Eduvest – Journal of Universal Studies
Volume 6 Number 1, January, 2026
p- ISSN 2775-3735- e-ISSN 2775-3727

Techno Economic Analysis of Relay Connectivity Using Satellites with Geo Infrastructure to Reach Telecommunications Blank Spot Areas

Andika Budi Wicaksono, Miftadi Sudjai, Rina Pudji Astuti
TelkomUniversity, Indonesia
Email: andhikab@student.telkomuniversity.ac.id, miftadi@telkomuniversity.ac.id, rinapudjiastuti@telkomuniversity.ac.id

ABSTRACT

The main problem in the telecommunications sector in Indonesia is the difficulty of developing wireless and cable network infrastructure, so that it cannot reach all regions. The purpose of this study is to determine the efficiency of capex and opex related to the use of GEO satellites to integrate BTS HUBs on Sapudi Island in terms of link budget and techno-economic analysis. The research employs a comprehensive technical and economic assessment framework. Technical feasibility is evaluated through link budget analysis, which is based on the availability of a Base Station Controller (BSC) at the transmitting ground station in Surabaya and on the availability of the receiver VSAT—namely, a BTS located on Sapudi Island—both of which are connected to the GEO Nusantara Satu satellite. Potential revenue in this study is the income value obtained from USO funds (operator involvement). The results of the study show that, technically, the application of GEO satellites on Sapudi Island yields a low Carrier-to-Noise (C/N) value of 13.90 dB, making it feasible to implement. Economically, the implementation has a positive NPV, an IRR of 11% (which exceeds the benchmark interest rate of 6%), and a Net Benefit-Cost Ratio (Net B/C) of 2.301. Thus, this business is feasible because it offers a high level of return.

KEYWORDS *GEO, Link Budget, Techno Economic*

INTRODUCTION

Indonesia is the largest archipelagic country in the world consisting of 13,466 islands with the 4th largest population in the world which is 237,556,363 people (Badan Pusat Statistik, 2011). With the large number of islands and population, there is a big problem in Indonesia, namely the telecommunication problem.

The main problem in the telecommunications sector in Indonesia is the difficulty of developing wireless and cable network infrastructure so that it cannot reach all regions (Oktarini & Kawano, 2019; Rohman, Naufal, & Naufal, 2025; Situmorang, Suryanegara, Gunawan, & Juwono, 2023). This can be seen in the Palapa Ring optical network as follows:

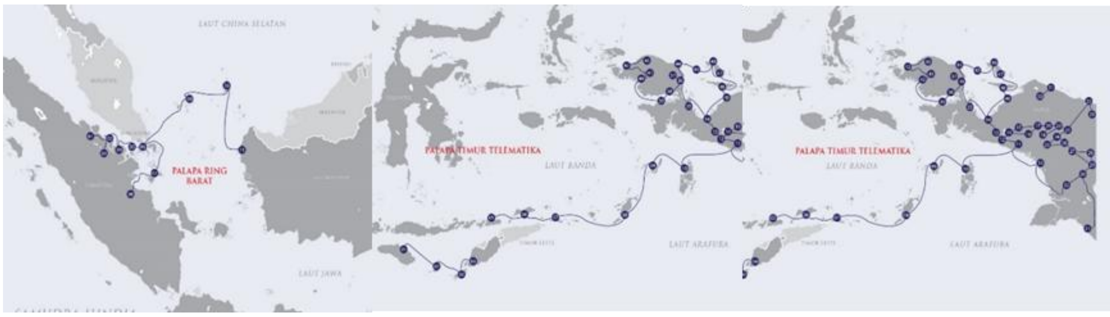

Figure 1. Palapa Ring Optic Network

As seen in figure 1, the Palapa Ring optical network has not been able to reach the archipelago area spread across Indonesia, especially including areas that are not reached by signals (Blank Spot), even though some islands have the potential for telecommunication business development (Sutrisno & Nugroho, 2019; Pratama et al., 2020). Despite significant government investment in the Palapa Ring project, numerous islands remain disconnected from the national telecommunications backbone (Kementerian Kominfo, 2021; World Bank, 2022). These blank spot areas not only suffer from lack of basic communication services but also face barriers to economic development, education access, and emergency response capabilities (Aker & Mbiti, 2018; Qiang et al., 2019; Suryahadi et al., 2020).

The challenges of infrastructure development in Indonesia's archipelagic context are multifaceted. According to Albandjar and Rasyid (2005), the reasons for the difficulty in developing wireless and cable network infrastructure are: (1) The large number of Indonesian islands requires large investment costs to build a network that connects the islands, and (2) Uneven distribution of population. There is a very striking difference between the population density in cities and villages, Java Island and other islands, as well as western and eastern parts of Indonesia.

Internationally, similar challenges have been addressed through various satellite-based solutions. González Fanfalone et al. (2017) demonstrate the evolving role of satellite networks in providing broadband access to rural and remote regions globally, highlighting that satellites offer unique advantages in terms of rapid deployment, wide coverage, and independence from terrestrial infrastructure. Research on High Throughput Satellites (HTS) shows significant improvements in capacity and cost-effectiveness for remote area connectivity (Fenech et al., 2013). Case studies from Canada, Australia, and other archipelagic nations demonstrate that GEO satellites can provide cost-effective solutions where fiber optic deployment is prohibitive.

In the Indonesian context, existing solutions have proven insufficient. While Low Earth Orbit (LEO) satellite constellations offer low latency, they require complex tracking systems and multiple satellite handovers. Medium Earth Orbit (MEO) systems present intermediate solutions but face similar complexity challenges. Terrestrial solutions such as underwater fiber optic cables, though providing high bandwidth, require substantial capital investment and extensive maintenance, particularly vulnerable to seismic activity common in Indonesia's location along the Pacific Ring of Fire. Microwave and troposcatter systems offer limited range and are susceptible to atmospheric conditions in tropical climates. These limitations underscore the need for alternative approaches specifically tailored to Indonesia's unique challenges.

There is a solution for Indonesia to be able to connect to the telecommunication network, namely by using GEO satellites. GEO Satellite is a satellite that is in GSO orbit located in the orbit of the equator or equator which is 36,000 km above the earth's surface. And the most commonly used to receive signals from GEO satellites is the VSAT, also known as the micro earth station (International Telecommunications Union, 1994). The main function of the VSAT is to receive and send data to the satellite. Satellites serve as access networks to be transmitted to other points on earth. The VSAT disk faces a geostationary satellite (Pahlevy, 2018). A geostationary satellite is a satellite that is always in the same place in line with the rotation of the earth on its axis which is possible because it orbits at the same point above the earth's surface, and follows the rotation of the earth. A geostationary satellite can cover an area of 40%

of the Earth's surface, 2 interconnected satellites can cover more than half of the Earth's surface and 3 satellites can cover the entire Earth's surface (Pahlevy, 2018).

