ABSTRACT
Indonesia as an archipelago state still needs an equality development with the intention in achieving the goals to fulfill the requirements of structure and infrastructure. The economy that has experienced growth, it can be seen with the rising of the demand for supply of electricity power whether it is coming from domestic more than from industrial usages. Lampung Province, as one of the regions which in a continuation to develop, requires the support of electric power, which at its peak load reaches 1200 MW, while the capacity of 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 reach 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 for tower installation in 2023 December 9th will be on time. Due to this delay, the researcher intends to carry out an acceleration analysis starting by preparing a network diagram using the Microsoft Project software, followed by the crashing process by adding groups of workers and tools of any activity 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. From the results of the analysis carried out, it was found that the normal project duration was 42 days after the crashing process was carried out to 36 days, with a normal work cost of Rp. 1,774,462,352.84 and after the crashing process was carried out with the alternative of adding labor groups and equipment the cost became Rp. 1,849,762,666.92. It was concluded that with the time cost trade off method there was a reduction in duration and an increase in costs.

Keywords: Time cost trade off, adding groups of workers and tools, tower SUTET 275 kV Gumawang-Lampung.
to the increase in greenhouse gas effects which are dominated by tall buildings and contemporary styles of residential homes, deforestation as a lung world/deforestation, excessive use of electricity by consumers causes an increase in the capacity of power plants to fulfill it and that causes fuel consumption to produce that energy to increase, methane waste from livestock and agriculture also has a role, the last rank is from the decay of wasted food which will produce gas methane too. In response to this, scientists and engineers are trying to maintain the existing natural harmony by prioritizing environmentally friendly development principles, usually called green building technology. This technology tries not to burden the environment too much with the concept of utilizing existing natural resources and using renewable energy. This green building technology building material has certain requirements. This concept includes reducing electrical energy consumption by implementing solar panel technology including regulating access to incoming sunlight which can reduce the use of lighting during working hours, saving water resources by installing a vacuum system toilet, non-toxic materials. Buildings will be categorized in the green building section, if they meet the 6 requirements set by the Green Building Council Indonesia/GBCI, in this case as the party responsible for making administrative and operational decisions for the company. These 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 component that is no less important is documenting all building materials. (Lawi, 2018)

According to the Ministry of Environment and Forestry, “Indonesia is currently lagging behind in the development of renewable energy because investment is considered less attractive. Based on Renewable Energy Country Attractiveness Index 2018” Indonesia is ranked 38th, beaten by China, India, the Philippines and Thailand.” (Surya Darma, Herrbert Lubis, 2019) Indonesia has solar energy whose management has not been optimized. Recently, people have started 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 is still a lot of understanding, both on a household and industrial scale, which misunderstands that if you have installed solar cells, then the electricity supply can be fully met by this device. The answer is that electricity bills from PLN will still be accepted, because PV cannot completely replace the role of electricity generation, it only reduces bills, and PV has effective working hours. The best performance is when the hot heat can be directly channeled to use equipment according to the total installed kilowatts, and when it starts to get late in the afternoon, the power will decrease. If PV is installed on a roof covering, a technical analysis of the existing structure must be carried out including the upper and lower structures. Don't forget that there is also heat propagation load on the PV frame which must be neutralized with insulators so as not to burden the structure, which is called heat propagation/heat transfer. This phenomenon will affect the existing structural connection system and also the
bending of the truss/rafter rods. Installing PV cannot be done as you wish, the module must be planned as well as possible and easy to maintain. This is closely related to the fact that if there is a leak in the roof covering, then the process of dismantling and reassembling the roof covering and PV will not be difficult. PV installed anywhere will require documents on the existing structure (except for new structures, the PV load must be included in the calculation), because the reliability factors and safety controls of the structure must be analyzed in detail. What can be done when investing in PV is structural strengthening. If it is installed in an industry that is actively operating, it must be coordinated with the user regarding the operation schedule, blackout schedule in danger areas, and all of these schedules require the role of construction management.

