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Article

Technical and Economic Analysis for 5G Nr Network Non-Standalone Planning In Yogyakarta City Using 2300 MHz Frequency

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Abstract : Yogyakarta City covers a total area of 32,819 km2 with a population of 378,913 in 2022. Yogyakarta City has the potential to improve connectivity and enhance telecommunication services, which will benefit the population and overall city development. Additionally, the adoption of 5G NR technology can also support various sectors such as education, business, tourism, and governance, benefiting the community and the local economy. Therefore, Yogyakarta City's support for the establishment of 5G NR planning can be explained by the potential benefits offered by the technology in improving the quality of life and overall city development. This research utilizes the Technical Planning of 5G New Radio networks in Yogyakarta City with the architecture of 5G New Radio (NR) in Non-Standalone (NSA) mode. It encompasses technical design aspects related to coverage and capacity, cost planning (NPV, PP, IRR, ROI), and economic analysis (Capex, Opex, and Revenue). In the simulation, coverage for 47 sites was achieved, meeting the criteria for good signal quality, and for capacity, 43 sites with good signal quality were obtained. The cost and economic results obtained over 4 years show that the initial capital will be recouped, indicating that the investment is feasible to proceed with.

Keyword : 5G New Radio (NR); Network; Non – Standalone; Techno Economy

1. Introduction

Yogyakarta City has a total area of 32,819 km^2 with a population of 378,913 people in 2022, with a population density of 11,659 people every km^2 [1]. The existing population density makes one of the reasons for the impetus for this research to be carried out, both technically and economically, services are needed that are able to run and operate properly to meet user needs. Yogyakarta City supports the establishment of 5G NR planning due to awareness of the importance of technological advancements in improving telecommunication services. With the design of 5G NR networks, Yogyakarta City has the potential to improve connectivity and enhance telecommunication services, which will benefit the population and overall city development. Additionally, the adoption of 5G NR technology can also support various sectors such as education, business, tourism, and governance, which will benefit the community and the local economy. Therefore, Yogyakarta City's support for the establishment of 5G NR planning can be explained by the potential benefits offered by the technology in improving the quality of life and overall city development.

5G NR network technology is the 5th generation network standard, 5G NR technology is expected to be able to improve the technology that has existed before [4]. For this reason, in order to implement the 5G NR network properly in the city of Yogyakarta, a comprehensive technical design is needed both in terms of coverage and in terms of capacity (Coverage and Capacity), cost structure (Capex,Opex,Revenue), and economic analysis (NPV,PP,IRR,ROI). this is due to the many references and plans that can be used, one of which is by 3GPP which issues a formula regarding the propagation model that can be used, the Urban Macro (UMa) propagation model is one of the propagation models suggested by 3GPP [2].

This research employs the Technical Planning of 5G New Radio (NR) networks in Yogyakarta City using the architecture of 5G New Radio (NR) in a Non-Standalone (NSA) mode with a frequency of 2300 MHz. After conducting simulations, the study will determine the number of gNodeBs in the Coverage Planning, along with the values of SS-RSRP, SS-SINR, and Throughput. Similarly, in Capacity Planning, the study will determine the number of gNodeB sites, along with the values of SS-RSRP, SS-SINR, and Throughput. The results obtained in the study will be evaluated according to the Key Performance Indicator (KPI) parameter category [3].

2 Research Materials and Methods

2.1 5G New Radio Network

Mobile networks are communication networks that connect users wirelessly using radio waves. Indonesia is one of the countries that follows technological advancements. The 5G network is an advancement from previous generations such as 4G, 3G, 2G, and 1G [4].

2.2 5G Network Architecture

5G Non-Standalone (NSA) means that 5G networks will be supported by existing 4G infrastructure. This architecture elevates the Envolved Packet Core (EPC)-based 5G NR cell as a core that is still under the 4G LTE network. Here, 5G-enabled smartphones will be connected to 5G radio frequencies to get faster data throughput but will still use 4G's core network [5].

2.3 Geographical Situation

Yogyakarta City is the capital city of the Special Region of Yogyakarta province. Yogyakarta City as a leading tourist destination city, rests on the strength and excellence of local tourism, business and education which has brought many changes and become a driving force for the overall development of Yogyakarta City [6]. Therefore, the city of Yogyakarta is one of the tourist destinations that is widely considered and becomes its own attraction [10].

2.4 Network Planning

Network planning in this study is carried out with 2 methods, namely Coverage Planning and Capacity Planning in order to get maximum results, network analysis is also carried out with two methods of observing in terms of coverage or size of the area and in terms of the capacity of the population or users of network services [7], network planning as follows:

2.4.1 Coverage Planning

Coverage Planning is used to estimate the number of cells needed in the planned area. Coverage Planning is cellular network planning based on the coverage area in one cell originating from the gNodeB. The calculation in Coverage planning is very considering the loss that occurs between gNodeB and User Terminal (UT) as well as in the planned area [8].