It is hoped that VSAT can be a cheap and efficient telecommunications connector compared to having to build terrestrial infrastructure such as fiber optic and sea cables which can be said to be a lot of money. However, an analysis is needed to minimize the design and implementation costs. Economic Technical Analysis itself is a theoretical analysis method to combine the analysis of the implementation aspects of a technology with its economic value so that it becomes more efficient. In this case, Economic Technical Analysis can be used as a reference material for selecting the right technology in terms of technology and economics in building a VSAT satellite network design.

This study addresses a critical gap in the literature by providing a comprehensive techno-economic analysis specifically tailored to Indonesia's unique geographical and regulatory environment. While previous research has examined satellite communications in isolated contexts, few studies integrate technical link budgeting with detailed capital budgeting analysis in the Indonesian archipelagic setting. Furthermore, this research incorporates regulatory considerations specific to Indonesia's telecommunications framework, including spectrum management and Universal Service Obligation (USO) funding mechanisms, which are essential for practical implementation.

Based on the explanation of the description above, it can be formulated that the problem that will be answered in this study is how to analyze technically, economically and regulatory connection technology using GEO satellites? The purpose of this study is to determine the efficiency of capex and opex related to the use of GEO satellites to integrate between BTS HUB on Sapudi Island in terms of link analysis, budget, techno economy and regulations. With the construction of a massive blank spot area. By taking into account the rental price that will be offered to cellular operators with the condition of the Indonesian archipelago consisting of more than 17,000 islands where it is not possible or very difficult to build terrestrial transmission.

METHOD

In this study, the system model used refers to the topology of the telecommunication network with the adaptation of the use of GEO satellites simulated on Sapudi Island. The network topology involves the Base Station Controller (BSC) located at the transmitting ground station in the city of Surabaya, the Base Transceiver Station (BTS) on Sapudi Island, and the Nusantara Satu Satellite, which is Indonesia's first high-capacity geostationary communication satellite. This satellite has wide coverage in the Southeast Asia region for the C-band and the rest of Indonesia for the Ku-band. The specifications of this GEO satellite include an EIRP of 59 dBw, a number of transponders of 52, and a distance from Earth of 36,000 Km. In addition, this research also involves the analysis of network infrastructure consisting of base stations, BTS equipment, and core network components that combine terrestrial and satellite networks. This combination is expected to increase coverage, reliability, and flexibility in providing telecommunication services in blank spot areas. The study also includes a scenario model that focuses on data collection in blank spot areas, such as in the east of Java, taking into account various parameters to produce business projections related to operator revenue. Technical analysis is carried out through a budget link to predict the performance of the communication network, while economic analysis includes an evaluation of Capital Expenditure (Capex) and Operating Expenditure (Opex) to determine the feasibility of the project. Data collection is carried out through observation and documentation methods and involves primary and secondary data to support the analysis carried out. This type of research is applied research that aims to provide practical solutions in the development of telecommunication infrastructure in remote areas.

RESULT AND DISCUSSION

The Link Budgeting analysis is based on the availability of Base Station Controller (BSC) at the transmitting ground station in the city of Surabaya and on the availability of the receiver VSAT, namely BTS located on Sapudi island, both of which are connected to the GEO Nusantara Satu satellite. Techno economic analysis is carried out by adopting Capital Budgeting analysis. The elements that make up Capital Budgeting include Capex consisting of RAN, MW, Power, VSAT and Tower in VSAT and FO. Opex consists of maintenance, NOC, Monthly Lease, Annual ISR and Drive Test as well as VSAT and FO. Potential Revenue in this study is the value of income obtained from USO funds (operator involvement). Model simulations, both budget and techno economic link, were validated by consulting the model with academic collaborators, namely supervisors.

Technical Analysis of Link Budgeting

Before conducting Link Budgeting analysis, the parameters that compose the standard value of the Geo satellite are determined to be used to calculate the Link Budget of the satellite. Here are the specifications of the GEO satellite:

Table 1 GEO Satellite Parameters

Parameter	GEO (ex: Nusantara Satu)
EIRP	59 dBw
SFD	105 dBw/Hz
G/T	11.8 dB
PAD	10 dB
IBO (Input Back Off)	3 dB
OBOE	2.5 dB
Number of Transponders	52
Distance from Earth	36.000 Km

Source: Nusantara Satu Satellite Parameters

Up-Link Analytics

The Uplink analysis is based on the availability of Base Station Controller (BSC) at the transmitting ground station in the city of Surabaya. The specifications include:

Table 2. BSC Parameters

Parameter	Specifications
Frequency	5925 Mhz
Diameter Antenna	3.8 meters
Redaman Hujan	0,17 dB
Temperature system	700 K
Antenna Efficiency	60%

The specifications of Up-Link Analysis in BSC include the number of carrier waves, IBO/carrier waves, Satellite Density Flux, EIRP and up-link gain, Power HPA, Free Space Loss (FSL) and C/N. The calculation of Up Link analysis is as follows:

1) Carrier Wave

Number of Carrier Waves = 36 pieces

$$\sum = 10\ Log\ \sum transponder \text{ ...... (2.1)}$$
$$\sum = 10\ Log\ 52$$
$$\sum = 17{,}16\ dW$$

2) IBO/carrier wave

$$IBO = IBO\ parameter - \sum \text{..... (2.2)}$$
$$IBO = -3 - 17{,}16$$
$$IBO = 20{,}16\ dB$$

3) Satellite Density Flux

$$FD = SFD - IBO \text{..... (2.3)}$$
$$FD = -105 - 20{,}16$$
$$FD = -125{,}16\ dBw/m2$$

4) EIRP

$$FD = EIRP - 10Log(4\pi R^2) \text{.... (2.4)}$$
$$FD = EIRP - 10Log(4\pi(3600000^2))$$
$$-125{,}16 = EIRP - 10Log(4\pi(3600000^2))$$
$$EIRP = 16{,}96\ dBW$$