Sustainable development in our country is fulfilled, one of which is the provision of electrification infrastructure with the launch of a 35,000 MW program by the government, only 8,400 MW of which has been realized. (Electricity Supply Business Plan, 2019) The stretches of islands that are not yet electrified with all efforts are being made to partially continue to meet this target. Efforts are needed to fulfill the factors of financial resources, natural resources, technology transfer including human resources who master their fields as the main elements. The government is also trying to fulfill the main support for the lifeblood of the generating system by adding weight to the level of domestic/TKDN components, turbines, boilers, preheaters and other important components which then emphasize local manufacturers to be able to contribute to this program. There is a huge difference in the value of building this facility if it has to be imported like its predecessor. In this case, policy makers must also visit the manufacturer’s industrial location in order to ensure that this program can run as planned.

PT. PLN (Persero) as one of the State-Owned Enterprises/BUMN which operates in the electrical energy sector realizes this program by creating a scheme through procurement Engineering Procurement Construction/EPC. That is, the facilities and energy produced all belong to PT. PLN (Persero), contractor as construction service provider. Meanwhile, in the Independent Power Producer/IPP model, all the power produced belongs to the private electricity developer/investor, including the sale of excess power by the operating permit holder to PT. PLN (Persero) buys electricity from them through an electricity purchase agreement (PPA) regulated in Minister of Finance Regulation Number 77/Pmk.01/2011. (Guidelines for the Implementation of Business Feasibility Guarantee of PT. Perusahaan Perusahaan Asli Negara (Persero) for the Construction of Electric Power Plants and/or Transmission Using Renewable Energy, Coal and Gas Carried Out in Collaboration with Developers, 2011) Until now, PT. PLN (Persero) as of 2020 on a megawatt scale is 43.69 MW owned, and 1.45 MW leased and 17.32 MW comes from IPPs and others, and this number is calculated from the 2011 period. (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) and the availability of a disaster mitigation program with the aim of preventing blackouts is a task that is always echoed.
The government's equal development program through PT. PLN (Persero) throughout the archipelago in an effort to meet electricity consumption needs continues in line with the demand for this energy supply from customers. The island of Sumatra also requires capacity expansion, apart from being a response to market demand, it is also a preparation for complete infrastructure to support regional development. Lampung, which continues to grow, 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, with additional flow support obtained from the interconnection network, so far it is still supplied via the SUTET 275 kV Gumawang-Lampung electricity network interconnection line. 1 with a capacity of up to 2000 MW. The construction of this short circuit 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 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 So far, 3 towers have been completed, 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 research. This means that not all project delays are caused by contractors or consultants, in this case the management and users of electrification services also have an important role in supporting its smooth running. Meanwhile, technical factors at the project location vary, including the presence of residential areas which limit the size of the tower foundation footprint, thus requiring negotiations for land acquisition, sometimes the tower plans are in valleys or mountains. The road to the location cannot be passed by heavy equipment, so the work is carried out using a manual drill, and casting using a manual molen/site mix. For each tower construction plan, a 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 method Time Cost Trade Off. The following is the use of the Microsoft Project assistance program on tower number 397 which experienced a delay in the tower installation schedule because the concrete age was only reached on December 13 2023, while the tower installation schedule was December 9 2023, so the concrete age to reach 98% compressive strength must be achieved on December 8 2023.

Based on the background accompanied by an explanation of the existing conditions, the aims of this research are:

1. Analyze the magnitude of changes in project implementation time.
2. Analyze the magnitude of changes in project implementation costs.
RESEARCH METHODS

Data collection
In carrying out this research secondary data is needed, here is the explanation;
Secondary data obtained by collecting directly from the contractor includes, among others;
a. Look for information on physical progress towards a total of 100% of the civil work target for one tower, ask about the number of workers used in one group, the capacity of the equipment used, the work methods carried out, the target date for completion of the reinforced concrete foundation casting work and the target for installing the transmission tower.
b. Implementation drawings/shop drawings which are the basis for calculating the volume of each activity description. Based on this information, estimates of work steps and phasing can be known.
c. Time schedule Project, is a project implementation schedule which serves as a common guideline in completing and knowing the 14 schedules for each work activity in the field. So the project schedule is very helpful in determining the duration of each activity and its completion time. The project schedule referred to is the S Curve which is the data needed as a time variable, which is also used as a reference for the normal duration of the project.
d. Details of the cost budget and RAB unit price analysis are the data needed as cost variables and are used as a reference for normal costs. In the Time Cost Trade Off analysis, the cost factor is very determining in order to speed up the implementation of the project. The effect of compressing project duration is to increase direct costs and reduce indirect costs.

