The International Journal of Social Sciences World
TIJOSSW is Available Online at:
https://www.growingscholar.org/journal/index.php/TIJOSSW
Vol. 4 No. 1, June 2022, pages: 313~329
DOI: https://doi.org/10.5281/zenodo.6687647
ISSN **2690-5167**
Growingscholar Publisher

Alternative Design Selection 150 kV Transmission Line *Holtekam – Angkasa* Papua Using MCDM TOPSIS Method

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Article history:
Received April, 24, 2022, Accepted: June, 03, 2022, Displayed Online: June, 23, 2022; Published: June, 30, 2022

Keywords

TOPSIS;
OHL;
UGC;
Submarine;
MCDM

Abstract

The Indonesian government's electricity company (PLN) has got Project Development Unit (UIP), which oversees the development of Electricity Infrastructure. In UIP Maluku Papua, the engineering consultant is hired to study the three alternative designs using available data. Based on the experience of the study process, the decision tends to the criteria for a faster construction time or a cheaper cost estimate. Meanwhile, the cheapest cost is not always the final solution because UIP has many experiences constructing SUTT in the Papua area. Many problems arise, resulting in design changes during construction and other social problems that can occur as inhibiting factors and delays. In addition, if the other alternatives directly implemented using SKTT and SKLTT, which generally estimated to be done faster in construction, also there's no one can guarantee it because this alternative is categorized as a new thing in Maluku & Papua, where there's a lot of uncertainty factor in implementation will also be immeasurable. Based on these things, empirical research using the TOPSIS method is needed to analyze the most appropriate alternative design decisions. The result of the research is SUTT as the recommended decision. But considering the sensitivity analysis, the weight of the preference factor has a significant role in changing the decision. Therefore, if it is deemed necessary, then, this can be developed in the next comprehensive research.

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1. Introduction

PT PLN (Persero) is one of the state-owned companies that holds a Business License for the Provision of Electricity for the public interest or the benefit of the wider community (Haraguchi, Miyano, & Nakamura, 2021), (Ibraheem, 2020), which is obliged to provide electricity continuously in sufficient quantities with good quality and reliability (Jayapriya, Monica, Nathiya, A., & Sowmiya, 2017), (Zohuri & P. McDaniel, 2019). The availability of electricity is one of the important needs in creating economic growth to achieve community welfare (Nkalo & Agwu, 2019). The Government of the Republic of Indonesia has launched the 35-thousand-Megawatt (MW) program, which is stipulated through Presidential Regulation No. 4 of 2016 concerning the Acceleration of Electricity Infrastructure Development (Aigboviosa, Idiake, Nkordeh, Ehimen, & Victory, 2018), in which PT Perusahaan Listrik Negara (Persero) PLN) was appointed as the executor of electricity infrastructure development in the program. To support government programs, especially in the Papua region, the targeted projects are handled by UIP Papua by the RUPTL 2021-2030 program (Kementerian Energi dan Sumber Daya Mineral Republik Indonesia, 2021), namely a total generating capacity of 431.4 MW, Substations of 781, 8 MW and a transmission length of 1,132 KMS. From this target, a transmission project plan for power evacuation (Garg & Ghatak, 2020), (Nirwan, Shah, Shah, & Velani, 2018) from the Holtekam power plant site to the Angkasa area targeted for 2022.

2. Literature Review

According to the historical experience of the high-voltage overhead line transmission (SUTT) project contract carried out in Papua, the SUTT transmission line with a distance of 10-15 km route has a planned completion time of 365 calendar days (1 year). However, there are many non-technical factors during the execution of the work, from the detailed design process to the construction process in the field, which causes this project to be late for completion. Therefore, the Holtekam-Angkasa Papua Transmission Line needs further research related to a more effective design (Fahad & Chillab, 2020), especially concerning maintenance issues when it is successfully established and used (Piana, Bignucolo, Donini, & Spezie, 2018). Considering that in the RUPTL, three alternative designs can be used so that the power evacuation plan that has been planned to operate in 2022 can be in line with expectations. Alternative transmission lines that are possible to implement according to the options stated in the RUPTL are High Voltage Overhead Line (SUTT), High Voltage Marine Cable Channel (SKLTT), and High Voltage Underground Channel (SKTT). To find alternative designs that are more effective to implement, the authors intend to use the multi-criteria decision-making model (MCDM) (Bhole & Deshmukh, 2018) to achieve the right recommendation approach.

In general, the location of a power center is in a special area so as not to disturb the environment and reduce the social aspect of the local population (BICEN, 2019) (Nawaz & Khan, 2016). The flow of electrical power that tends to be around the power center is carried out using special distribution lines at the medium voltage and then transformed to low voltage to be further distributed to the electricity user community through existing substations. However, load centers (power users) who are far from the power plant location with long distances with large power evacuations tend to use high-voltage power transmission lines (Unni & Soumya, 2016) to evacuate power from the power center to the load center through the system of the substations so that the evacuated power does not experience a voltage drop or looses so that the electric current in the load center is in a reliable state. According to Budiyanto (2018) the types of voltage in Indonesia are divided based on the voltage criteria into Very Low Voltage / LV (50 volts - 1000 volts / 1 KV volts), Medium Voltage / MV (1 kV-36KV), High Voltage / HV (36 kV -150 kV), Extra High Voltage / HEV (150 kV-750 kV), and Ultra High Voltage / HUV (range above 750 kV).