5) Gain up-link

$$Gain\ Uplink = 20{,}4 - 20LogD + 20LogF + 10Log\mu \text{..... (2.5)}$$
$$Gain\ Uplink = 20{,}4 - 20Log3{,}8 + 20Log5{,}945 + 10Log0{,}6$$
$$Gain\ Uplink = 19{,}85\ dB$$

6) Power HPA required

$$P = EIRP - Gain\ UpLink + Loss \text{..... (2.6)}$$
$$P = 16{,}96 - 19{,}85 + (0{,}02 + 0{,}17)$$
$$P = -3{,}08$$
$$Power\ HPA = 10^{P} \text{...... (2.7)}$$
$$Power\ HPA = 10^{-0{,}308}$$
$$Power\ HPA = 0{,}49\ watt$$

7) Free Space Loss (FSL)

$$FSL = 32{,}44 + 20LogD + 20LogF \text{.... (2.8)}$$
$$FSL = 32{,}44 + 20Log36000 + 20Log5945$$
$$FSL = 199{,}05\ dB$$

8) Carrier To Noise (C/N)

$$\frac{C}{N} = EIRP - FSL + \frac{G}{T} - L + 228 \text{ .... (2.9)}$$
$$C/N = 16{,}96 - 199{,}05 - 2 - (0{,}02 + 0{,}17) + 228$$
$$C/N = 33{,}92dB$$

Downlink Analysis

The Uplink analysis is based on the availability of the recipient VSAT, namely BTS located on Sapudi island. The specifications include:

Table 3. Receiver VSAT Parameters

Parameter	Specifications
Frequency	3720 Mhz
Diameter Antenna	3.8 meters
Redaman Hujan	0,17 dB
Temperature system	700 K
Antenna Efficiency	60%

Downlink analysis includes EIRP, IBO/carrier wave, EIRP per carrier wave, down-link gain, Free Space Loss (FSL) and C/N. Downlink analysis calculation is as follows:

1) EIRP
The satellite EIRP is known to have a value of 59 dBw
OBO (Output Back Off)
$$OBO = OBO\ parameter - \textstyle\sum .... (2.10)$$
$$IBO = -2{,}5 - 17{,}16$$
$$OBO = -19{,}66\ dB$$
2) Flux Density
$$FD = SFD - OBO ..... (2.3)$$
$$FD = -105 - 19{,}66$$
$$FD = -124{,}66\ dBw/m2$$
3) EIRP
$$FD = EIRP - 10Log(4\pi R^2) .... (2.4)$$
$$FD = EIRP - 10Log(4\pi(3600000^2))$$
$$-124{,}66 = EIRP - 10Log(4\pi(3600000^2))$$
$$EIRP = 17{,}46\ dBW$$
4) Gain down-link
$$Gain\ Downlink = 20{,}4 - 20LogD + 20LogF + 10Log\mu .... (2.12)$$
$$Gain\ Downlink = 20{,}4 - 20Log3{,}8 + 20Log3{,}720 + 10Log0{,}6$$
$$Gain\ Downlink = 41{,}19\ dB$$
5) G/T at receiver
$$G/T = Gr - 10LogTs(dB/K) .... (2.13)$$
$$G/T = 41{,}19 - 10\ log\ 70$$
$$G/T = 22{,}74\ dB$$
6) Free Space Loss (FSL)
$$FSL = 32{,}44 + 20LogD + 20LogF .... (2.14)$$
$$SL = 32{,}44 + 20Log36000 + 20Log3720$$
$$FSL = 194{,}98\ dB$$
7) Carrier To Noise (C/N)
$$C/N = EIRP - FSL + G/T - L - 228 .... (2.15)$$
$$C/N = 17{,}46 - 194{,}98 + 22{,}74 - (0{,}02 + 0{,}5) + 228{,}6$$
$$C/N = 27{,}82\ dB$$

Total Budgeting Link System Analysis

The total system analysis is the Carrier To Noise (C/N) comparison value of the C/N uplink and downlink analysis values. The value of the total C/N is the sum of the up-link C/N and the down-link C/N. Carrier To Noise Ratio Total (C/N) Total is a parameter that represents the quality of carrier power received by the end device in satellite communications (receiving ground stations). The calculation of Total C/N is as follows:

$$\frac{1}{C/N} = \frac{1}{(C/N)up} + \frac{1}{(C/N)down} \text{.... (2.16)}$$

$$\frac{1}{C/N} = \frac{1}{33{,}92} + \frac{1}{27{,}82}$$

$$= 6{,}572.\,10^{-7}$$

$$(C/N)0 = 10Log\ \frac{1}{C/N} \text{.... (2.17)}$$

$$= 10log6{,}572.\,10^{-7}$$

$$= 11{,}82\ dB$$

Azimuth and Elevation Angle Analysis

The angle of elevation is the angle formed by the satellite with a tangent angle at a certain point on the earth. In this study, an elevation angle comparison was used by comparing the elevation angle formed between the Nusantara Satu satellite and the Base Transceiver Station (BTS) located on Sapudi Island, Raas Island and Giligenting. The initial stage is to determine the coordinate points of the three locations with the help of Google Maps. After mapping, it was found that the coordinates of the three islands were as follows:

Table 4 Coordinates of Sapudi Island, Raas Giligenting Island and Nusantara Satu Satellite

Location	Longitude	Longitude Position	Latitude	Latitude Position
Sapudi Island	114,33	BT	7,12	LS
Raas Island	114,57	BT	7,14	LS
Gili Genting	113,91	BT	7,19	LS
Nusantara Satu	146		BT	

Source: Data Processed by Researchers, 2024

After the coordinate mapping is carried out as in table 4.4, the next stage is to determine the Azimuth and Elevation. In this study, the AZ/EL Calculator from Satlex Digital English was used as a calculation tool with location coordinate input. The input process carried out is as follows:

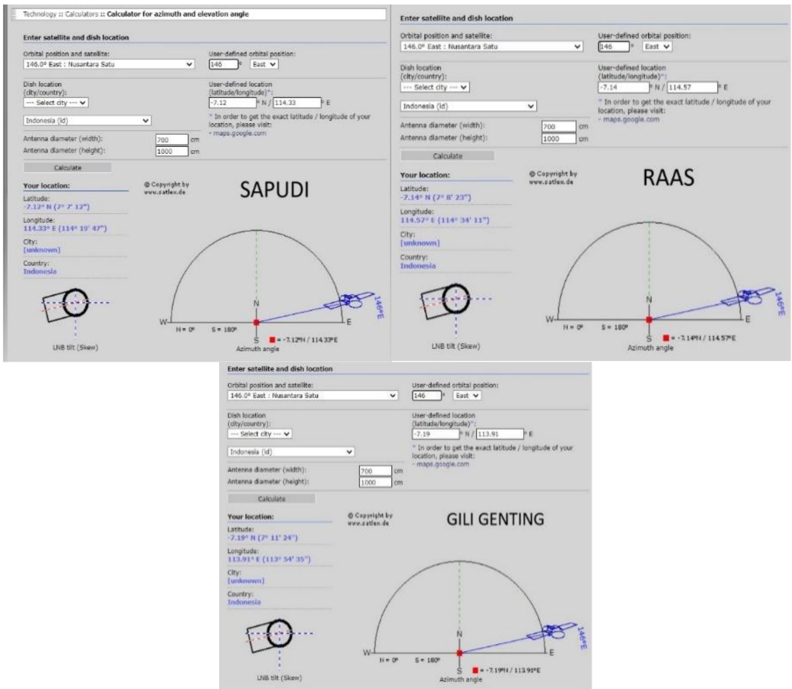

Figure 2. Input Coordinate AZ/EL Calculator
Source: Satlex Digital English, 2024

After the input process is carried out, the AZ/EL Calculator will determine the elevation angle and azimuth. The results of the elevation and azimuth calculations of Sapudi Island, Raas Island and Giligenting are as follows:

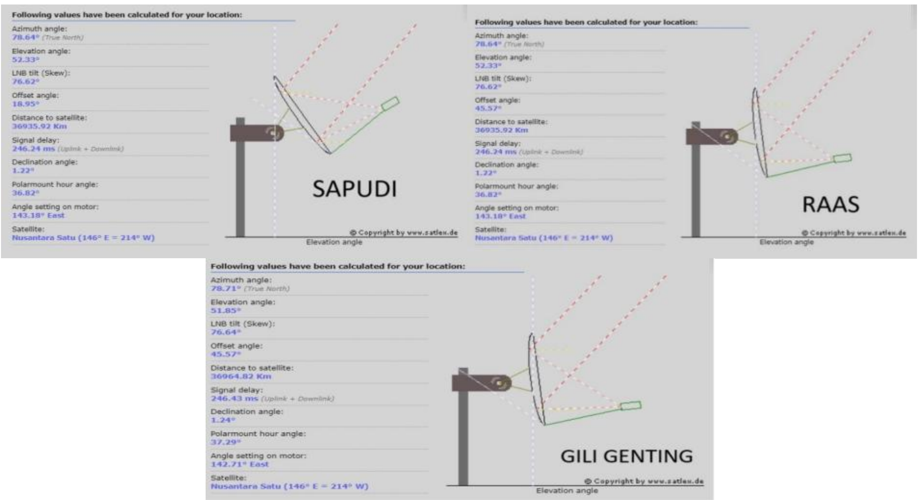

Figure 3. Elevation and Azimuth of Sapudi Island, Raas and Giligenting Island
Source: Satlex Digital English, 2024

Based on the calculation results, it was found that the elevation and azimuth of Sapudi Island and Raas Island have the same value, namely an azimuth angle of 78.64 degrees with an elevation angle of 52.33 degrees. This is due to the position of the two adjacent islands. On the other hand, Giligenting Island has an azimuth angle of 78.71 degrees with an elevation angle of 51.85 degrees.

Comparison of Budgeting Links for Sapudi Island, Raas Island and Giligenting

To produce technical considerations in the analysis of link budgeting, it is necessary to compare the results of the link budgeting analysis between Sapudi Island, Raas Island and Giligenting. The results of the comparative analysis of the budgeting link between Sapudi Island, Raas Island and Giligenting are as follows:

Table 5 Comparison of GEO Satellite Budget Analysis Results

Parameter	Unit		Result
	Uplink		
Carrier Wave	dW		17,16
IBO	db		-20,16
Fluks Density	dBW/m2		-125,16
EIRP	dBW		16,96
Gain Uplink	dB		19,85
HPA	Watt		0,49
FSL	dB		199,05
C/N	dB		33,92
	Downlink		
EIRP	dBW		59,00
OBO	dB		-19,66
Density Flux	dBW/m2		-124,66
EIRP	dBW		17,46
Gain down-link	dB		41,19
G/T	dB		22,74
FSL	dB		194,98
C/N	dB		27,82
	Total		
(C/N)o	dB		11,82
Parameter	**Location**		
	Sapudi Island	**Raas Island**	**Giligenting**
Longitude	114,33 BT	114,57 BT	113,91 BT
Latitude	7,12 LS	7,14 LS	7,19 LS
Azimut (True North)	78.64th	78.64th	78,71st
Elevasi	52,33rd	52,33rd	51.85th

Source: Data Processed by Researchers, 2024

When analyzing satellite connections, a number of considerations will be required. Of all that, the use of C-Band frequency bands is very necessary. This paper provides a detailed description of link budgeting and the various loss processes associated with C-Band frequency band usage propagation path statistics. Using a case study of GEO (Nusantara Satu) satellite applications, various propagation effects were analyzed and signal strength on the islands of Sapudi, Raas, and Giligenting was calculated using the latest climatic factors. The link budget summarizes the key elements required to establish a reliable satellite link with the use of the C-Band frequency band. The integration and growth of communication services in blank spot areas is supported by this study. In addition, the study can help satellite system developers to evaluate the performance of C-Band frequency band signal quality with error rates in various weather scenarios and accurately predict atmospheric disturbances that may affect channels. Radio technicians will also find this article useful for predicting link margins.

Economic Analysis of Capital Budgeting

After conducting a technical analysis, it was found that the communication system model scenario with the GEO Nusantara Satu satellite adapts the use of the C-Band frequency band. Therefore, the Capex and Opex analysis in this study was prepared on the basis of the use of instrument specifications related to the C-Band frequency band.

