included in the critical path. The alternative acceleration carried out is by adding 1 group of workers and adding 1 tool each, both for excavators and manual molen. The following is an example of crashing calculation for excavation work;

1) Land excavation

a. Calculating duration and cost by labor;

Production per day = → addition of 1 labor group

$$\frac{1}{(0.0414+0.0041)}\times 7\times 2\times 2=87.912\ \text{m}^3/\text{day}$$

$$\text{Duration} = \frac{664.372/4}{87.912}=1.889\approx 2\ \text{days}$$

$$\text{Wages}=664.372/4\times(0.0414\times 85{,}000+0.0041\times 150{,}000)\times 7\times 2=\text{Rp.}19{,}225{,}596.94$$

b. Calculating duration and cost by tool rental;

The excavator is added 1 unit with the same bucket capacity, so equation 2.4 becomes ;

$$\text{Production Capacity per houn, } Q=\left[\frac{1.50\times 1\times 0.83\times 60}{11\times 1.1}\right]\times 2=12.347\ \text{m}^3/\text{hour}$$

The production formula per day with the addition of 1 tool is as follows;

Production per day = 12.347 x 7 = 86.430 m3/day

$$\text{Duration} = \frac{664.372/4}{86.430}=1.922\approx 2\ \text{days}$$

$$\text{Rent}=664.372/4\times(0.0231\times 168{,}000)\times 7\times 2\times 2=\text{Rp.}18{,}079{,}456.51$$

2) . Sand backfill

Calculating duration and cost by labor;

Production per day =→ addition of 1 labor group

$$\frac{1}{(0.40+0.04)}\times 2\times 2=9.091\ \text{m}^3/\text{day}$$

$$\text{Duration} = \frac{8.836/4}{9.091}=0.243\approx 1\text{days}$$

Wages = 8.836/4 x (0.400 x 85,000 x 0.040 x150,000) x 1 = Rp.88,360

3) Work floor

Calculating duration and cost by labor;

Production per day = → addition of 1 labor group

$$\frac{1}{(1.320+0.220+0.022+0.132)}\times 4\times 2=4.723\ \text{m}^3/\text{day}$$

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Duration = $\frac{4.418/4}{4.723} = 0.234 \approx 1$ days

$$\text{Wages} = 4.418/4 \times \begin{pmatrix} 1.320 \times 85{,}000 + 0.220 \times 100{,}000 + \\ 0.022 \times 125{,}000 + 0.132 \times 150{,}000 \end{pmatrix} \times 1 = \text{Rp. } 173{,}130.38$$

4) Fixing

Calculating duration and cost by labor;
Production per day = → addition of 1 labor group

$$\frac{1}{(0.700 + 0.700 + 0.070 + 0.070)}$$
$$\times 4 \times 100 \times 2 = 519.481 \text{ kg/hari}$$

$$\text{Duration} = \frac{(4{,}549.125 + 154.134)/4}{519.481} = 2.263 \approx 3 \text{ days}$$

$$\text{Wages } (4{,}549.125 + 154.134)/4 \times \frac{\begin{pmatrix} 0.700 \times 85{,}000 + 0.700 \times 125{,}000 + \\ 0.070 \times 125{,}000 + 0.070 \times 150{,}000 \end{pmatrix}}{100}$$
$$\times 3 \times 2 = \text{Rp. } 11{,}728{,}752.70$$

5) Formwork

Calculating duration and cost by labor;
Production per day = → addition of 1 labor group

$$\frac{1}{(0.500 + 0.250 + 0.025 + 0.05)} \times 4 \times 2 = 9.040 \text{ m}^2/\text{ day}$$

$$\text{Durasi} = \frac{101.600/4}{9.040} = 2.810 \approx 3 \text{ days}$$

$$\text{Upah} = \frac{101.600/4}{4.520} \times \begin{pmatrix} 0.560 \times 85{,}000 + 0.250 \times 100{,}000 + \\ 0.0250 \times 125{,}000 + 0.050 \times 150{,}000 \end{pmatrix}$$
$$\times 3 \times 2 = \text{Rp. } 11{,}949{,}455.40$$

6) Cast reinforced concrete

a. Calculating duration and cost by labor;

$$\text{Production per day} = \frac{1}{(1.650 + 0.275 + 0.025 + 0.165)} \times 4 = 1.889$$

$$\text{Duration} = \frac{43.374/4}{1.889} = 5.742 \approx 6 \text{ days}$$

$$\text{Wages} = 43.374/4 \times \begin{pmatrix} 1.650 \times 85{,}000 + 0.275 \times 100{,}000 + \\ 0.028 \times 125{,}000 + 0.165 \times 150{,}000 \end{pmatrix} \times 6$$
$$= \text{Rp. } 12{,}751{,}956$$

b. Calculating duration and cost by tool rental;
Manual molen equipment is added 1 unit with the same capacity, so equation 2.7 becomes ;