2.4.1.1 Link Budget

The Link Budget is a total calculation to determine the gain and loss in a system in order to ascertain the Received Signal Level (RxSL) received by the User Equipment (UE) receiver. The received Received Signal Level is then compared to the receiver's Receiver Sensitivity (RxS) to check whether the channel status is pass or fail. The link budget calculation is a power level calculation carried out to ensure that the received power level is greater than or equal to the transmitted power level.

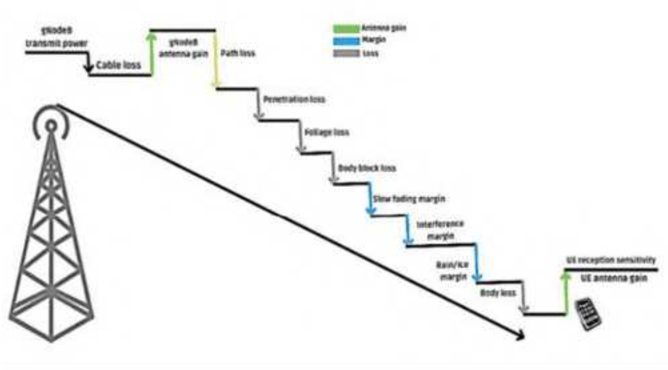

Figure 1. Factors Affecting Link Budget

The aim is to maintain a balance of gain and loss from the transmitter antenna (Tx) to the receiver antenna (Rx). From the link budget calculation, the Maximum Allowable Path Loss (MAPL) or maximum signal attenuation received between the mobile antenna and the mobile station antenna on the downlink side can be obtained [12]. To find the Allowable Path Loss (APL) value, it can be calculated using the link budget parameters in Figure 1. [9].

2.4.1.2 Thermal Noise

Thermal Noise is Noise or obstructions that affect the signal formula used to calculate Noise is:

$$\text{Nthermal} = 10 \text{ x} \log(\text{ K x T x B}) \tag{1}$$

Description :

K = Boltzman constanta (1.38 x 10^{-20} Joule/K).

T = Temperature (293° K).

B = Bandwidth (Hz)

2.4.1.3 Subcarrier Quantity

After calculating the value of Thermal Noise then calculate the value of Subcarrier Quantity with the following formula:

$$S_{cq} = R_B \text{ x } S_{RB} \tag{2}$$

Description :

S_{cq} = Subcarrier Quantity

R_B = Resource Block

S_{RB} = Subcarrier Resource Block

2.4.1.4 Pathloss

In this Pathloss calculation, the amount is influenced by several parameters used in the Link Budget. The formula for calculating pathloss is as follows [11]:

$$\text{Path loss (dB)} = \text{gNodeB transmit power (dBm)} - 10\text{x}\log(\text{subcarrier quantity}) + \text{gNodeB antena gain (dBi)} - \text{gNodeB cable loss (dB)} - \text{penetration loss (dB)} - \text{foliage loss (dB)} - \text{body blok loss(dB)} - \text{obtrusion margin (dB)} - \text{rain snow margin (dB)} - \text{slow fading margin (dB)} + \text{UE antena gain (dB)} - \text{Thermal noise power(dBm)} - \text{UE noise figure (dB)} - \text{demodulation threshold SINR (dB)} \tag{3}$$

The $d3D$ value from the Pathloss formula above requires $d'BP$, Value $h'UT$, This using the formula:

$$h'_{BS} = h_{BS} - hE \tag{4}$$

$$h'_{UT} = h_{UT} - hE \tag{5}$$

$$d'_{BP} = 4 \text{ x } h'_{BS} \text{ x } h'_{UT} \text{ x } f_C/c \quad (6)$$

Description :

hE = Height of Equipment

h_{BS} = Heigh of Base Station

h'_{UT} = Height of User Terminal

d'_{BP} = Distance of Break Point

2.4.1.5 Propagation Model Urban Macro (UMa)

Propagation model is a modeling used based on density justification and also needs in a certain area on a network. Yogyakarta is classified as a fairly dense city, so it uses the Urban Macro (UMa) propagation model [11]. The formula for calculation is :

$$PL = 28.0 + 40 \log_{10} d_{3d} + 20\log_{10} f_c - 9\log_{10}((d'_{BP})^2 + (h_{BS} - h_{UT})^2) \quad (7)$$

Description :

PL = Pathloss value (dB).

d_{3d} = $(h_{BS} x h_{UT})$ with value d_{2d}

2.4.1.6 Cell Radius

After calculating the propagation model, the next step is to find the value of $d2D$, obtained as the Cell Radius value that conforms to the Pythagorean principle with the following formula :

$$\text{Cell Radius } (d_{2d}) = \sqrt{((d_{3D})^2 - (h_{BS} - h_{UT})^2)} \quad (8)$$