GEO Satellite Capex Analysis

In conducting capital budgeting, the first thing to do is to determine the total cost needed for the implementation of satellites with radio access networks from the Capex side. Capex is the budget to buy/replace/repair everything necessary. This economic analysis uses assumptions from Nusantara Satu Capex. The Capex analysis for the application of GEO satellites with radio access networks on Sapudi Island is divided into two segments, namely FO and VSAT, which are shown in the following table:

Table 6 GEO Satellite Application Capex

Segmen	Capex Element	Cost (IDR)
BSC Surabaya	RAN BSC	1.325.150.215
	VSAT C-Band frequency	275.913.629
	Power	125.913.629
BTS Sapudi	RAN BTS	1.325.150.215
	VSAT C-Band frequency	275.913.629
	Power	90.913.629
	Tower	1.125.150.215
	Total Capex	4.544.105.160

Source: Data from PT. TBIG, 2023

The capex needed in the implementation of GEO satellites on Sapudi Island costs up to 4.5 billion rupiah. The fees include RAN, VSAT C-Band frequency and Power for the BSC Surabaya segment. The BTS Sapudi segment includes RAN, C-Band frequency VSAT, Power, and Tower.

GEO Satellite Opex Analysis

Opex (Operating expenditure) is an allocation planned in the budget to carry out the company's operations normally. In other words, operating expenditure (operating costs) is used to maintain the continuity of assets and ensure that the planned company's activities run well. This economic analysis uses assumptions from the Palapa Ring Capex. Similar to Capex, Opex analysis for the application of GEO satellites with radio access networks on Sapudi Island is divided into two segments, namely FO and VSAT which are displayed in the following table:

Table 7. GEO Satellite Application Opex

Segmen	Opex Element	Cost in 1 Year (IDR)
VSAT	Site Visit for maintenance	8.400.000,00
	NOC =10 people	6.000.000,00
	Monthly Lease satellite	34.287.730,62
	Annual ISR for Terestrial	36.887,62
	Annual Drive Test	5.000.000,00
FO	Site Visit for maintenance	8.400.000,00
	NOC =10 people	6.000.000,00
	Monthly Lease satellite	2.285.848,67
	Annual ISR for Terestrial	36.887,62

Annual Drive Test	5.000.000,00
Total Opex per Year	183.447.353,94

Source: Data from PT. TBIG, 2023

The opex needed in the implementation of the GEO satellite on Sapudi Island costs 183,447,353.94 rupiah.

Revenue Capital Budgeting of GEO Satellite on Sapudi Island

Potential Revenue in this study is the value of income obtained from USO funds (operator involvement). The Potential Revenue value of the USO fund (operator involvement) is as follows:

Tabel 8. Potential Revenue Satelit GEO

Revenue	
Number of Operator Slots in the Tower	4
Active Period	10 Years
Rental Cost per Month	IDR 20,000,000
Total Revenue per Year	IDR 960,000,000

Source: Data from PT. TBIG, 2023

Based on the table, it can be seen that if GEO satellites are applied, the potential for total revenue obtained is around 960 million per year. However, to determine the feasibility of investment from the application of GEO satellites, it is necessary to calculate the Net Present Value (NPV) and Internal Rate of Return (IRR) value of this.

Present Value Capital Budgeting of GEO Satellite on Sapudi Island

Present Value is a value that indicates how much the current value of a certain amount of money will be received in the future. The calculation of the PV value pays attention to the amount of interest rate applied. In this study, an investment interest rate of 6% was used, which is the average interest rate of Bank Indonesia in 2023. The results of the calculation of the Present Value of the implementation of GEO Satellites on Sapudi Island are as follows:

Table 9. Present Value of GEO Satellites on Sapudi Island

Year	***Present Value (IDR)***
1	IDR 732,596,835.9
2	IDR 691,129,090.5
3	IDR 652,008,575.9
4	IDR 615,102,430.1
5	IDR 580,285,311.4
6	IDR 547,438,973
7	IDR 516,451,861.4
8	Rp. 487,218,737.1
9	IDR 459,640,318.1
10	IDR 433,622,941.6

Source: Data Processed by Researchers, 2024

The Present Value is obtained by dividing the year's Cash Flow by the square of the investment interest rate plus one. Based on the table, it can be seen that the Present Value obtained by the implementation of the GEO Satellite on Sapudi Island is decreasing, this is due to the assumption of the research that conditions the revenue received to always be constant Rp. 776,552,646.06 for 10 years.

1. NPV, IRR and Net B/C Capital Budgeting of GEO Satellites

The calculation of the financial feasibility of this business was obtained from the data from the Capital Budgeting calculation. In this study, an investment interest rate of 6% was used, which is the average interest rate of Bank Indonesia in 2023. The results of the calculation of investment eligibility criteria which include NPV, IRR, and Net B/C Ratio. The Cash Flow value obtained is then discounted with an investment interest rate of 20% to obtain the Net Present Value (NPV). The IRR (Internal Rate of Return) value is obtained to find an interest rate that equals the present value of the expected future cash flow or cash receipts, by taking out the initial investment. Meanwhile, the Net B/C Ratio is carried out by comparing the benefits or receipts of a business with the costs incurred to realize the plan to establish and operate the business. The Financial Feasibility Analysis of the implementation of the GEO Satellite on Sapudi Island is presented in the following table:

Table 10. Financial Feasibility Analysis of the Implementation of GEO Satellites on Sapudi Island

Analysis Tools	Analysis Results	Information
***Net Present Value* (NPV)**	IDR 1,171,389,915.28	Proper
***Internal Rate of Return* (IRR)**	11%	Proper
***Net Benefit Cost Ratio* (Net B/C)**	2,301	Proper

Source: Data Processed by Researchers, 2023

Based on the results of the financial feasibility analysis in the table, it is stated that this business has an NPV of IDR 1,171,389,915.28 which means that this business will provide a profit of IDR 1,171,389,915.28 for 10 years according to the current money time value. The IRR value is 11% which means it is larger than the benchmark interest rate (6%). So this business is feasible because it can obtain a high level of return.

The Net B/C Ratio value is 2,301 which means that every Rp 1,- cost incurred, will provide a profit of Rp 1,422. Based on the feasibility criteria in the Table, where the NPV is positive, the Net B/C is greater than one, and the IRR is greater than the applicable interest rate (6%), then in terms of investment feasibility, the implementation of the GEO Satellite on Sapudi Island is worth pursuing.

The positive value in the calculation of Net Present Value (NPV) from the implementation of the GEO Satellite on Sapudi Island shows the benefit of the investment given in the simulation capital. Kasmir and Jakfar (2012) stated that a positive NPV value (NPV > 0) indicates that the revenue is greater compared to the value invested while a negative NPV value (NPV < 0) indicates that the income is smaller compared to the expenditure or will suffer losses on the investment after considering the Time Value of Money. However, if the NPV calculation result is Zero (NPV = 0), then it means that the investment or purchase is only a break-even (no profit and no loss). And of course, the greater the positive number, the greater the reception it can get. Therefore, this NPV calculation is not only used to evaluate whether or not it is feasible to invest, but also used to compare which investments are better if there are two or more investment options.