Production Capacity per hour, Q

$$=\left[\frac{(15+25)\times 0.83\times 60}{1000\times 2}\right]\times 2=1.992\ \text{m}^3/\ \text{hour}$$

The formula for production per day with the addition of 1 tool is as follows;
Produksi per hari =1.992 x 7 =13.944 m3/day

Duration = $\frac{664.372/4}{13.944}=0.778\approx 1$ days

Wages = 43.374/4 x (0.1434 x 250,000) x 1x 2 = Rp. 777,646.30

7) Dismantle formwork

Calculating duration and cost by labor;
Production per day = → addition of 1 labor group

$$\frac{1}{(0.04+0.004)}\times 2\times 2=90.909\ \text{m}^2/\text{day}$$

Duration = $\frac{101.600/4}{90.909}=0.279\approx 1$ days

Wages $=101.600/4\times(0.040\times 85{,}000+0.004\times 150{,}000)\times 1=\text{Rp. }101{,}600$

8) Backfill soil

a. Calculating duration and cost by labor;

Production per day = $\frac{1}{(0.0414+0.004)}\times 2\times 2=87.912\ \text{m}^3/\text{day}$

Duration = $\frac{607.744/4}{87.912}=1.728\approx 2$ days

Wages = $607.744/4\times(0.0414\times 85{,}000+0.004\times 150{,}000)\times 7\times 2=$ Rp. 17,586,895 .87

b. Calculating duration and cost by tool rental;
The excavator is added 1 unit with the same bucket capacity, so equation 2.4 becomes ;

Production Capacity per hour, $Q=\left[\frac{1.50\times 1\times 0.83\times 60}{11\times 1.1}\right]\times 2=12.347\ \text{m}^3/\text{hour}$

Produksi per hari $=12.347\times 7=86.430\ \text{m}^3/\ \text{day}$

Duration = $\frac{607.744/4}{86.430}=1.758\approx 2$ days

Rent $=607.744/4\times(0.0231\times 168{,}000)\times 7\times 4=\text{Rp. }16{,}538{,}447\ .16$

3.2.3. Calculating cost slope

Cost slope is the ratio between the increase in cost and the acceleration of project completion time calculated from the result of the reduction between crashing costs (crash cost) and normal project costs (normal cost) and then divided by the result of the reduction between normal duration (normal duration) and acceleration duration (crash duration). The shape of the graph is a straight line that has a certain slope.

As an example of the calculation of the cost slope used for soil excavation activities, the following calculation;

$$\text{Cost slope soil excavation} = \frac{38{,}451{,}193.87 - 19{,}225{,}596.94}{3.84 - 1.92} = 10{,}004{,}416.66$$

Selanjutnya disusun hasil analisis durasi normal dan crashing dalam bentuk tabel, dapat dilihat pada Lampiran 7 Tabel durasi biaya normal crash dan cost slope.

3.2.4. Cost slope graph

The relationship between the time-cost trade-off analysis for the normal duration and the accelerated duration is shown in the form of a linear graph below;

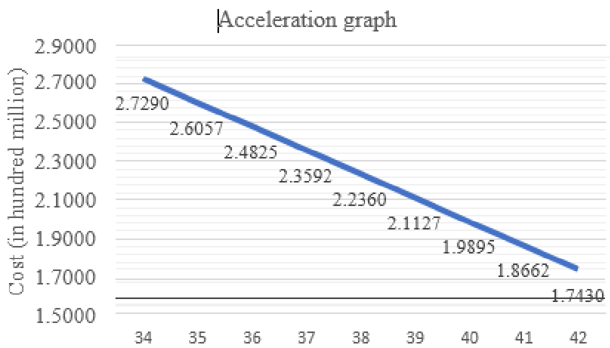

Figure 1. Acceleration graph using Microsoft Excel
Source of analysis by researchers, 2023

3.3. Analysis result

Acceleration alternatives with the addition of 1 labor group and 1 tool resulted in a time acceleration of 9 days, where in the normal duration the concrete reached the age of 28 days on December 13, 2023, after crashing the concrete results reached the age of 28 days on December 8, 2023. So that the schedule for installing the SUTET tower latiice is fulfilled.