Description : d_{2d} = Pythagoras cell radius

2.4.1.7 gNodeB Coverage Area

From the value obtained for the Cell Radius, the Coverage Area served by a Single Site can also be determined, which is needed for the area's size calculation, and can be calculated using the following formula:

$$\text{gNodeB Coverage Area} = 1{,}9 \text{ x } 2{,}6 \text{ x } d_{2D}{}^2 \quad (9)$$

Description :

C_A = gNodeB Coverage Site (m^2)

d_{2d} = Cell radius (m)

2.4.1.8 Number of *gNodeB*

For a research area, it is necessary to determine the number of Sites required by knowing the area's size to conduct planning in a network. This can be calculated using the following formula:

$$\text{N gNodeB} = \frac{\ell \text{ area}}{C_A} \quad (10)$$

Description :

N gNodeB = Number of gNodeB

ℓ area = Area total (m^2)

C_A = Coverage area gNodeB (m^2)

2.4.2 Capacity Planning

Planning based on capacity prioritizes meeting the needs of user traffic. Data estimates of the number of customers in several districts in the city of Yogyakarta are obtained from the Central Statistics Agency for the Yogyakarta area [1].

2.4.2.1 Bass Model

The Bass model is used to make estimates/predictions of network users to measure the number of consumers and also the potential for network planning in this research. The formula used is*:*

$$N(t) = M\frac{1-e^{-t(p+q)}}{1+\frac{q}{p}e^{-t(p+q)}} \quad (11)$$

Description :

N(t) = Users Market Predicted

M = Market Volume

p = Innovation value, p ≥ 0

q = Imitation value, q ≤ 0

2.4.2.2 Demand Traffic

The density of network users must be estimated within the research area. In order to determine the traffic needs within each kilometer, and to achieve optimal results, this research uses the following formula :

$$G(t) = \rho \, . \frac{8}{N_{dh}N_{md}} \, . \varphi(t) \, . D_k \quad (12)$$

Description :

G(t) = Traffic demand forecast

N_{dh} = Daily busy hours

N_{md} = Number of days in a month

φ(t) = Peak traffic demand

D_k = Traffic demand of month

2.4.2.3 Data Rate

Data Rate is a measure indicating the amount of data in the transmission process that can be sent in unit of time, measured in bits in second. The calculation formula is as follows :

$$\text{Data rate} = 10^{-6} . \Sigma_{j=1}^{j}(v_{layer}^{(j)} \, . Q_m^{(j)} \, . f^{(j)} . R_{max} . \frac{N_{PRB}^{BW.(j).\mu} .12}{T_s^{\mu}} \, . (1 - OH^{(j)}) \quad (13)$$

Description :

J = Number of aggregated carrier components

$Q_m^{(j)}$ = Modulation order

$f^{(j)}$ = Scaling factor where its values are 1; 0.8; 0.75; and 0.4

T_s^{μ} = Average duration of OFDM symbol in a subframe for numerology

$N_{PRB}^{BW.(j).\mu}$ = Maximum bandwidth allocation

$OH^{(j)}$ = Overhead for channel control

2.4.2.4 Number of gNodeB

After obtaining the previously sought values in capacity planning, the number of gNodeB sites is also calculated based on the number of users and the capacity used by customers. The formula used is as follows :

$$\text{Number of gNodeB} = \frac{G(t)}{\text{Data Rate}} \quad (14)$$

2.4.3 Cost and Economic Structure

In the cost structure, there are 3 planning methods: Capital Expenditure (CAPEX), Operational Expenditure (OPEX), and Revenue. Meanwhile, in the economic planning of this research, Net Present Value (NPV), Payback Period (PP), Internal Rate of Return (IRR), and Return On Investment (ROI) are used.

2.4.3.1 Net Present Value (NPV)

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+K)^t} - I_0 \qquad (15)$$

Description :

CF_t = Net cash flow

K = Interest rate

2.4.3.2 Playback Periode (PP)

$$PP = \frac{\text{Investasi Awal}}{\text{Arus Kas per Periode}} \qquad (16)$$

2.4.3.3 Internal Rate Of Return (IRR)

$$Io = \sum_{t=1}^{n} \frac{CF_t}{(1+IRR)^t} \qquad (17)$$

Description :

I_0 = Initial investment value

CF_t = Net cash flow

IRR = Interest rate at which the loss is sought

2.4.3.4 Return Of Investment (ROI)

$$ROI = \frac{\text{Net Profit After Tax}}{\text{Total Asset}} \times 100\% \qquad (18)$$

Parameters :