The results of the study showed that the value of the Internal Rate of Return (IRR) in the capital budgeting analysis of the implementation of the GEO Satellite on Sapudi Island was 11%. This value is greater than the benchmark interest rate value of 6%. According to Umar (2009) Internal Rate of Return is a method used to find an interest rate that equals the present value of the expected cash flow in the future or cash receipts, by issuing initial investments. This formula uses the rule If the IRR > interest rate, then the project proposal is accepted. Based on this, the results of the calculations obtained indicate that the implementation of the GEO Satellite on Sapudi Island is feasible.

The results of the study show that the Net Benefit Cost Ratio (Net B/C) value in the business performance analysis of the application of GEO satellites on Sapudi Island is 2,301. According to Gittinger in Mowarin (2019) the Benefit/Cost Ratio is the ratio of cost and benefit comparison. With this opinion, it can be concluded that the benefits obtained by the application of GEO satellites on Sapudi Island exceed the costs that have been incurred. So that the Net B/C Ratio value of the GEO satellite application on Sapudi Island is 1,090 (> 1), so the project is feasible or can be continued.

Analysis of Regulations in the Implementation of Satellite Communication Services

Spectrum Management for the Implementation of Satellite Communication Services

Article 33 of the Law of the Republic of Indonesia (UU) Number 36 of 1999 (36/1999) concerning Telecommunications states that the provisions for the use of radio frequency spectrum and satellite orbits used in the implementation of telecommunications are regulated by Government Regulations. This was then followed up with the issuance of Government Regulation of the Republic of Indonesia Number 53 of 2000 concerning the Use of Radio Frequency Spectrum and Satellite Orbit and Government Regulation of the Republic of Indonesia Number 46 of 2021 concerning Post, Telecommunications, and Broadcasting. Which various regulations are oriented towards the radio spectrum.

Spectrum regulators must make decisions about the use of spectrum and to whom it should be allowed to use (i.e., use and users). The international framework for the utilization of the radio frequency spectrum is set out in the ITU Radio Regulation. The radio spectrum is a part of radio waves that is in the frequency range from 9 KHz to 30GHz.

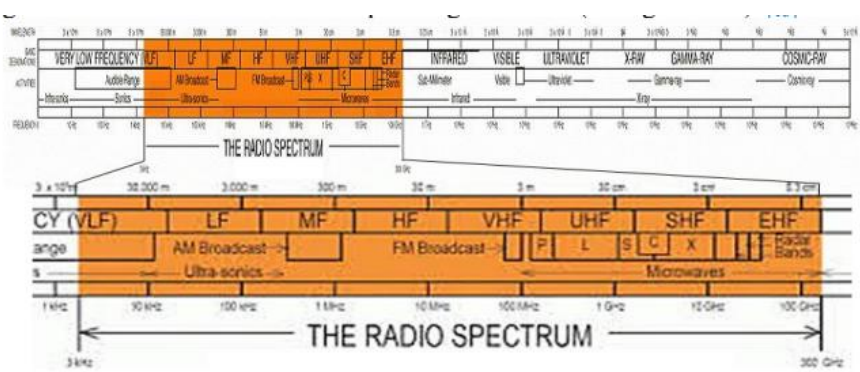

Figure 4. Frequency Spectrum

Spectrum management reflects many separate activities, including planning the use of spectrum, allocating and assigning spectrum licenses, enforcing licensing conditions, interacting with regional and international organizations and so on. Economic objectives relate to ensuring that the spectrum is used in a way that meets the objectives of the country which includes the efficient allocation of resources in accordance with the economic development of the country and various other objectives. Other technical objectives relate to the more specific objective of ensuring that the frequencies of the service are used in a way that allows maximum utilization of resources, avoiding interference, the frequency spectrum gap does not need to be large ('guard band') between users. High-level policy objectives relate to consistency in government policies on matters such as access, competition, non-discrimination, and equity and fairness in terms of spectrum allocation, and assignment to various users. This study accommodates these three objectives for the implementation of the use of GEO Satellites in blank spot areas such as Sapudi Island.

THE Radio Regulation has divided the world into three different regions as seen in the image

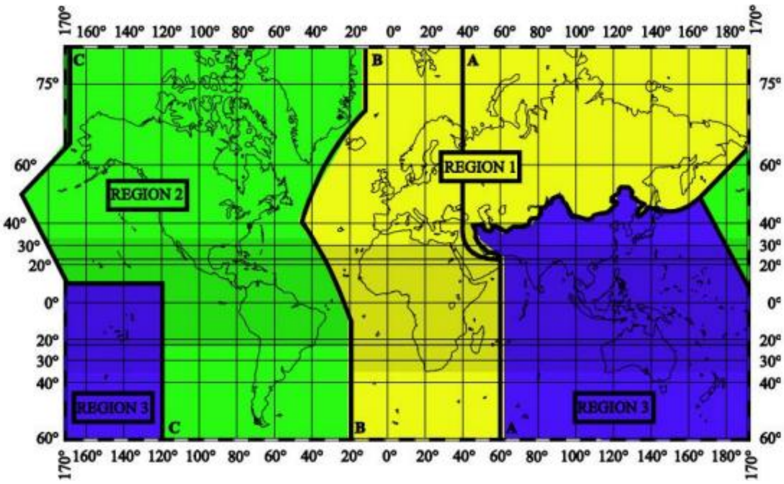

Figure 5. ITU Region Mapping

The Directorate General of Postel has mapped the current use of the radio frequency spectrum and plans in the future in the form of an allocation table of Indonesia's radio frequency spectrum. In 2014, the Regulation of the Minister of Communication and Information Technology No. 25 of 2014 concerning the Indonesian Frequency Spectrum Allocation Table (TASFRI) was issued. TASFRI contains the allocation of radio frequency spectrum in Indonesia and serves as a reference in the management of more specific, detailed and operational frequency bands. Existing users and prospective users of the frequency spectrum, are encouraged to recognize the allocations that have been made in the field of frequency spectrum contained in the TASFRI document to the types of services, allocations and channels related to it. The allocation of radio frequency spectrum in Indonesia contained in TASFRI refers to the allocation of frequency spectrum allocation table officially issued by the ITU in the 2012 edition of the Radio Regulation which is also a reference for other countries in the world. The ITU frequency spectrum allocation table consists of three columns, where each column represents the division of the world frequency allocation expressed as the ITU Region allocation. The frequency bands referenced in each of the ITU radio frequency spectrum allocation tables are located in the upper-left corner of each part of the box in that table.