Data analysis
Secondary data obtained from contractors, one of which is the Microsoft Project, which contains job descriptions and scheduling along with duration, and the analysis stages that will be carried out are as follows;
1. Identify the critical path by:
a. Calculate the normal duration according to the number of existing workers and work tools.(Rizal Rosiyid, Gede Sarya, Michella Beatrix & Manyar-Surabaya, 2020)
b. Using the Microsoft Project program, enter the normal duration of the calculation results from stage 1 and adjust the date to actual field conditions.
c. After all activity descriptions are filled in according to the normal duration calculation results until the end date for plan implementation is obtained, then identify the critical path using the Microsoft Project support program.
2. Acceleration method by:
In accelerating the duration of the project, 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 more effective construction materials, meaning that it does not require a lot of tools and energy in the installation or work. Acceleration efforts like this will definitely result in additional costs, which is better than having to pay a fine. This acceleration calculation takes into account the critical path, the time target that has
been set, and considerations that are easy to obtain and apply in the field. The results of calculating the acceleration duration are then input into the Microsoft Project model to obtain a new critical path which may still be present in other activity descriptions, or there may even be no new critical path, which means the process of calculating the acceleration duration 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 on a priority scale using the Microsoft Project support program. (Yaqin et al., 2023)

**Normal duration**

Normal duration calculation analysis is obtained from the work network diagram by taking into account the time required to complete all remaining work. Normal duration of 1 type 2AA tower reinforced concrete foundation Quadruple Zebra+3, no. 397 does not include the tower steel structure installation and all cables including accessories.

**Normal cost**

Calculation of normal costs is the multiplication of the labor used for the type of work being analyzed and the work tools, all of which are calculated based on the Guidelines for Analysis of Unit Prices for Public Works, Minister of Public Works Regulation No. 11/PRT/M/2013.

**Acceleration Alternatives**

Before calculating crash costs and crash duration, a crashing plan or what is usually called a crashing scenario is first carried out, which is carried out based on the resource requirements of each job whose work can be accelerated. This transmission tower project will be analyzed using the Time Cost Trade Off method by adding labor groups (Rifaldi Adi & Ari Ida Ayu, 2021) and add tools (Fitri et al., 2023).

**Crash Duration and Crash Costs**

Crash duration and crash cost calculations are calculated by first finding the accelerated productivity of each job, which is calculated based on the volume, labor coefficient, materials and number of tools used for each job.

**Crash Duration**

After the acceleration productivity is obtained, it can be calculated how much acceleration time can be carried out on this project. Calculation of the acceleration duration is done by dividing the volume by the total productivity after crashing to obtain the formula:

\[
\text{Durasi Crashing} = \text{durasi normal} - \text{durasi setelah crashing}
\]

**Crash Cost**

The next stage in accelerating project time is calculating crash costs or acceleration costs. Calculation of acceleration costs is carried out by adding normal costs with other work acceleration cost items, such as additional costs for workers' wages and equipment rental.

**Cost Slopes**

Cost slope is a comparison between the increase in costs and the acceleration in the duration of work. So the Cost Slope calculation can be done by comparing the difference between Crash Cost and Normal Cost to the difference between Crash Duration and Normal Duration. If formulated then the form is as follows;

\[
\text{Cost slope} = \frac{\text{biaya percepatan} - \text{biaya normal}}{\text{durasi normal} - \text{durasi percepatan}}.
\]
RESULTS AND DISCUSSION

Calculation of Costs and Normal Duration

**Calculate normal duration and normal cost**

In calculating normal costs, data on work volume, craftsman or tool coefficient, effective working hours, unit price of labor, materials, equipment rental are required. The following is a calculation of normal costs and duration for activities included in the critical path.

**Soil excavation**

From table 2.2, Digging with an excavator.