- If ROI > 0, then the investment is profitable
- If ROI < 0, then the investment is a loss
- If ROI = 0, then the investment is a breakeven investment (no provide advantages or disadvantages)

The scheme can be seen in the following figure 2. :

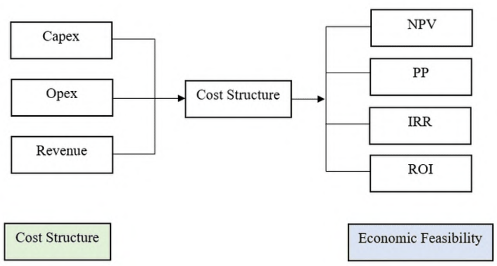

Figure 2. Flowchart of Cost Structure Calculation and Feasibility

The financial parameters in this study are chosen because this method allows us to determine and analyze the feasibility in designing a 5G NR Non-Standalone network in the city of Yogyakarta with a frequency of 2300. This can be considered feasible for network implementation because the cost and economic calculations are in line with the reference financial parameters.

3. Results and Analysis

3.1 Classification of Research Areas

Classification of regions is necessary for justifying an area for propagation modeling. In Yogyakarta city, regional justification is used in calculations and analysis in coverage planning as well as in terms of the population or users used in analysis and calculations in capacity planning. Both of these are used in classification or justification based on the geographical conditions of the area type, which falls into categories such as Rural, Suburban, Urban, or Dense Urban. The following is the population data in 2022, which can be seen in figure 3 [10]. The area of Yogyakarta City falls under the Urban category as shown in the above figure, with a population density ranging from 10,000 to 50,000 people in square kilometer. The parameters for the regional classification categories can be seen as follows :

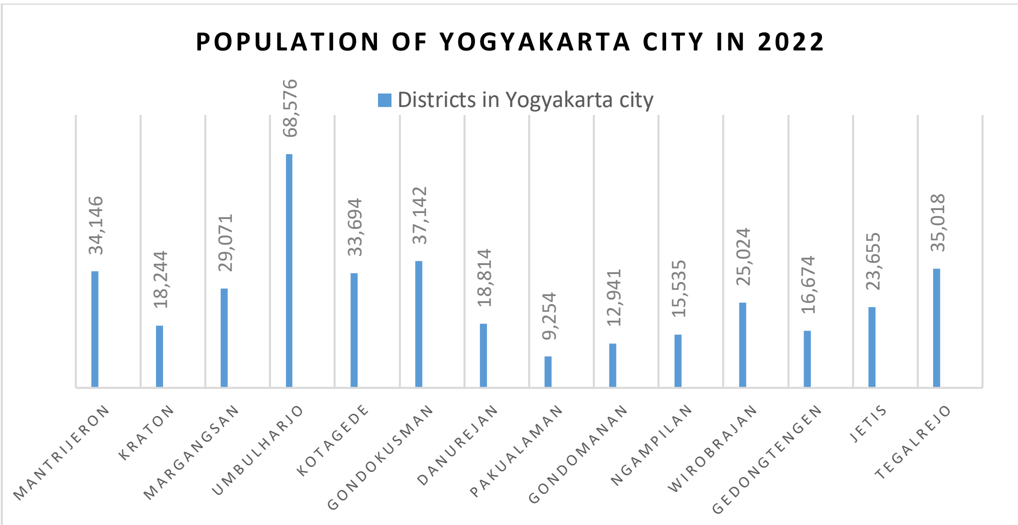

Figure 3. Population of Yogyakarta City in 2022

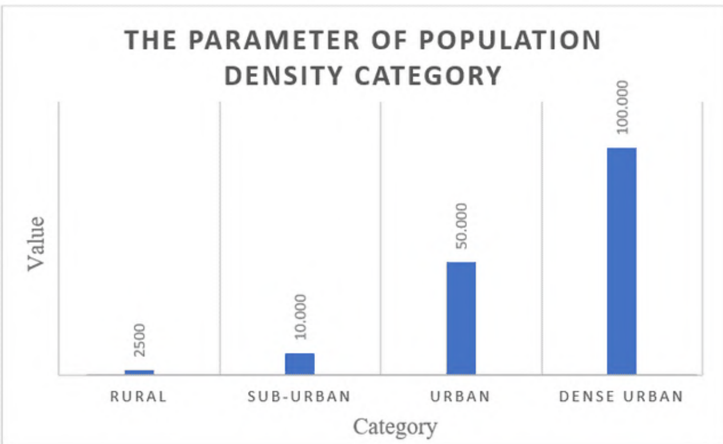

Figure 4. Parameters for Regional Classification Categories

3.2 Coverage Planning

In this Coverage planning, the aim is to estimate the number of gNodeB used to cover the research area of Yogyakarta City, based on the geographic conditions of the region, classification of area types, link budget, propagation model, and cell radius to determine the number of gNodeB sites needed to cover the research area in that region.