For TASFRI, it consists of four columns, where the fourth column is the frequency spectrum allocation for Indonesia which refers to Region 3 of the ITU frequency spectrum allocation table. For footnote references that appear in the Table, under allocated services, apply to all assigned allocations. The footnote reference that appears to the right of the name of the service is only valid for the service. The footnotes for Indonesia in column four are marked with the INS code, where the allocation is a description of the planning and use of the frequency band based on national needs and priorities. Directorate General of Postel in determining the band plan to be applied to each service in TASFRI based on technical considerations, including: bandwidth, frequency difference between transmitter frequency and receiver frequency (duplex separation), etc. Another important consideration in determining the bandwidth planning in the TASFRI is the development of technology and the availability of radio communication devices. For the purpose of determining frequency, the band planning is further divided into several channels to determine the channeling plan. The government is responsible for developing spectrum management policies that are in accordance with the obligations of the Radio Regulation international agreement to meet national spectrum needs. The National Frequency Allocation Table (NTFA) is known in Indonesia as the Frequency Allocation Table of the Republic of Indonesia (TAFRI), One of the most important tools for effective spectrum management that can show how spectrum can be used domestically.

1. Problems and Solutions of C-band and Extended-C-band Frequencies as BMI Frequencies

The need for frequency spectrum for mobile broadband is also very urgent. So far, it seems that the government will provide support to mobile to develop Indonesia's broadband. This is because national broadband development is highly dependent on the ability of the mobile industry to develop mobile broadband services (>90%).

The VSAT satellite network in Indonesia has become one of the options to support telecommunications in Indonesia with a total of 21,638 VSAT points throughout Indonesia. Indonesia has been heavily dependent on the use of satellites since 1976. Satellite telecommunications play an important role in connecting Indonesian territories and serving blank spots such as Sapudi Island. Even Western Indonesia and Central Indonesia, which have been widely reached by terrestrial networks, still need VSAT.

The problem that occurred was that the Indonesian government delegation in the WRC-2015 led by the Ministry of Communication and Informatics finally stated that it did not identify C-band and Extended-C-band frequencies as BMI frequencies. It is stated in the CPM Report that when an FSS Station (or VSAT) is installed with or without an individual license, frequency sharing between FSS and IMT cannot be possible in the same area due to the lack of certainty of minimum separation distance that can be guaranteed (interference interference with FSS) (Commonwealth of Australia, 2006). In other words, the Indonesian government does not approve of the C-band and Extended-C-band frequencies being used for mobile. The Indonesian government remains on the previous frequency allocation that this frequency is used only for Fixed Satellite Service or Fixed Satellite Service.

For Mobile Agencies (for example: Cellular Networks), having a new frequency band that is very reliable for the development of Cellular Networks, especially anticipating a surge in data usage by mobile devices. However, for Fixed Satellite Services (for example: VSAT

Telecommunications, Satellite Broadcasting), because these frequencies are used together there are several disadvantages:

1) According to the results of research by Khawar et al. (2014), it is said that in VSAT with an elevation of 5°, it can be affected by Out Of Band Emission (OOBE) interference if frequency sharing is carried out and to secure/protect a VSAT, a protective distance separation of as far as 9.49 Km for Indoor Small Cell and as far as 48,046 Km for the implementation of Outdoor Small Cell must be applied.
2) Meanwhile, to avoid Saturation, Low Noise Amplifier, according to Awais Khawar et al., requires a varied distance, for example, 300 meters for VSAT elevation, 5° to 1100 meters, for VSAT elevation, 45°, for the installation of Indoor Small cell cells. That means if what is to be installed is a Macro Cell with a stronger range, then it is rarely necessary to have a larger separation between VSAT and BTS.
3) For Mobile Agencies (e.g., Mobile Networks), because about 65% of VSAT usage is for mobile backhaul, it is likely that mobile backhaul bandwidth through VSAT will experience a lack of frequency allocation. The use of the C-band Frequency that was previously allocated for the Fixed Satellite Service which is then used for cellular backhaul via VSAT will be eaten by the BTS signal, as if it eats its own feet.
4) If the interference is not resolved by IMT, then IMT operators are required to rent transponders from satellite operators whose frequency allocation coincides with Indonesian satellites.

The use of C-Band frequencies is still very much needed by the Satellite Industry as the Primary Frequency because Indonesia's archipelago geography makes it difficult to develop Fiber Optic infrastructure between islands and remote locations. This selection is based on the following data:

1) The frequencies used by the FSS as the downlink frequencies (space to Earth) Extended-C-Band and C-Band are frequencies that are immune to rain attenuation with high intensity, especially in tropical areas such as Indonesia.
2) The FSS KU-Band frequency at the frequency of 10.95-12.75GHz and the Ka-Band frequency at the frequency of 17.30-21.20GHz as the downlink frequency frequency (space to Earth) alternative FSS C-Band is the frequency that is less immune to rain damping due to a decrease in reception due to high-intensity rain.
3) Frequency sharing between FSS and IMT is still not smooth due to interference issues. Meanwhile, there is no minimum distance separation solution so that the FSS is free from interference from IMT
4) Terrestrial networks that do not yet cover the entire land and areas that have not yet been reached by the signal make FSS the only option in certain areas. Even mobile BTS uses FSS as a backhaul.

This result is in line with the government's thinking contained in a release from the Directorate General of Postal and Information Resources and Devices (SDPPI) which states that the C band satellite frequency band is a very strategic frequency for Indonesia because it is used for satellite communication. Many areas in Indonesia, especially in eastern Indonesia, have not been reached by terrestrial (optical) communication, so they are very dependent on satellite communication. Meanwhile, European countries, Korea and Japan that have advanced terrestrial communication systems (optical cables) want C-band satellite frequency bands to be used for IMT needs. Changing the C Band band for IMT will be detrimental to Indonesia's interests. Therefore, in this conference, Indonesia is fighting for the non-use of satellite bands for IMT services"[11

The problem point lies in the potential for intervention. Interference is highly undesirable in all sorts of radio propagation techniques. Interference will usually result in the system's inability to deliver information from the transmitter to its receiver. Several techniques have also been developed to be used to reduce BMI interference in VSAT, which are as follows:

1) Distance Separation[7][19][20][21][22][23][24][26]

Separation of the distance between the VSAT device and the interference source is one solution to the problem. This solution can solve the problem of both the location of the VSAT installation and the location of the nearest BTS is known.