<table>
<thead>
<tr>
<th>No.</th>
<th>Uraian</th>
<th>Satuan</th>
<th>Koefisien</th>
<th>Harga satuan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pekerja</td>
<td>Jam</td>
<td>0.0414</td>
<td>85,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Mandor</td>
<td>Jam</td>
<td>0.0041</td>
<td>150,000.00</td>
</tr>
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Sewa peralatan

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<th>No.</th>
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<th>Satuan</th>
<th>Koefisien</th>
<th>Harga satuan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Excavator</td>
<td>Jam</td>
<td>0.0231</td>
<td>168,000.00</td>
</tr>
</tbody>
</table>

a. calculating duration and costs by labor wages;

Production per day = 

\[
\frac{1}{(0.0414 + 0.0041)} \times 7 \times 2 = 43.956 \text{ m}^3/\text{hari}
\]

Duration = \[
\frac{664.372/4}{43.956} = 3.779 \approx 4 \text{ hari}
\]

Wage = 

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

(2.3)

b. Calculating duration and costs by equipment rental;

\[V\text{ bucket capacity} = 1.50 \text{ m}^3\text{secondary field data}\]

Facebook is bucket factor = 1 \rightarrow table 2.3

\[f_a\text{ is the tool efficiency factor} = 0.83 \rightarrow \text{table 2.4}\]

\[f_k\text{ is a factor in land development} \rightarrow \text{taken 1.1}\]

**T1** is the time for digging, loading, etc. = 7 minutes \rightarrow table 2.5

**T2** is round/swingback and others = 4 minutes \rightarrow table 2.6

\[T_s\text{ is the cycle time, }T_s = 7 + 4 = 11 \text{ menit}\]

60 is the multiplication of 1 hour to minutes

So the production capacity is 1 excavator per day =

\[
Q = \frac{1.50 \times 1 \times 0.83 \times 60}{11 \times 1.1} = 6.17 \text{ m}^3/\text{jam}
\]

Produksi per hari = 6.17 \times 7 = 43.215 \text{ m}^3/\text{hari}

Duration = \[
\frac{664.372/4}{43.215} = 3.843 \approx 4 \text{ hari}
\]

Sewa = 664.372/4 \times (0.0231 \times 168,000) \times 7 \times 4 = \text{Rp.}18,079,456.5

**Sand filling**

a. Calculating duration and costs by labor wages;

From table 2.7, Sand pile as filling material (1 m³)

<table>
<thead>
<tr>
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<th>Uraian</th>
<th>Satuan</th>
<th>Koefisien</th>
<th>Harga satuan</th>
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<tr>
<td>1</td>
<td>Pekerja</td>
<td>OH</td>
<td>0.4000</td>
<td>85,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Mandor (2.1)</td>
<td>OH</td>
<td>0.0400</td>
<td>150,000.00</td>
</tr>
</tbody>
</table>

Bahan

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<th>No.</th>
<th>Uraian</th>
<th>Satuan</th>
<th>Koefisien</th>
<th>Harga satuan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pasir</td>
<td>m³</td>
<td>1.2000</td>
<td>150,000.00</td>
</tr>
</tbody>
</table>

Production per day =

\[
\frac{1}{(0.40 + 0.04)} \times 2 = 4.545 \text{ m}^3/\text{hari}
\]

Duration = \[
\frac{8.836/4}{4.545} = 0.486 \approx 1 \text{ hari}
\]

Wage =

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

b. Calculating costs by materials;

Bahan = 8.836/4 \times (1.200 \times 150,000) = \text{Rp.}397,620
Workshop floor

a. Calculating duration and costs by labor wages;
From table 2.8, 1 m³ of concrete for the work floor (bedding)

<table>
<thead>
<tr>
<th>No.</th>
<th>Uraian</th>
<th>Satuan</th>
<th>Koefisien</th>
<th>Harga satuan</th>
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</thead>
<tbody>
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<td>Upah tenaga kerja</td>
<td>OH</td>
<td>1.3200</td>
<td>85,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Pekerja</td>
<td>OH</td>
<td>0.2200</td>
<td>100,000.00</td>
</tr>
<tr>
<td>3</td>
<td>Tukang batu</td>
<td>OH</td>
<td>0.0220</td>
<td>125,000.00</td>
</tr>
<tr>
<td>4</td>
<td>Mandor</td>
<td>OH</td>
<td>0.1320</td>
<td>150,000.00</td>
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Bahan

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<thead>
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<th>Koefisien</th>
<th>Harga satuan</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Portland cement</td>
<td>kg</td>
<td>247.000</td>
<td>1,300.00</td>
</tr>
<tr>
<td>2</td>
<td>Pasir beton</td>
<td>m³</td>
<td>0.6210</td>
<td>175,000.00</td>
</tr>
<tr>
<td>3</td>
<td>Kerikil</td>
<td>m³</td>
<td>0.7400</td>
<td>400,000.00</td>
</tr>
<tr>
<td>4</td>
<td>Air</td>
<td>L</td>
<td>215.000</td>
<td>25.00</td>
</tr>
</tbody>
</table>