Table 1. MAPL Parameters

Maximum Allowable Path Loss (MAPL)			
Comment Parameter	Notasi	Value	
gNodeB Transmiter Power (dBm)	a	49	
Resource Block		273	
Subcarrier Quantity	b	3276	
gNodeB Antena Gain (dBi)	c	18,6	
gNodeB Cable Loss (Dbi)	d	0	
Penetration Loss	e	26,85	
Foliage Loss	f	19,59	
Body Block Loss (dB)	g	3	
Interference Margin (dB)	h	6	2
Rain/Ice Margin (dB)	i	0	
Slow Fading Margin (dB)	j	7	
UE Antena Gain (dBi)	k	0	
Bandwidth (MHz)		100	
Boltzman Constant (mWs/K)		$1,38 \times 10^{-20}$	
Temperature (Kelvin)		293	
Termal Noise Power (dBm)	l	-153,93	
UE Noise Figure (dB)	m	9	
Demodulation ThresholdSINR (dB)	n	22,9	

3.2.1 Thermal Noise

The results of the Thermal Noise calculation yield the following values :

$$\text{Nthermal} = 10 \times \log\ (1{,}38 \times 10^{-20} \times 293 \times 100)$$

$$\text{Nthermal} = -153{,}93253 \text{ dBm}$$

3.2.2 Subcarrier Quantity

The results of the Subcarrier Quantity calculation yield the following values :

$$S_{cq} = 3276$$

3.2.3 Pathloss

According to the reference values of MAPL used, the following are the results of the Pathloss calculation :

$$\text{Pathloss} = 49 - 10\log(3276) + 18{,}6 - 0 - 26{,}85 - 19{,}59 - 3 - 6 - 0 - 7 + 0 - (-153{,}93253) - 9 - 22{,}9$$

$$\text{Pathloss} = 92{,}0365611 \text{ dB}$$

After calculating the Pathloss values above, the value of $d3D$ is also required along with the values of $h'UT$ and $d'BP$. These values are used to determine the correct height at the Transmitter (Tx) and Receiver (Rx). The results obtained from the calculation are as follows :

$$h'_{BS} = 25 \text{ m} - 1 \text{ m} = 24 \text{ m}$$

$$h'_{UT} = 1{,}5\ m - 1\ m = 0{,}5 \text{ m}$$

$$d'_{BP} = 4 \times 24 \times 0{,}5 \times 2{,}3 \times 109 / 3 \times 108 = 368 \text{ m}$$

3.2.4 Urban Makro Propagation (UMa)

According to the population density justification, the propagation model used in this study is the Urban Macro (UMa) propagation model. The results obtained from the calculations are as follows:

$$99{,}43 = 28.0 + 40\log_{10}(d_{3d}) + 20\log_{10}(2{,}3) - 9\log_{10}((368)^2 + (24 - 1{,}5)^2)$$

$$d_{3d} = 375{,}906034 \text{ m}$$

3.2.5 Cell Radius

The results of the calculation to obtain the Cell Radius value are :

$$\text{Cell Radius } (d_{2d}) = \sqrt{((375{,}906034)^2 - (25 - 1{,}5)^2)}$$

$$\text{Cell Radius } (d_{2d}) = 375{,}170756 \text{ m}$$

3.2.6 gNodeB Coverage Area

From the values obtained for the cell radius, it is also known the coverage area served by each site, which is required for the size of a certain area as follows :

$$\text{CA} = 1{,}9 \text{ x } 2{,}6 \text{ x } (375{,}170756)^2$$

$$\text{CA} = 0{,}6953203 \text{ km}^2$$

3.2.7 Number of *gNodeB*

After obtaining the values from the previous calculations in coverage planning, the next step is to determine the number of gNodeB sites that can cover the research area's extent. The calculation results for the number of gNodeB sites obtained are as follows:

$$\text{N gNodeB} = 47 \text{ gNodeB}$$

3.3 Capacity Planning

Capacity Planning involves efficiency calculations within a network in terms of users or user capacity. This can estimate the number of gNodeB needed based on the number and density of 5G network users for a five-year projection.