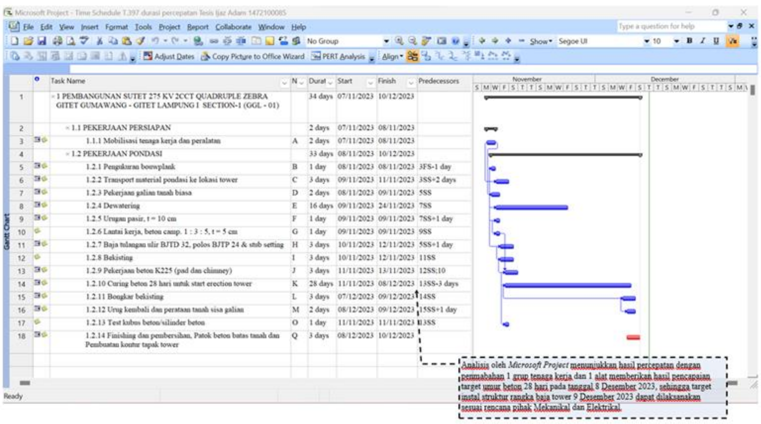

Figure 2. The model opf this analysis use the microsoft project program
Source of analysis by researchers, 2023

4. CONCLUSION

1) Based on the results of the analysis, the initial duration of the foundation work was 42 days, resulting in a time acceleration of 9 days to 34 days. Concrete curing was achieved on December 8, 2023 as planned.
2) The initial cost of workers' wages and tool rental was Rp. 109,735,331.86, after crashing the cost increased to Rp. 219,470,663.73. The initial total cost budget plan was Rp. 1,620,555,230.42 and after the acceleration increased to Rp. 1,730,290,562.28 equivalent to 6.77%.

5. ADVICE

1) This research discusses efforts to accelerate the foundation through cost and time analysis using the time cost trade off method by applying alternatives to add 1 labor group and 1 tool in order to meet the target of installing the SUTET tower structure(Witjaksana & TJendani, 2023). Due to the limitations of this research, it is recommended that further research use other than TCTO analysis. Considering that this foundation structure is a typical 4 feet, the Precast concept can also be another alternative choice, accompanied by a reliability study.
2) Activities related to the electromagnetic component of mechanical and electrical including tower installation/erection, installation, cable pulling/stringing, saging are not discussed in this thesis. The common point of the Civil and Mechanical-Electrical disciplines is the achievement of concrete curing the day before the tower installation schedule. So in the preparation of the schedule must be separated for activities that are not directly related.

REFERENCES

indonesia, M. P. U. R. (N.D.). *Peraturan Menteri Pekerjaan Umum Republik Indonesia Nomor: 11/Prt/M/2013 Tentang Pedoman Analisis Harga Satuan Pekerjaan Bidang Pekerjaan Umum*.

Okayana. (2022). *Teknologi Pv (Photovoltaic) : Mengubah Cahaya Matahari Menjadi Listrik. Kementrian Perhubungan Direktorat Jenderal Pehubungan Laut Distrik Navigasi Tipe A Kelas Ii Benoa.* 13 November 2023. Https://Www.Asahi.Com/Ajw/Articles/15055646

Pln, P. T. (2019). Rencana Usaha Penyediaan Tenaga Listrik 2019–2028. *Pt Pln (Persero): Jakarta, Indonesia*.

Prateapusanond, A. (2003). *A Comprehensive Practice Of Total Float Pre-Allocation And Management For The Application Of A Cpm-Based Construction Contract*. Virginia Tech.

Ratnaningsih, A., Hasanuddin, A., & Hermansa, R. (2019). Penilaian Kriteria Green Building Pada Pembangunan Gedung Isdb Project Berdasarkan Skala Indeks Menggunakan Greenship Versi 1.2 (Studi Kasus: Gedung Engineering Biotechnology Universitas Jember). *Berkala Sainstek*, *7*(2), 59–66.

Rosyid, R., Sarya, G., Beatrix, M., & Oetomo, W. (2020). Studi Analisis Biaya Dan Waktu Menggunakan Metode Time Cost Trade Off (Tcto) Pada Proyek Telkom Manyar-Surabaya. *Extrapolasi*, *17*(1), 20–29.

Saputra, R. A., & Angreni, I. A. A. (2021). Perencanaan Percepatan Pelaksanaan Proyek Apartemen Setiabudi Skygarden Dengan Metode Time Cost Trade Off. *Jurnal Tera*, *1*(1), 1–10.

Soeharto, I. (1999). *Manajemen Proyek* (Kedua). Erlangga.

Surya Darma. (2019). *Mendorong Transisi Menuju Eenergi Terbarukan Demi Masa Depan Yang Berkelanjutan*. 28 Agustus 2019. Http://Pojokiklim.Menlhk.Go.Id/Read/Mendorong-Transisi-Menuju-Energi-Terbarukan-Demi-Masa-Depan-Yang-Berkelanjutan

Witjaksana, B., & Tjendani, H. T. (2023). Cost And Time Analysis Of The Construction Of The 275 Kv 2cct Quadruple Zebra Sutet Project Gumawang–Gitet Lampung 1 Using The Time Cost Trade Off Method. *Asian Journal Of Engineering, Social And Health*, *2*(12), 1772–1778.

Yaqin, H. N., Tjendani, H. T., & Witjaksana, B. (2023). Analysis Of The Acceleration Of Time And Cost Of Implementing Building Construction Projects Using The Critical Path Method (Cpm) Method. *Devotion Journal Of Community Service*, *4*(2), 336–346.

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