Production per day = \[
\frac{1}{(1.320+0.220+0.022+0.132)} \times 4 = 2.361 \text{m}^3/\text{hari}
\] (2.7)

Duration = \[
\frac{4.418/4}{2.361} = 0.468 \approx 1 \text{ hari}
\]

Wage = \[
4.418/4 \times \frac{1.320 \times 85,000 + 0.220 \times 100,000 + 0.022 \times 125,000 + 0.132 \times 150,000}{1} = \text{Rp.} 173,130.38
\]

b. Calculating costs by materials;
Material = \[
\frac{4.418/4 \times (247 \times 1,300 + 0.621 \times 175,000 + 0.740 \times 400,000 + 215 \times 25)}{801,624.42} = \text{Rp.} 801,624.42
\]

Reinforcing

a. Calculating duration and costs by labor wages;
From table 2.9, 100 kg of steel is made with plain and threaded iron

<table>
<thead>
<tr>
<th>No.</th>
<th>Uraian</th>
<th>Satuan</th>
<th>Koefisien</th>
<th>Harga satuan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Upah tenaga kerja</td>
<td>OH</td>
<td>0.7000</td>
<td>85,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Pekerja</td>
<td>OH</td>
<td>0.7000</td>
<td>125,000.00</td>
</tr>
<tr>
<td>3</td>
<td>Tukang besi</td>
<td>OH</td>
<td>0.0700</td>
<td>125,000.00</td>
</tr>
<tr>
<td>4</td>
<td>Mandor</td>
<td>OH</td>
<td>0.0700</td>
<td>150,000.00</td>
</tr>
</tbody>
</table>

Bahan

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<tr>
<th>No.</th>
<th>Uraian</th>
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<th>Koefisien</th>
<th>Harga satuan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Besi beton (polos/ulir)</td>
<td>kg</td>
<td>105.000</td>
<td>15,000.00</td>
</tr>
<tr>
<td>2</td>
<td>Kawat ikat</td>
<td>kg</td>
<td>1.5000</td>
<td>21,000.00</td>
</tr>
</tbody>
</table>

Production per day = \[
\frac{1}{(0.700+0.700+0.070+0.070)} \times 4 = 4.520 \text{m}^2/\text{hari}
\]

Duration = \[
\frac{101.600/4}{4.520} = 5.620 \approx 6 \text{ hari}
\]
Time and Cost Analysis on Procurement of Sutet 275 Kv 2CCT Quadruple Zebra Gumawang – Gitet Lampung 1 Using Time Cost Trade Off Method

Wage=
\[
\frac{101.600/4 \times (0.560 \times 85,000 + 0.250 \times 100,000 + 0.025 \times 125,000 + 0.050 \times 150,000)}{4.520 \times 6} = \text{Rp.}12,683,490
\]

a. Calculating costs by materials;
Material=
\[
101.600/4 \times \left( \frac{0.245 \times 300,000 + 0.0135 \times 31,000 + 0.245 \times 17,000 + 0.200 \times 1,200}{0.250 \times 125,000 + 0.025 \times 150,000} \right) = \text{Rp.}1,991,575.9
\]

(2.9)

Cast reinforced concrete
a. Calculating duration and costs by labor wages;
From table 2.11, 1 m³ Quality concrete, f’c = 19.3 MPa (K225)

<table>
<thead>
<tr>
<th>No.</th>
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<th>Harga satuan</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Pekerja</td>
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<td>1,6500</td>
<td>85,000.00</td>
</tr>
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<td>2</td>
<td>Tukang batu</td>
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<td>0.2750</td>
<td>100,000.00</td>
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<td>3</td>
<td>Kepala tukang</td>
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<td>0.0280</td>
<td>125,000.00</td>
</tr>
<tr>
<td>4</td>
<td>Mandor</td>
<td>OH</td>
<td>0.1650</td>
<td>150,000.00</td>
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<th>Koefisien</th>
<th>Harga satuan</th>
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<tr>
<td>1</td>
<td>Portland cement</td>
<td>kg</td>
<td>371</td>
<td>1,300.00</td>
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<tr>
<td>2</td>
<td>Pasir beton</td>
<td>kg</td>
<td>698</td>
<td>150.00</td>
</tr>
<tr>
<td>3</td>
<td>Kerikil</td>
<td>kg</td>
<td>1.047</td>
<td>160.00</td>
</tr>
<tr>
<td>4</td>
<td>Air</td>
<td>L</td>
<td>215</td>
<td>3.00</td>
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</table>