Nowadays, many regions in Indonesia still use the system of 70 kV and 150 kV according to the power to be evacuated, especially in the Papua region. To reduce the decrease in voltage quality and power loss along the transmission line, high voltage is used in the distribution of electrical energy (Arismunandar, 2001, Jurnal Surya Energy Vol 3, 2019). Based on this, in terms of evacuating high-voltage electric power from the generator to the location of the substation or load center, several types of transmission can be carried out, such as 1. High Voltage Overhead Line (SUTT), 2. High Voltage Underground Line (SKTT), 3. High Voltage Marine Cable Channels (SKLTT). All three have their own advantages and disadvantages, both in terms of usage, operational costs, and others.

a. High Voltage Overhead Line (SUTT/OHL)
   A high Voltage Overhead Line (SUTT) is a facility/equipment that stretches in the air and aims to distribute electrical power from the generating center to the substation (GI) or from the substation to the main substation by using a conductor cable that is stretched between the poles to the poles (tower) through insulators with high-voltage systems (30 kV, 70 kV, 150 kV) (National Symposium RAPI XII-2013 FT UMS) (Setayeshgar, 2016). High Voltage Over Head Lines Transmission is currently the most commonly used and most widely used type of transmission in Indonesia for the evacuation of electrical power from generators or from one substation to another substation to the load center. All materials for this type of transmission can generally be easily found in Indonesia, so the main materials used, such as tower materials and conductor materials, are not the main problem in carrying out their work.
   In general, the type of high voltage SUTT transmission used in Indonesia, especially in the Papua region, currently uses the 150 kV SUTT type made of Steel Tower (Tower Lattice) or often also called Over Head Lines (OHL) using the ACSR type of conductor wire (Aluminum Conductor Steel Reinforced Cable) (Sontakke & Sakhale, 2021). This SUTT is generally a top priority for areas that still have a wide area coverage (Chetty & Ijumba, 2012), such as Papua, and are more economical in general. However, the condition of Papua with its vulnerability to social problems cannot be specifically ascertained whether this can be the sole solution for evacuation routes in this region.
b. High Voltage Underground Line (SKTT/UGC)
   High Voltage Underground Line (SKTT) are facilities/equipment prepared in the context of evacuating electrical power from a generator or substation by using cables that are stretched in the ground with certain methods, either by drilling in the ground (HDD) or by digging the soil like drainage (open trench) (Public Service Commission of Wisconsin, 2016). In today's era, SKTT with XLPE (Cross-Linked Polyethylene) cable is an attractive choice for transmission lines located in densely populated areas or urban areas in terms of aesthetics. Unlike the Air Duct, this SKTT is covered with insulation that can withstand temperatures up to 90 degrees Celsius. When placed at temperatures above 90 degrees, this cable will experience accelerated damage (B Kukharchuck IOP material Science & Engineering 2018). So that in its application, a detailed survey must be carried out for the existing media or soil conditions (Puget Sound Energy, 2014). The planning and implementation of this SKTT must comply with Ministerial Regulation Number 10 of 2021 concerning Electricity Safety and SPLN.
c. High Voltage Marine Cable Channels (SKLTT/Marine Cable)
   A high Voltage Marine Cable Channel is one type of transmission used to transmit low or high voltage electrical power from a generator to the load center by laying submarine cables on the seabed (Umeda et al., 2007). The use of High Voltage Marine Cable Channels (SKLTT) is also widely used to transmit electricity from Offshore Wind Power Plants to the mainland or the nearest load center or also used in an interconnection system. The selection of the type of cable in accordance with the characteristics of the local seawater will affect the quality of the evacuation of electric power and affect the power losses that occur, so the parameters of this

cable must be evaluated properly in order to function properly. The following variables influence the reliability of the performance of the SKLTT:

1. Load center ends stress condition.
2. Active power state
3. Reactive power state
4. Efficiency Value

The cable parameters used are evaluated based on the condition of the electric magnetic field, which is determined by the flow of power in the cable, which is determined by the material geometry of the cable itself. These materials can affect the level of reliability of the electrical power supplied. There are some challenges in reliability issues also based on wave height conditions and undersea current velocity, so for conditions with high wave levels and undersea current velocities with significant path lengths, it is necessary to consider the results of the delivered power using SUTT whenever possible.

3. Materials and Methods

This study uses the concept of quantitative analysis using feasibility study data (Masanja, 2020) published by the expert consultant of PLN Engineering. At the beginning of the study, the author will collect a list of core parameters and attributes obtained from each design option starting from the High Voltage Overhead Line (SUTT), High Voltage Underground Channel (SKTT), and High Voltage Marine Cable Channel (SKLTT) then modeled in the form measurements for each of the design parameters. The measurement results obtained from the results of each alternative will become a measurable criterion and have a value that will be used for further modeling as a composing decision matrix criterion. To determine the preference scale for the criteria, a questionnaire survey will be conducted to determine the data for the appropriate preference weight for each criterion in each alternative design.

Primary data collection was carried out by conducting focused group discussions (O.Nyumba, Wilson, Derrick, & Mukherjee, 2018) with consultants or practitioners who are considered experts as outlined in the form of Minutes of Technical Discussion Meetings relating to the discussion of choices in this design. Questionnaire survey data was also carried out regarding analysis based on practitioners considered experts (Ponto, 2015) to find a comparison scale and preference weights. For secondary data collection, this study uses data such as data transmission route plans for the three design alternatives (SUTT/SKTT/SKLTT), which consist of technical analysis & specification data, construction cost estimate data, work schedule data for the duration of the implementation plan, risk analysis data for the three design alternatives according to PLN E Feasibility Study Document. Next, an empirical approach will be carried out on the criteria results as they are, which can be used as a decision matrix. So that the decisions obtained can be more precise, the author will use the TOPSIS method (Zulqarnain, Saeed, Ahmad, Dayan, & Ahmad, 2020).

Data processing with the TOPSIS method has several stages (Parida, 2019), namely: 1) processing and analyzing technical and cost data, 2) Processing and analyzing time duration data, and 3) Processing and analyzing risk and environmental data. Some data related to preference weights can be used for the above criteria based on urgency and purpose. A questionnaire survey was conducted among experts in the PLN team and PLN E consultants, which included elements of Management and Specialists who were considered competent and had at least eight years of work experience in the SUTT/SKTT/SKLT transmission project are as follows: Senior Manager of Planning UIP MPA (1 person), Manager of the Papua Region Project Unit – UIP MPA (1 person), Manager of Civil Planning UIP MPA (1 person), Senior Manager of Transmission & Distribution of PLN Engineering (1 person), PLN Engineering Transmission & Distribution Manager (1 person), Project Team Leader Feasibility Study (2 people), Civil Engineer PLN E Specialist (3 people),

Electromechanical Engineer PLN E Specialist (3 people), and Specialist Contract Engineer PLN E (1 person).