3.3.1 Bass Model

In the Bass Model, it is used to predict the estimated number of users on the network in the next five years in Yogyakarta City. The calculations in the Bass Model are as follows:

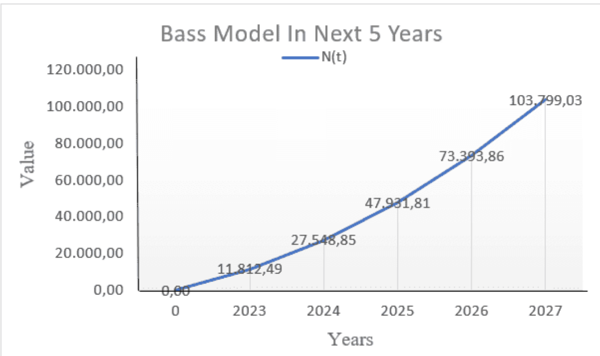

Figure 5. Bass Model in 5 years

3.3.2 Demand Traffic

Demand Traffic is useful for calculating the density of network users to determine traffic needs in each kilometer of the research area. The calculation for Demand Traffic over the next five years is computed as follows:

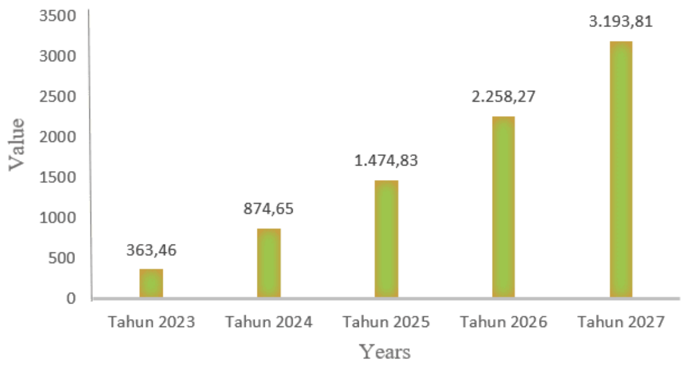

Figure 6. ρ value 2022 until 2027

3.3.3 Data Rate

The calculation for Data Rate will be used to find the data speed in a transmission. Data Rate calculation also serves to determine the number of gNodeB sites obtained in terms of user capacity. The Data Rate calculation is as follows :

$$\text{Data rate} = 10^{-6}\left(4 \times 4 \times 1 \times 0{,}926 \times \frac{273 \times 1 \times 12}{\frac{10^{-3}}{14 \times 2^{1}}} \times (1 - 0{,}14)\right) = 1{,}169 \ \text{Gbps (gNodeB)}$$

3.3.4 Number of gNodeB

The calculation results for the number of gNodeB sites in each district in Yogyakarta City can be computed using the following formula and obtained results as shown in the table below :

Table 2. Number of gNodeB In Each District

District	Number of gNodeB
Mantrijeron	3
Kraton	3
Margangsan	3
Umbulharjo	2
Kotagede	3
Gondokusuman	2
Danurejan	4
Pakualaman	3
Gondomanan	3
Ngampilan	4
Wirobrajan	3
Godongtengen	4
Jetis	3
Tegalrejo	3

3.4 Simulation Network Planning

3.4.1 Simulation Results of Coverage Planning

3.4.1.1 Simulation Secondary Synchronization - Reference Signal Received Power (SS-RSRP)

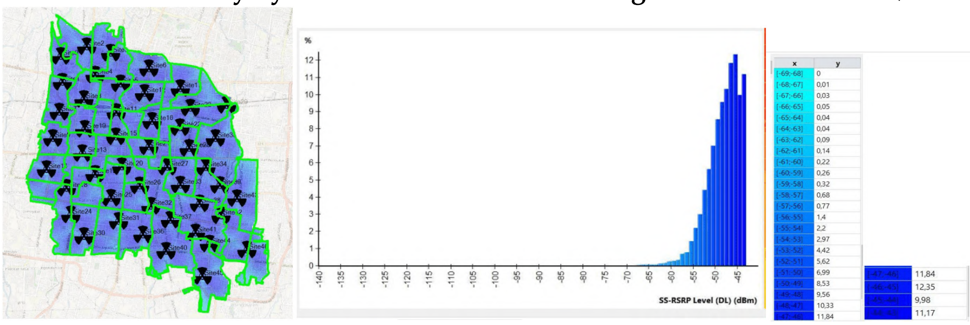

Figure 7. Signal Level SS-RSRP

According to the Coverage simulation, the SS-RSRP value is -47.97 dBm, with the highest Signal Level being -44 dBm at 11.168% or 3.685 km² and the lowest Signal Level being -67 dBm at 0.01% or 0.003 km² of the entire area of Yogyakarta City. The obtained signal falls into the Very Good category according to the (KPI).