Sewa peralatan

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<th>Koefisien</th>
<th>Harga satuan</th>
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<td>Molen manual</td>
<td>Hari</td>
<td>0.1434</td>
<td>250,000.00</td>
</tr>
</tbody>
</table>

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

(2.7)

Duration = \[\frac{43.374/4}{1.889} = 5.742 \approx 6 \text{ hari} \] (2.2)

Wage=
\[
43.374/4 \times \left( 1.650 \times 85,000 + 0.275 \times 100,000 + 0.028 \times 125,000 + 0.165 \times 150,000 \right) \times 6
\]

= Rp.12,751,956

(2.8)

b. Calculating duration and costs by equipment rental;
Kapasitas produksi beton/jam, \(Q = \frac{V \times F_a \times 60}{1000 \times T_s} \rightarrow m^3/jam \)

(2.8)

With:
\( V \) is the capacity of the mixing tank, taken as 350 liters
\( F_a \) is the tool efficiency factor, taken as 0.83
\( V_1 \) is the average speed of contents, 15 km/hour
\( V_2 \) is the average empty speed, 25 km/hour
\( T_1 \) is the length of time to fill, taken as 0.50 minutes
\( T_2 \) is the length of mixing time, taken as 1.00 minutes
\( T_3 \) is the length of time of shedding, taken as 0.30 minutes
\( T_4 \) is the length of waiting time, etc., taken as 0.2 minutes
\( T_s \) is the cycle time, \( T_s = 0.50 + 1.00 + 0.30 + 0.20 = 2 \) minutes
60 is the multiplication of 1 hour to minutes

So the production capacity is 1 manual molen per day =
\[
Q = \frac{(15 + 25) \times 0.83 \times 60}{1000 \times 2} = 0.996 m^3/jam = 0.996 \times 7 = 6.972 m^3/hari
\]

Duration = \[\frac{43.374/4}{6.972} = 1.555 \approx 2 \text{ hari} \]

Sewa = \[\frac{43.374/4 \times (0.1434 \times 250,000) \times 2}{2} = \text{Rp.}777,646.30 \]

Dismantle the formwork
Calculating duration and costs by labor wages;
From table 2.12, Dismantle 1 m² of formwork normally (and clean up the debris)

<table>
<thead>
<tr>
<th>No.</th>
<th>Uraian</th>
<th>Satuan</th>
<th>Koefisien</th>
<th>Harga satuan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pekerja</td>
<td>OH</td>
<td>0.0400</td>
<td>85,000.00</td>
</tr>
<tr>
<td>4</td>
<td>Mandor</td>
<td>OH</td>
<td>0.0040</td>
<td>150,000.00</td>
</tr>
</tbody>
</table>
Disassembly of formwork and fireplace debris in one day, and does not require tools.

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

Duration = \( \frac{101.600}{45.455} = 0.559 \approx 1 \text{ hari} \)

Upah = 101.600/4 \times (0.040 \times 85,000 + 0.004 \times 150,000)

\( \text{(2.8)} \)

**Backfilling of land**

a. Calculating duration and costs by labor wages;

Production per day = \( \frac{1}{(0.0414 + 0.004)^2} = 43.956 \text{ m}^3/\text{hari} \)  \( \text{(2.7)} \)

Duration = \( \frac{607.744}{43.956} = 3.457 \approx 4 \text{ hari} \)

Wage = 607.744/4 \times (0.0414 \times 85,000 + 0.004 \times 150,000) \times 7 \times \text{Rp.17,586,895.87}

\( \text{(2.8)} \)

b. Calculating duration and costs by equipment rental;

So the production capacity is 1 excavator per day =

\[ Q = \frac{1.50 \times 1 \times 0.83 \times 60}{11 \times 1.1} = 6.17 \text{ m}^3/\text{jam} \]

Produksi per hari = 6.17 \times 7 = 43.215 \text{ m}^3/\text{hari}

Duration = \( \frac{664.372}{43.215} = 3.843 \approx 4 \text{ hari} \)

Sewa = 664.372/4 \times (0.0231 \times 168,000) \times 7 \times 4 = \text{Rp.1.}

The results of this normal duration analysis are used as duration input in the Microsoft Project auxiliary program model according to the work sequence, and the critical path is obtained as in Appendix 4. Critical path analysis by Microsoft Project is based on the description of RAB activities, concrete curing must be accelerated, as well as Appendix 5, 6 Network planning normal duration and critical path.