All data will be collected, and an average assessment of the survey results will be carried out as the most suitable preference weight for further modeling. After getting the results of all the criteria from the cost and technical side, the analysis of the duration of the implementation and the risk aspects have been found. Then the author will calculate the decision matrix using the TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution). The stages of the TOPSIS method (Parida, 2019) carried out include: 1) deciding matrix and a normalized decision matrix, 2) calculating the weighted normalized decision matrix, 3) determining the positive and negative separation, 4) measuring the preference value on each alternative. After the results of the TOPSIS method are obtained, decision recommendations and sensitivity tests are carried out. The analytical thinking flow can be seen in figure 1 below.

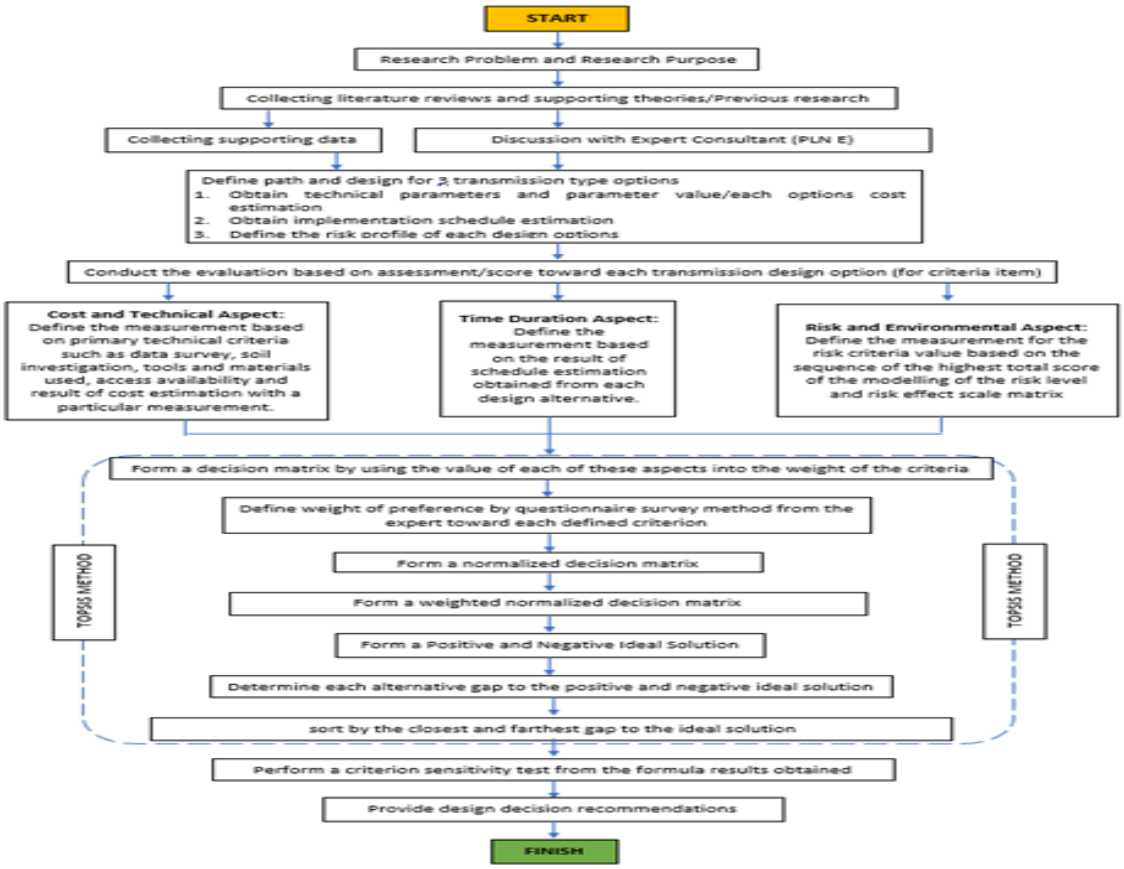


Figure 1. Solution Framework Flowchart

4. Results and Discussions

Data Processing and Analysis of Concept

Transmission Design Concept Stage

In the early stages of finding recommendations for decisions, it was found that, in general, PLN Project Development Unit (UIP) has the main task of ensuring and managing projects whose targets have been determined in accordance with the Electricity Supply Business Plan (RUPTL) issued by the government. In particular, for the Holtekam-Angkasa Papua Transmission Line project at RUPTL 2021-2030, there are three alternative transmission line designs specified in the target, namely SUTT/SKTT/SKLTT, so in this case, the Maluku & Papua UIP is not only tasked with ensuring the target of this line transmission project achieved but also given the assignment to determine which alternative is more appropriate to apply, so the chosen solution is matched with the vision of the corporation that to be the leading electricity company in Southeast Asia and became the number one of customer choice in Energy Solution.

Transmission Line Design Alternatives

From a direct inspection together with the PLN Engineering consultant team, 3 (Three) alternative transmission lines concept were found as follows:

1. Alternative – 1 is SUTT (OHL) 150 kV which starts from the location of the Holtekam Substation along the new road to Youtefa Bridge and continues towards Skyland using a 2-circuit configuration, and then from Skyland 4 circuits are planned to consider the area for the development of new circuit lines and then to the point the planned location of the Angkasa Substation with a route length of about 29.8 km. The route uses the Lattice tower and several sections using the Steel Pole.
2. Alternative – II is an SKTT (UGC) 150 kV, which starts from the location of the Holtekam Substation using two circuits along the 24 km route. Because there is a limited area in the area of the Holtekam substation and the space substation, there are several points using Lattice towers with cable sealing end construction for this route.
3. Alternative – III is SKLTT (Submarine Cable) 150 kV starting from the location of the Holtekam Substation by following the coastline along the 21 km route. In this alternative, the sea cable from the Holtekam Substation Bay line point uses the Cable Sealing End (CSE) towards the sea via the Landing Point. On the other hand, in the Angkasa Substation area, there is also a Cable Sealing End and landing point from the direction of Pasir Tiga beach. In connection with the terrain from the coast (CSE area) to the Angkasa Substation area, the elevation difference is quite significant (±20 m), so it uses the help of 1 lattice tower from CSE to the Bay Line of the Angkasa Substation.