3.4.1.2 Simulation Secondary Synchronization-Signal to Noise and Interference Ratio (SS-SINR)

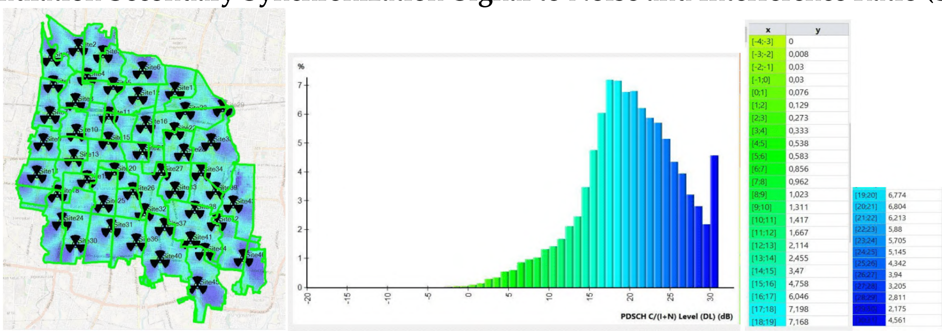

Figure 8. Signal Level SS - SINR

According to the Coverage simulation, the minimum number of gNodeB required is 47 gNodeB. The simulation results show that the SS-SINR value is 20.09 dB, with the highest signal level being 30 dB at 1.505 km² or 4.561% and the lowest signal level being -2 dB at 0.008 km² or 0.003% of the entire area of Yogyakarta City. The obtained signal falls into the Good category according to the Key Performance Indicator (KPI).

3.5.1.3 Troughput Simulation

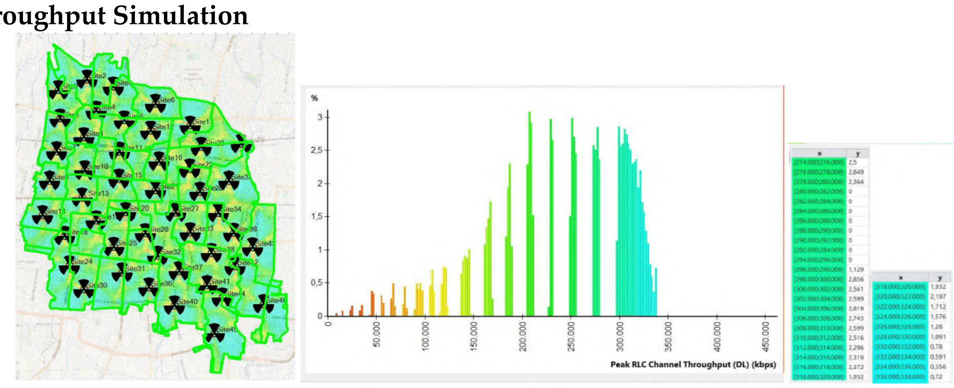

Figure 9. Signal Level Troughput

The results obtained from the Signal Level Throughput Coverage simulation in Yogyakarta City with a minimum of 47 gNodeB show that the average Throughput value is 243,947.8 Kbps. The highest Signal Level Throughput is 336,000 Kbps at 0.2375 km² or 0.72%, and the lowest Signal Level Throughput is 10,000 Kbps at 0.0125 km² or 0.038% of the entire area of Yogyakarta City.

3.5.1 Simulation Results of Capacity Planning

3.5.1.1 Simulation Secondary Synchronization - Reference Signal Received Power (SS-RSRP)

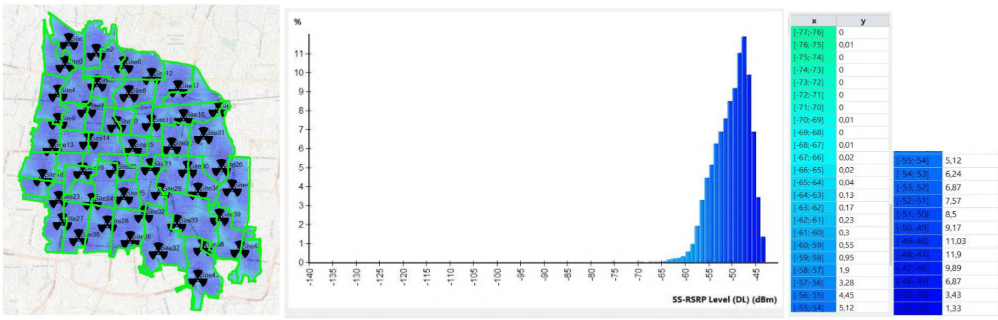

Figure 10. Signal Level SS-RSRP

The SS-RSRP Capacity signal level yielded a result of 43 gNodeB across the 14 districts in Yogyakarta City. The SS-RSRP signal level graph resulted in an average value of -50.17 dBm, with the highest signal level at -44 dBm covering 1.33% or 0.438 km² and the lowest signal level at -75 dBm covering 0.01% or 0.003 km² of the entire area of Yogyakarta City. The SS-RSRP signal level falls into the Very Good category according to the Key Performance Indicator (KPI).