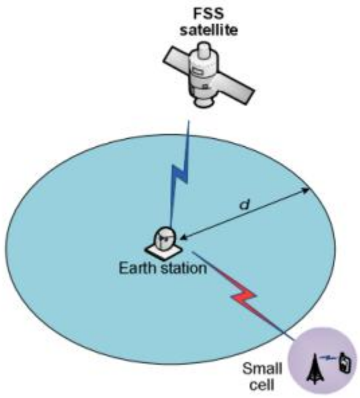

Figure 5. Separation Distance between Small Cell IMT and FSS

In Indonesia, the location for VSAT installation is usually not registered. The distance itself can depend on the power of the BTS transmit, the EIRP of the satellite in the area, the size/diameter of the VSAT antenna and others.

2) LNB/LNA Filter Installation[19][24]

The LNB Filter here serves as a band pass filter that works on the C-band satellite frequency band. With this LNB/LNA filter, unwanted emissions outside 3400-4200 can be reduced so that there is no Product Intermodulation in LNA/LNB.

3) Antenna placement on hilly topography

By installing VSAT antennas in valley locations surrounded by hills/mountains, it will help VSAT to avoid sources of interference. Usually for the construction of a earth station pay great attention to this as a natural protector.

4) Construction of protective walls around antennas[7][22][24][27]

With the construction of a protective wall around the antenna, the interference radiation will be reduced by about 10dB.

Figure 7. Construction of a protective shield on the FSS

This shield can be a wall that surrounds the VSAT antenna. However, the construction of this shield will spend more money on VSAT service providers.

5) Shutting down the source of the Interference

The Fixed Satellite Service as a PRIMARY user in the frequency allocation table has the right to get protection in the event of interference interference. The cause of the interference must be turned off to eliminate interference.

6) Using Indoor Type IMT BTS[17][18][20]

The use of indoor BTS (EIRP<24dBm) can be used for sharing between FSS and IMT, but distance separation and protective walls must still be used.

CONCLUSION

The research concludes that integrating GEO satellites to connect BTS HUBs on Sapudi Island is both technically and economically feasible: technically, it achieves a low Carrier-to-Noise (C/N) ratio of 13.90 dB, indicating reliable performance; economically, it yields a positive NPV, an IRR of 11% (exceeding the 6% benchmark interest rate), and a Net Benefit-Cost Ratio (Net B/C) of 2.301, enabling a high return on investment. These findings support GEO satellite deployment as a viable solution for telecommunications blank spots. For future research, stakeholders should consider this as input for optimizing business models by capping capital return rates at 6%, while expanding analyses to include LEO satellite alternatives, Payback Period, and Profitability Index to better align with real-world conditions.

REFERENCES

Albandjar, & Rasyid. (2005). *Infrastructure development challenges in Indonesia*.

Badan Pusat Statistik. (2011). *Statistik Indonesia*. Jakarta: BPS.

Commonwealth of Australia. (2006). *Introduction to cost-benefit analysis and alternative evaluation methodologies*. Australia: Commonwealth of Australia.

Fenech, H., Amos, S., Tomatis, A., & Soumpholphakdy, V. (2013). High throughput satellites: An analytic approach. *31st AIAA International Communications Satellite Systems Conference (ISCCAIAA)*.

Fenech, P. T., Geng, H. G. P. J. D. (2008). Performance optimization of multibeam broadband payloads. *14th Ka and Broadband Communications Conference (KaConf)*.

González Fanfalone, A. L., Weber, V., Yokomori, Y., & Paltridge, S. (2017). *The evolving role of satellite networks in rural and remote broadband access*. OECD Digital Economy Papers.

International Telecommunications Union. (1994). *VSAT systems and earth stations*. Radio Communication Bureau, Geneva.

International Telecommunication Union. (2019). *Radio regulations articles edition of 2020*. Geneva: Bureau Radiocommunication.

Kasmir, & Jakfar. (2012). *Studi kelayakan bisnis*. Jakarta: Kencana Prenada Media Group.

Khawar, A., Ahmad, I., & Sulyman, A. I. (2014). Review of terabit/s satellite, the next generation of HTS system. *7th Advance Satellite Multimedia Systems Conference and 13th Signal Processing for Space Communication Workshop (ASMS/SPSC)*.

Mowarin. (2019). *Economic analysis and project evaluation*.

Pahlevy, R. N. (2018). Purwarupa penerima ADS-B pada satelit nano untuk mendeteksi pesawat komersial. *Jurnal Teknologi Dirgantara, 2*, 31-33.

Umar, H. (2009). *Studi kelayakan bisnis: Teknik menganalisis kelayakan rencana bisnis secara komprehensif* (3rd ed.). Jakarta: Gramedia Pustaka Utama.

Aker, J. C., & Mbiti, I. M. (2018). Mobile phones and economic development in Africa. *Journal of Economic Perspectives, 24*(3), 207–232. https://doi.org/10.1257/jep.24.3.207

Kementerian Komunikasi dan Informatika Republik Indonesia. (2021). *Laporan perkembangan infrastruktur telekomunikasi nasional*. Kementerian Kominfo RI. https://www.kominfo.go.id

Pratama, A. R., Hidayat, R., & Wibowo, S. (2020). Infrastructure inequality and digital divide in Indonesia's outer islands. *Telecommunications Policy, 44*(8), 102020. https://doi.org/10.1016/j.telpol.2020.102020

Qiang, C. Z.-W., Rossotto, C. M., & Kimura, K. (2019). Economic impacts of broadband. *Information and Communications for Development*, World Bank Group.

Sutrisno, D., & Nugroho, S. (2019). Palapa Ring project and connectivity challenges in Indonesia's archipelagic regions. *Journal of ICT Development, 6*(2), 45–58.

Suryahadi, A., Izzati, R., & Suryadarma, D. (2020). Digital access and regional development disparities in Indonesia. *Bulletin of Indonesian Economic Studies, 56*(3), 287–310. https://doi.org/10.1080/00074918.2020.1798588

World Bank. (2022). *Indonesia digital economy diagnostic: Connectivity for inclusive growth*. World Bank Group. https://www.worldbank.org