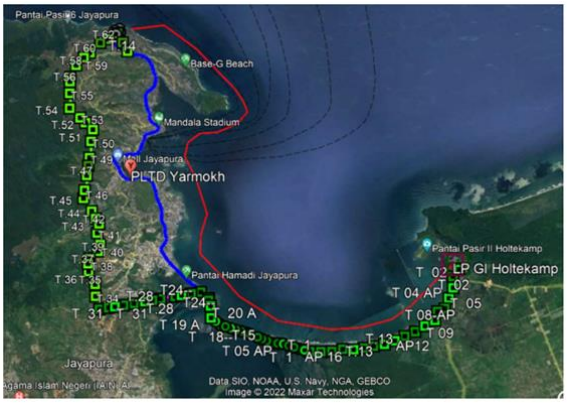


Figure 2. Alternative Route Based on Design Plan

Design of Criteria and Data Processing

The installed capacity at the Holtekam Papua location, in accordance with the 2021-2030 RUPTL in 2027, consists of PLTU 2 Papua 20 MW, MPP PLTMG 50 MW, PLTMG Jayapura Peaker 40 MW, and PLTMG Jayapura 2 50 MW. So that the total installed capacity planned for that year for the Holtekam Power Plant location needs to be evacuated with a total power of 160 MW. Considering design concepts that have been analyzed and using the results of survey data from several design parameters, so that power evacuation can be carried out properly, All the alternatives must design with at least the Basic Design as follows:

Basic Design SUTT 150kV

1. This construction plan uses a varied tower type Lattice tower two circuits along the 29.8 km route, which varies with a basic span between towers of 350 meters with a height of 25-30 meters.
2. Soil conditions around the location vary with data from field testing and refer to soil data for existing transmission land, which is close to the range 10 kg/cm2 – 200 kg/cm2, but most land points are in the Rigid category with a value of QC = 30-60 kg/cm2
3. This design requires the land acquisition of 24,080 m2 for the acquisition of the entire tower footprint.
4. The insulator used is adapted for 150 kV facilities.
5. The conductor is ACSR/AS type 1x240 mm2 per phase with 16 mm2 ground wire / SA1A-7+OPGW.
6. Construction of the foundation plan using the standard quality of the K-225 foundation.

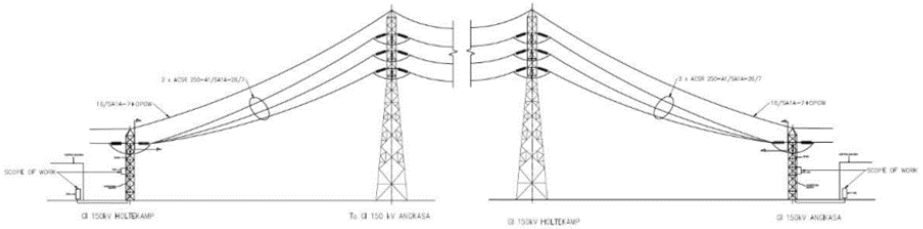


Figure 3 SUTT Section

7. The estimated cost required is 183 billion rupiahs.

8. From the estimated components above, it is estimated that 100% of work items are sourced from within the country because all the procurement and goods are commonly used and ready in domestic.
9. The estimated duration of work with the alternative SUTT design in this condition is 32 months, the details of which can be seen in Table 1 below.

Table 1. Estimated Work Duration of SUTT

Transmission Alternative	No	Work Activity	...th Month
SUTT (OHL)	1	Perform Permit & Licensing	
	2	Environmental Document	
	3	The land acquisition	
	4	Survey & Soil Investigation	
	5	Bid Doc,DED &HPE (Cost Est)	
	6	Procurement Process	
	7	Construction	

Basic Design SKTT 150 kV

1. Construction, according to the conditions of this location, uses a combination of open trenching and Horizontal Directional Drilling (HDD) with a type of 1 (single-core) XLPE Ground Cable, CU 2 cct (3x1x300 mm2) along 25.7 km.
2. Installed parallel (horizontal) parallel two circuits.
3. The soil condition of the path through which the SKTT is passed is carried out by visual observation, where the soil conditions along the SKTT path are in a very rigid condition with a range of 60-120 kg/cm2.
4. The land requirement needed for the acquisition is 9180 m2 which consists of the need for the gantry and towers from start to the end of the span.
5. Maximums short-circuit current 31.5 kA
6. Optical Cable; Fiber Optic Armor 24 Core

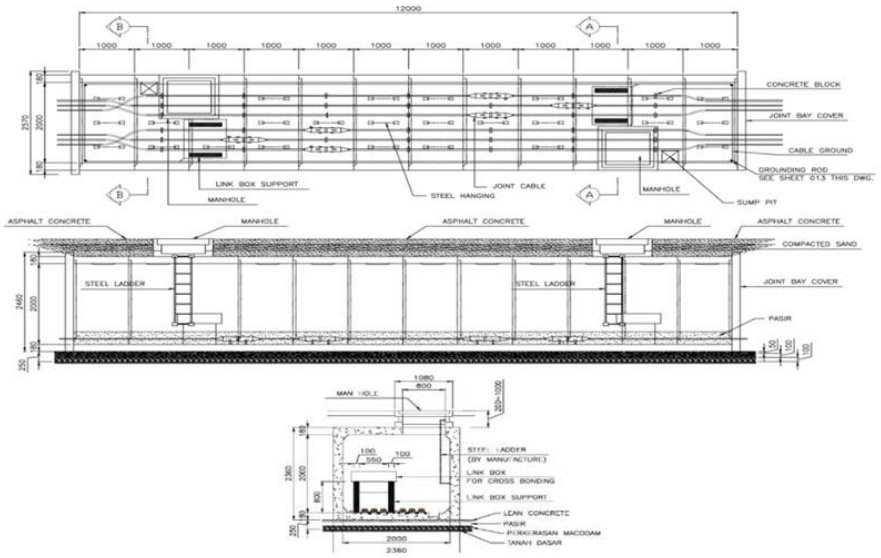


Figure 4**.** SKTT Cross-sectional Sample

7. The estimated duration of the work with the alternative design of the SKTT in this condition is 34 months, the details of which can be seen in Table 2 below.