**Calculate crash duration and crash cost**

In calculating crash costs, data on work volume, craftsman or tool coefficient, effective working hours, unit price of labor, materials, equipment rental are required. The following is an example of calculating normal costs for activities that are included in the critical path. The acceleration alternative is to add 1 group of workers and add 1 tool each, both for excavators and manual mills. The following is an example of a crashing calculation for earth excavation work;

**Soil excavation**

a. Calculating duration and costs by labor wages;

Production per day = \( \frac{1}{(0.0414 + 0.004)^2} \times 7 \times 2 = 87,912 \text{ m}^3/\text{hari} \)

Duration = \( \frac{664.372/4}{87,912} = 1.889 \approx 2 \text{ hari} \)

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

\( \text{(2.4)} \)

b. Calculating duration and costs by equipment rental;

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

\[ \text{Kapasitas produksi per jam, } Q = \left[ \frac{50 \times 1 \times 0.83 \times 60}{11 \times 1.1} \right] \times 2 = 12.347 \text{ m}^3/\text{jam} \]

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

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

Duration = \( \frac{664.372/4}{86.430} = 1.922 \approx 2 \text{ hari} \)
Sewa = 664.372/4 × (0.0231×168,000) × 7 × 2 × 2 = R p. 12,751,956

Sand filling
Calculating duration and costs by labor wages;
Production per day = →addition of 1 labor group
\[1 \div (0.40 + 0.04) \times 2 \times 2 = 9.091 \text{ m}^3/\text{hari}\]
Duration = \[\frac{8.836/4}{9.091} = 0.243 \approx 1 \text{ hari}\]
Upah = 8.836/4 x (0.400 x 85,000 + 0.040 x 150,000);

Workshop floor
Calculating duration and costs by labor wages;
Production per day = →addition of 1 labor group
\[1 \div (1.320 + 0.220 + 0.022 + 0.132) \times 4 \times 2 = 4.723 \text{ m}^3/\text{ha}\]
Duration = \[\frac{4.418/4}{4.723} = 0.234 \approx 1 \text{ hari}\]
Upah = 4.418/4 x (1.320 x 85,000 + 0.220 x 100,000 + 0.022 x 125,000 + 0.132 x 150,000);

Reinforcing
Calculating duration and costs by labor wages;
Production per day = →addition of 1 labor group
\[1 \div (0.700 + 0.700 + 0.070 + 0.070) \times 4 \times 100 \times 2 = 519.481 \text{ kg/ha}\]
Duration = \[\frac{4,549.125 + 154.134}{519.481} = 2.263 \approx 3 \text{ hari}\]

Wage = \[\frac{1,320 \times 85,000 + 0.275 \times 100,000 + 0.028 \times 125,000 + 0.165 \times 150,000}{1,889} \times 6 = Rp. 12,751,956\]

Formwork
Calculating duration and costs by labor wages;
Production per day = →addition of 1 labor group
\[1 \div (0.500 + 0.250 + 0.025 + 0.05) \times 4 \times 2 = 9.040 \text{ m}^2/\text{hari}\]
Duration = \[\frac{101.600/4}{9.040} = 2.810 \approx 3 \text{ hari}\]
Upah = \[\frac{101.600/4}{4.520} \times (0.560 \times 85,000 + 0.250 \times 100,000 + 0.025 \times 125,000 + 0.050 \times 150,000) \times 3 \times 2 = Rp. 11,949,455.40\]