Table 2. Estimation of SKTT Work Duration

Transmission Alternative	No	Work Activity	...th Month
			1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
SKTT (UGC)	1	Perform Permit & Licensing	
	2	Environmental Document	
	3	The land acquisition	
	4	Survey & Soil Investigation	
	5	Bid Doc,DED &HPE (Cost Est)	
	6	Procurement Process	
	7	Construction	

8. The estimated value of the work obtained with this SKTT design concept by considering the terrain traversed reaches 351 billion rupiahs.
9. From the estimated details of the components of the work items above, the estimated value of domestic work obtained is 47.30%.

Basic Design SKLT 150 kV

1. The construction used is a type of 3 (three) cores (three cores) with two circuits using XLPE Marine Cable, 3 x 400 mm2 Cu, + FO 24 cores, without connection along the 21 km route.
2. Soil conditions at this location were reviewed by making visual observations and secondary data, namely pushidrosal maps, including the category of firm soils ranging from qc: 10-35 kg/cm2
3. The land requirement for acquisition is 500 m2 which will be used to construct the Landing Point Cable and Gantry tower.
4. Maximum short circuit current 31.5 kA

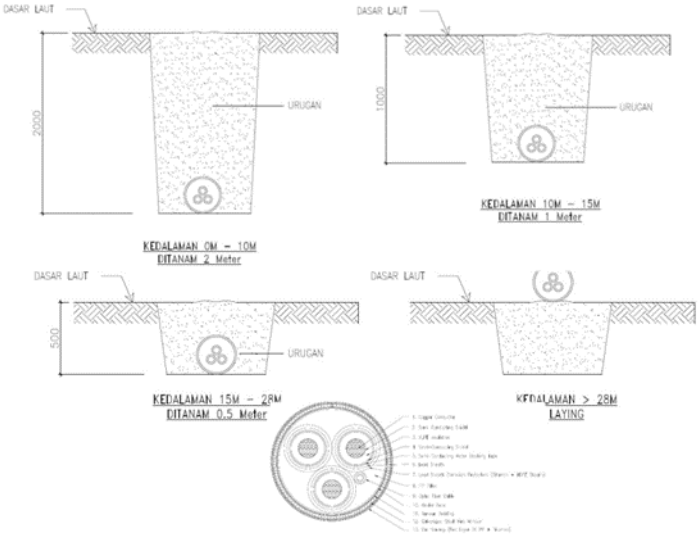


Figure 5. SKLTT cross-sectional sample

5. The estimated value of the work for the SKLTT design concept in this condition reaches 705 billion rupiahs.
6. Based on the estimate of the components mentioned above, the estimated domestic work is 8.88%.
7. The estimated duration of the work with the alternative SKLT design in this condition is 28 months, with details which can be seen in Table 3 as follows:

Table 3. Estimated SKLTT Work Duration

Transmission Alternative	No	Work Activity	...th Month																																
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
SKLTT (Marine Cable)	1	Perform Permit & Licensing																																		
	2	Environmental Document																																		
	3	The land acquisition																																		
	4	Bathymetry Survey																																		
	5	Bid Doc,DED &HPE (Cost Est)																																		
	6	Procurement Process																																		
	7	Construction																																		

Risk Analysis of Each Alternative

From the results of the search and internal discussions between consultants PLN Engineering and PLN UIP Papua, it was found that several things became special views in risk analysis, referring to the impact scale and the possible level of risk. In this analysis, it was found that to anticipate possible risks, apart from technical risk factors, there are several main things that need to be studied as follows.

a. For problems related to the environment, it is necessary to produce UKL/UPL/AMDAL environmental documents that are approved by the Ministry of Environment and Forestry and the Directorate General of Sea Transportation.
b. Licensing for project development requires permits from the local government, the Directorate General of Sea Transportation (HUBLA), Pelindo, and the Harbormaster and Port Authority Office (KSOP).
c. For each alternative, identification is carried out starting from the pre-construction period, the construction period, and the post-construction (operation) period, where each risk criterion is described and calculated based on the results of an agreement made by a team of experts (expert judgment) with a score that can be seen visually, details in table 4 below:

Table 4. Risk Analysis

NO	IDENTIFICATION	OBJECTIVE	RISK	SKLT						SKTT						SUTT					
				Probability Level		Risk Scale/Severity		Risk Level	Score	Probability Level		Risk Scale/Severity		Risk Level	Score	Probability Level		Risk Scale/Severity		Risk Level	Score
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
				Pre-Construction Period																			
I	Legal Aspect	Manage development permits from the local government, HUBLA (Sea Crossing) and related agencies	The project cannot obtain a permit or there is a problem with project development from the local government	B	Not Often	3	Medium	**B 3**	**Medium**	3	D	Often	3	Medium	**D 3**	**High**	2	D	Often	4	Major	**D 4**	**Extreme**	1
	Technical Aspect	Topographic Survey, Bathymetry (SKLT), Georadar (SKTT) Technical Studies regarding Basic Design & Technical Specifications	The results of the survey and technical studies do not represent the condition of the site	C	Roughly	3	Medium	**C 3**	**High**	2	C	Roughly	3	Medium	**C 3**	**High**	2	D	Often	3	Medium	**D 3**	**High**	2
		Land Acquisition for tower site and ROW	Did not get the land according to the plan	A	Seldom	1	Low	**A 1**	**Low**	4	D	Often	4	Major	**D 4**	**Extreme**	1	E	Most Often	5	Disaster	**E 5**	**Extreme**	1
	Economical Aspect	Financial Review	Big Investment	D	Often	4	Major	**D 4**	**Extreme**	1	D	Often	4	Major	**D 4**	**Extreme**	1	C	Roughly	2	Minor	**C 2**	**Moderate**	3
	Social, Security, and Environmental Aspect	UKL-UPL Study and Socialization	UKL-UPL is not approved and there is no agreement with the community	B	Not Often	2	Minor	**B 2**	**Low**	4	D	Often	4	Major	**D 4**	**Extreme**	1	D	Often	5	Disaster	**D 5**	**Extreme**	1
	Funding Aspect	APLN	APLN funding does not exist	C	Roughly	3	Medium	**C 3**	**High**	2	C	Roughly	3	Medium	**C 3**	**High**	2	B	Not Often	2	Minor	**B 2**	**Low**	4
	Construction Service Procurement Aspect	Supply Chain is conducted by PLN	Auction failed	B	Not Often	2	Minor	**B 2**	**Low**	4	B	Not Often	2	Minor	**B 2**	**Low**	4	B	Not Often	2	Minor	**B 2**	**Low**	4
				Construction Period																			
II	Technical Aspect	Detailed Design Review	Changes in Design Details due to field conditions	D	Often	3	Medium	**D 3**	**High**	2	D	Often	3	Medium	**D 3**	**High**	2	C	Roughly	3	Medium	**C 3**	**High**	2
	Economical Aspect	On schedule project disbursement	Actual time deviation from planned schedule	B	Not Often	2	Minor	**B 2**	**Low**	4	D	Often	4	Major	**D 4**	**Extreme**	1	D	Often	4	Major	**D 4**	**Extreme**	1
	Social and Security Aspect	Societal socialization	Socialization not succed	B	Not Often	2	Minor	**B 2**	**Low**	4	D	Often	4	Major	**D 4**	**Extreme**	1	D	Often	4	Major	**D 4**	**Extreme**	1
	Manufacture	Conformity with quality specifications and quantity	The required material does not exist/does not meet requirement specifications	C	Roughly	3	Medium	**C 3**	**High**	2	C	Roughly	3	Medium	**C 3**	**High**	2	B	Not Often	2	Minor	**B 2**	**Low**	4
	Installation	Compliance with time, quality, and quantity	Delay in execution of work / not according to schedule	B	Not Often	3	Medium	**B 3**	**Medium**	3	D	Often	4	Major	**D 4**	**Extreme**	1	D	Often	4	Major	**D 4**	**Extreme**	1
	Commissioning	Compliance with time, quality, and quantity	Time, Quality and Cost for commissioning does not meet the to spesification plan	C	Roughly	3	Medium	**C 3**	**High**	2	C	Roughly	3	Medium	**C 3**	**High**	2	B	Not Often	2	Minor	**B 2**	**Low**	4
				Post-Construction Period (Operation)																			
III	Legal Aspect	Issued RLB and SLO	Commencement of RLB and SLO (operation certificate) is delayed	B	Not Often	2	Minor	**B 2**	**Low**	4	B	Not Often	2	Minor	**B 2**	**Low**	4	B	Not Often	2	Minor	**B 2**	**Low**	4
	Technical Aspect	Performed maintenance	Maintenance using special equipment	C	Roughly	3	Medium	**C 3**	**High**	2	D	Often	3	Medium	**D 3**	**High**	2	D	Often	2	Minor	**D 2**	**Moderate**	3
	Economical Aspect	Operating Budget	No operating budget available	B	Not Often	2	Minor	**B 2**	**Low**	4	C	Roughly	3	Medium	**C 3**	**High**	2	B	Not Often	2	Minor	**B 2**	**Low**	4
	Social Aspect	Providing information services for the surrounding community	Socialization not succed	B	Not Often	4	Major	**B 4**	**High**	2	C	Roughly	4	Major	**C 4**	**High**	2	C	Roughly	3	Medium	**C 3**	**High**	2
	Security and Environment Aspect	Installation of signs regarding electrical hazards	Missing/damaged HSE signs	C	Roughly	3	Medium	**C 3**	**High**	2	C	Roughly	3	Medium	**C 3**	**High**	2	C	Roughly	3	Medium	**C 3**	**High**	2
										51							34							44

Recapitulation of Criteria Data Processing Results

From the description above and through the results of an agreement from a team of experts (expert judgment), the main points can be seen which can be seen in the following Table 5, which will then be used as criteria data that will be used in the next stage (Decision Design Stage).

Table 5. Recap of Criteria Results for Each Alternative

Criteria Description	Criteria		Category	Result						
				SUTT	X_n	SKTT	X_n	SKLTT	X_n	Unit
Line Length (km)	Criteria 1	(c1)	Cost	29,8	X_{11}	25,7	X_{21}	21	X_{31}	Km
Soil Investigation (qc)	Criteria 2	(c2)	Benefit	30	X_{12}	60	X_{22}	10	X_{32}	Kg/cm^2
Domestic Material Portion (%) – (rupiah currency)	Criteria 3	(c3)	Benefit	100	X_{13}	47,3	X_{23}	8,88	X_{33}	%
Land Acquisition requirement (m2)	Criteria 4	(c4)	Cost	24.080	X_{14}	9.180	X_{24}	500	X_{34}	m^2
Estimated Work Cost (Rp)	Criteria 5	(c5)	Cost	183.600.392.324	X_{15}	351.249.274.496	X_{25}	705.549.192.081	X_{35}	Rupiah
Estimated Duration (month)	Criteria 6	(c6)	Cost	32	X_{16}	34	X_{26}	28	X_{36}	Month
Risk Analysis	Criteria 7	(c7)	Benefit	44	X_{17}	34	X_{27}	51	X_{37}	unit

Data Analysis Criteria using TOPSIS

Calculations and formulations of the data that have been collected at the data processing stage/intelligence phase using TOPSIS calculations according to the stages as shown in the following figure:

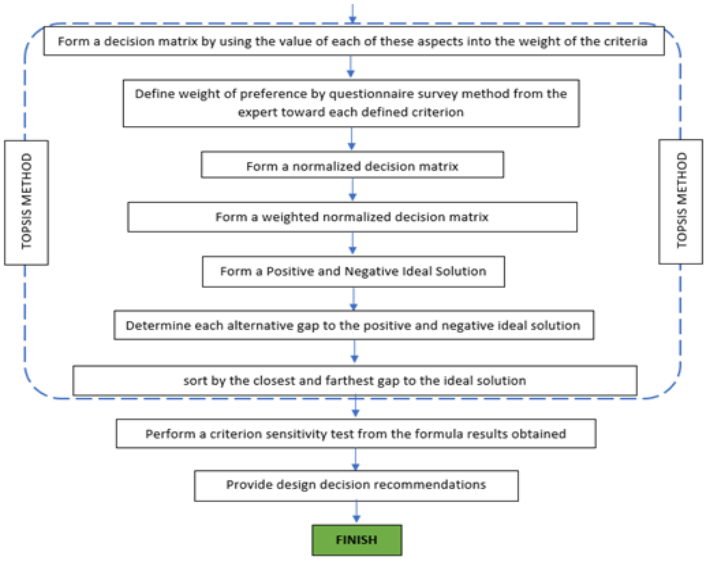


Figure 6. Design Process with TOPSIS

Decision Matrix Formation

The decision matrix obtained from the results of the recap of the criteria can be seen as follows:

Table 6. Decision Matrix

No	Alternative	Cost/Technical Criteria					Time Duration Criteria	Risk Criteria
		c1	c2	c3	c4	c5	c6	c7
1	SUTT (OHL)	29,80	30	100	24.80	183.600.392.324	32	44
2	SKTT (UGC)	25,70	60	47,30	9.180	351.249.274.496	34	34
3	SKLTT (MARINE)	21	10	8,88	500	705.549.192.081	28	51

Note:
c1 = Path Length
c2 = Soil Investigation Data
c3 = Domestic Material Portion
c4 = Free Land Requirement
c5 = Estimated Cost of Work
c6 = Estimated Work Time Duration
c7 = Risk & environmental analysis

Determination of Preference Weight

Accordingg to Figure 6 above,parameters ares needed to determine the validity of the preference weights for each attribute. In connection with this, a questionnaire survey was conducted to experts both from the UIP Maluku Papua side and to a team of experts from PLN Engineering. The survey data carried out is by using an online google form that requires an opinion related to attributes that will be assessed based on a significant scale of importance and need from 1 to 5. The results of the survey data obtained can be seen in Figure 7 below.

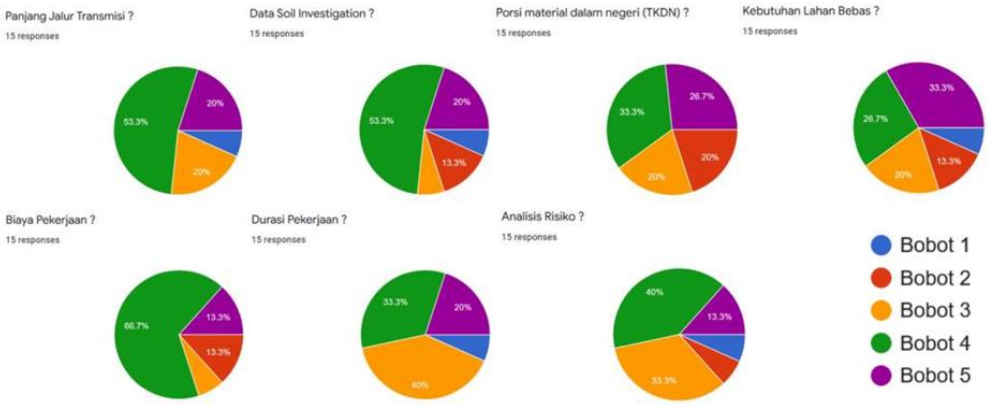


Figure 7. Results of the Preference Weight Questionnaire Survey

Decision Ideal Solution

From the decision matrix that has been obtained in Table 6 above, by following the steps that have been determined in accordance with Figure 6 and using the results of the preference weight survey in accordance with Figure 7 above, we get an ideal solution that is close to what is seen in Table 7 below:

Table 7. Solution Value of Each Alternative

No	Value	Alternatives
v1	0,612304	SUTT (OHL)
v2	0,399136	SKTT (UGC)
v3	0,601292	SKLTT (Marine)

From the results, the value of the ideal solution with the greatest preference is v1 which is the SUTT alternative. So, with this calculation, the SUTT results can be recommended as an alternative to the chosen decision.

Sensitivity Analysis

After obtaining alternative results that will be recommended according to the results obtained in Table 7 above, then an iteration is carried out using the equation in the TOPSIS calculation against the value obtained from each criterion to test the sensitivity level of the alternative solution along with the calculated criteria as follows:

a. Iterating the preference weight value is changing the value of the preference weight obtained by adding and subtracting its value. In this case, the author examines each preference weight value (one by one) which is then found that there will be a change in the decision if one of the preference weight variables has a certain value. This can be seen in the following image.

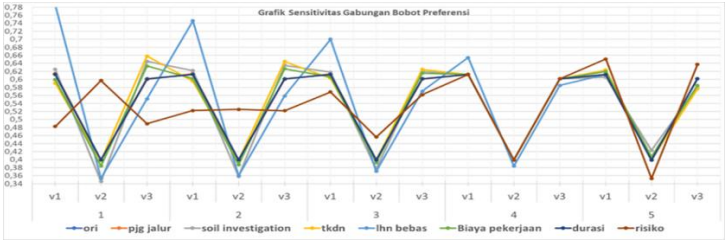


Figure 8. Sensitivity Analysis of Weight Preference

b. Iterating the value of the results of each criterion is how to change the value by adding and subtracting its value iteratively until it produces a change in alternative solutions, and then recording the value of each criterion will cause these changes. In this case, changes are made to each criterion (one meeting) until finding the value of a criterion will result in a change in the value of the decision solution. From the results of this iteration, the results are obtained as we can see in the following figure:

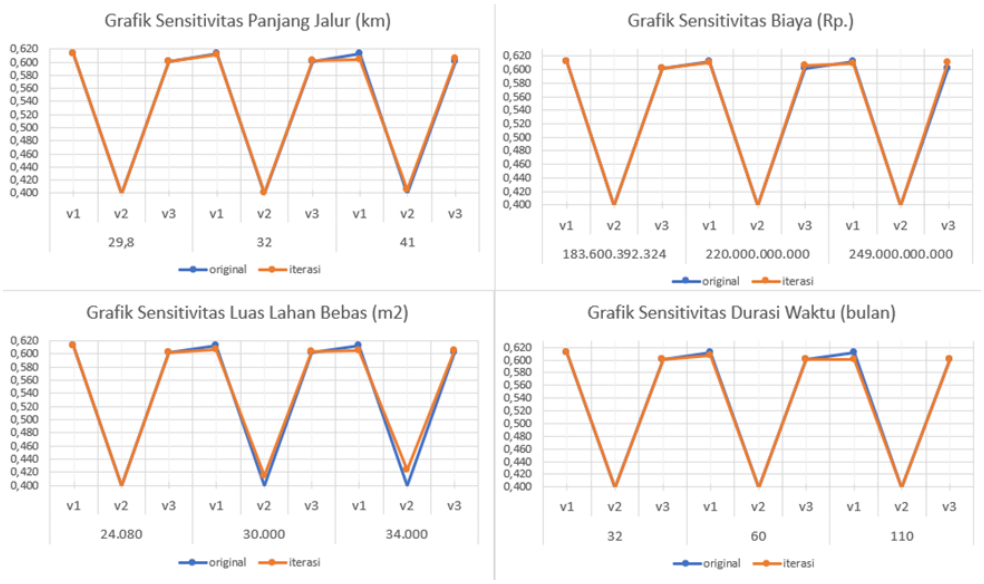


Figure 9. Sensitivity Value Analysis of Criteria

c. From the sensitivity analysis shown in the two tables above, interpretations of several sensitivity limits can be obtained as follows:
   1. For the brown line graph (risk attribute), where if the preference weight value is at a value of 1, then the ideal solution will change so that the value of v2 (SKTT) shows a higher value and becomes the recommended solution, but if it is at a preference weight of 2 to 5 still shows the value of v1 (SUTT) as the maximum value.
   2. For the grey graph line (soil investigation attribute), the yellow graph line (TKDN attribute), and the green graph line (work cost attribute), these attributes tend to produce the ideal solution value v3 (SKLTT) which is higher if the preference weights are in the value 1 to 3, while the preference weight values 4 and 5 remain in the initial solution, namely v1 (SUTT).
   3. The light blue graph line (Land acquisition), light brown graph line (Length of Distance attribute), and dark blue graph line (duration) tend to have the same solution in each preference weight value (1 to 5), which results in a v1 solution (SUTT) as the maximum value.
   4. Changes in the value of the Line Length of Distance criterion from 29.8 km to 41 km will cause a change in the decision recommendation to SKLTT (Stay with the SUTT decision when the maximum line length is 40 km).
   5. Changes in the value of the Estimated Cost of Work criteria from 183 M to 249 M will cause a change in the decision recommendation to SKLT (Stay with the SUTT decision until the price is < 249 M).
   6. Changes in the value of the Land Acquisition Requirement for criteria from 24,080 M2 to 34,000 M2 will cause a change in the decision recommendation to SKLTT. (Stay with the SUTT decision until the land is free < 34,000 M2).
   7. Changes in the value on the Duration of Work criteria from 32 Months to 110 months will cause a change in the decision recommendation to SKLTT (Stay with the SUTT decision if the duration is < 110 months).

Recommendations Decisions and Implementation plans

The SUTT alternative recommendation is a near solution to optimum based on analysis that has been carried out using a mathematical approach with the TOPSIS method with sensitivity limitations that need to be considered further. Furthermore, this recommendation can be submitted to the GM UIP MPA as Leader of UIP Maluku Papua for consideration from the academic side. As the results of this study are deemed appropriate, this can be considered for submission to knowledge capturing in PLN.

5. Conclusion

Based on the results of research conducted with the TOPSIS method, it can be concluded as follows. Decision-making with the TOPSIS method approach can be used to find solution recommendations and empirical decisions so that the basis for decision-making can be achieved by valid calculations and tested mathematically. From the results of research and calculations that have been carried out, it was found that the alternative SUTT 150 kV ACSR/AS, 1 x Hawk, 2 Circuit along 29.8 km is the closest solution to optimum recommendation as an alternative solution chosen for the Holtekam - Angkasa transmission plan. The sensitivity analysis found that the preference weight value greatly affects the results of the TOPSIS that has been carried out, where the dominant change that is most likely to occur in the iteration is the change in the decision solution to an alternative to SKLTT rather than SKTT. From the calculations and iterations carried out under these conditions, the chosen alternative solution is SUTT (OHL) transmission, which will still be a recommended decision solution if it is still within the sensitivity limits at the following values. (1) Line Length of Distance < 41 km; (2) Work Cost < 249 M; (3) Land Acquisition Requirement < 34,000 m2; and (4) Duration of Work < 110 Months.

Next, there are a few suggestions for the development of this research in the future are as follows:

1. Specifically, for SKLTT, a more detailed calculation is needed for the design to be applied, including bathymetry and sea tide data analysis to estimates related to the laydown cable design can be more accurate because this has an impact on the estimated value of the work costs incurred so that the accuracy of calculations related to cost estimates can be achieved.
2. Considering the type of attribute and the weight of preference factor on the criteria greatly determines the results of the decision recommendations. Then if needed for further development and analysis, this can be developed in the next comprehensive research.
3. Considering the magnitude of the potential design changes in SUTT, it is also necessary to consider calculations and estimates based on the deviation of the actual work that has been carried out according to experiences such as time duration, path length, and work costs against the sensitivity limits that have been obtained in the calculations.

Acknowledgments: This is a self-funding research. An appreciation is given to the reviewers of the TIJOSSW publisher who have spent more time making valuable corrections dealing with technical writing styles or ideas about this writing.

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