Cast reinforced concrete
a. Calculating duration and costs by labor wages;
Production per day = \[1 \div (1.650 + 0.275 + 0.025 + 0.165) \times 4 = 1.889\]
Duration = \[\frac{43.374/4}{1.889} = 4.3842 \approx 6 \text{ hari}\]
Wage = \[43.374/4 \times (1.650 \times 85,000 + 0.275 \times 100,000 + 0.028 \times 125,000 + 0.165 \times 150,000) \times 6 = Rp. 12,751,956\]

b. Calculating duration and costs by equipment rental;
The manual molen tool is added with 1 unit with the same capacity, so that equation 2.7 becomes;
Kapasitas produksi per jam, Q
\[= \frac{(15 + 25) \times 0.83 \times 60}{1000 \times 2} \times 2 = 1.992 \text{ m}^3/\text{jam}\]
The production formula per day with the addition of 1 tool is as follows;
Produksi per hari = 1.992 \times 7 = 13.944 \text{ m}^3/\text{hari}

Duration = \frac{664.372/4}{13.944} = 0.778 \approx 1 \text{ hari}

Sewa = 43.374/4 \times (0.1434 \times 250,000) \times 1 \times 2 = \text{Rp. 77}

**Dismantle the formwork**

Calculating duration and costs by labor wages;
Production per day = \text{addition of 1 labor group}
\[
\frac{1}{(0.04+0.004)} \times 2 \times 2 = 90.909 \text{ m}^2/\text{hari}
\]

Duration = \frac{101.600/4}{90.909} = 0.279 \approx 1 \text{ hari}

Upah = 101.600/4 \times (0.040 \times 85,000 + 0.004 \times 150,000)

**Backfilling of land**

a. Calculating duration and costs by labor wages;
Production per day =
\[
\frac{1}{(0.0414+0.004)} \times 2 \times 2 = 87.912 \text{ m}^3/\text{hari}
\]

Duration = \frac{607.744/4}{87.912} = 1.728 \approx 2 \text{ hari}

Wage =
607.744/4 \times (0.0414 \times 85,000 + 0.004 \times 150,000) \times 7 \times \text{Rp. 17,586,895.87}

b. Calculating duration and costs by equipment rental;
The excavator tool is added by 1 unit with the same bucket capacity, so that equation 2.4 becomes;
Kapasitas produksi per jam, \(Q = \left[\frac{1.50 \times \frac{0.83 \times 60}{11 \times 1.1}}{2} \times 2 = 12.347 \text{ m}^3/\text{jam}\)

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

Duration = \frac{607.744/4}{86.430} = 1.758 \approx 2 \text{ hari}

Sewa = 607.744/4 \times (0.0231 \times 168,000) \times 7 \times 4 = \text{Rp. 1}

**Calculating cost slope**

Cost slope is a comparison between the increase in costs and the acceleration of project completion time which is calculated from the results of the reduction between crash costs and normal project costs and then divided by the results of the reduction between normal duration and crash duration. The form of the graph is a straight line that has a certain slope.

As an example of cost slope calculations used for earth excavation activities, here are the calculations;

\[
\text{Cost slope galian tanah} = \frac{38,517,193.87 - 19,225,596.94}{10,004,416.66} = 19,291,596.94
\]

The results of the normal and crash duration analysis are compiled in tabular form, which can be seen in Appendix 7. Table of normal and crash duration analyses are displayed in the following linear graph form;

**Cost slope graph**

The relationship between time exchange analysis and costs on normal duration and accelerated duration is displayed in the following linear graph form;

**Figure 1. Acceleration graph using Microsoft Excel**

Source of analysis results by researchers, 2023
Results Analysis

Alternative acceleration by adding 1 group of labor and 1 tool results in an acceleration of 9 days, where in the normal duration the concrete reaches 28 days of age on December 13 2023, after crashing the concrete reaches 28 days of age on December 8 2023. So the schedule installing SUTET tower latice is fulfilled. The model for this analysis uses the Microsoft Project support program, can be seen in Appendix 8 Analysis by Microsoft Project after acceleration, concrete curing is fulfilled.

CONCLUSION

1. Based on the analysis results, the initial duration of foundation work was 42 days, a time acceleration of 9 was obtained so that the days became 34 days. Concrete curing was achieved on December 8, 2023 as planned.
2. Initial costs for workers' wages and equipment rental Rp. 109,735,331.86, after the crash the cost increased to Rp. 219,470,663.73. Initial total cost budget plan Rp. 1,620,555,230.42 and after acceleration it increased to Rp. 1,730,290,562.28 equivalent to 6.77%.

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