3.5.1.2 Simulation Secondary Synchronization-Signal to Noise and Interference Ratio(SS-SINR)

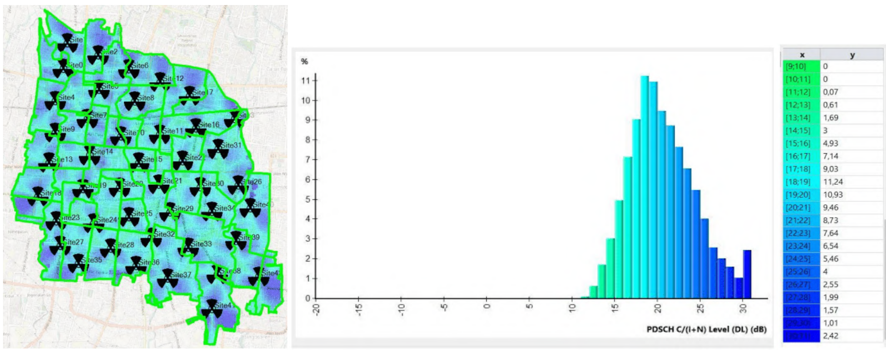

Figure 11. Signal Level SS-SINR

The SS-SINR Capacity signal level in Yogyakarta City resulted in 43 gNodeB. The SS-SINR Capacity signal level yielded an SS-SINR value of 20.66 dB, with the highest signal level at 30 dB covering 0.798 km² or 2.42% and the lowest signal level at 12 dB covering 0.023 km² or 0.07% of the entire area of Yogyakarta City. The SS-SINR signal level falls into the Very Good category according to the (KPI).

3.5.1.3 Troughput Simulation

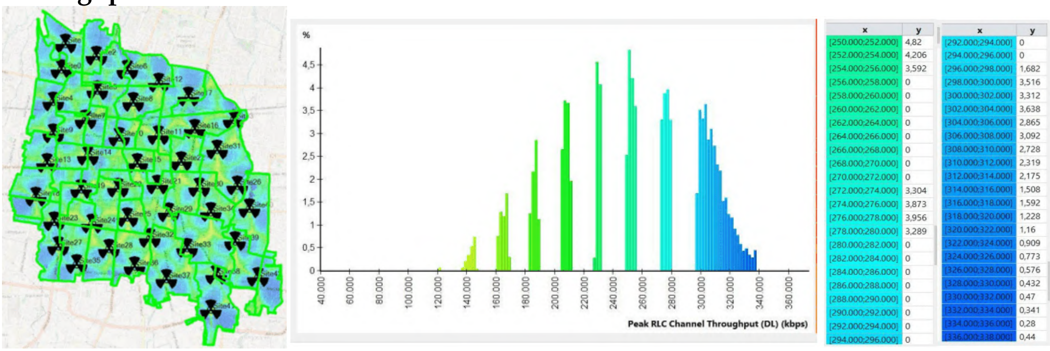

Figure 12. Signal Level Throughput

The Throughput signal level in Yogyakarta City resulted in 43 gNodeB. The Throughput signal level graph yielded an average Throughput value of 256,913.8 kbps, with the highest signal level at 336,000 Kbps covering 0.145 km² or 0.44% and the lowest signal level at 122,000 Kbps covering 0.018 km² or 0.053% of the entire area of Yogyakarta City.

3.6 Analysis Results Simulation

3.6.1 Analysis in Coverage Planning using Atoll

In the Coverage Planning simulation in Yogyakarta City with 47 sites, the SS-RSRP simulation resulted in a value of -47.97 dBm, classified as very good. The SS-SINR result was 20.09 dB, classified as good, and the Throughput value was 243,947.8 Kbps. These results align with the KPI.

In Coverage Planning, the number of gNodeB sites is based on the calculation of the area's extent and the propagation model used. Therefore, the calculation to find the sites is influenced by pathloss calculations, propagation models, obtained cell radius, coverage area size of gNodeB, and the size of the research area. This determines the number of sites in Coverage Planning.

3.6.1 Analysis in Capacity Planning using Atoll

In the Capacity Planning simulation results in Yogyakarta City with 43 sites, the SS-RSRP result from the simulation was -50.17 dBm, classified as very good. The SS-SINR result was 7,820.66 dB, categorized as very good, and the Throughput value was 256,913.8 Kbps. The results are in accordance with the Key Performance Indicator (KPI).

The number of gNodeB sites in Capacity Planning is influenced by the number of users. So, after calculating N(t) (market user prediction) and determining ρ (user density in the area) and also G(t) (traffic demand forecast), we obtain User Data Rate and Data Rate capacity gNodeB, thus determining the number of gNodeB sites in each district. However, some districts have a high number of gNodeB sites despite having a smaller area. In Capacity Planning, the calculation is based on the number of users and the calculation of data rate user and capacity gNodeB. Therefore, if a district has many users but insufficient gNodeB capacity, the number of gNodeB sites will increase in each district.

3.7 Results Capacity Expenditure

In Capital Expenditure, the calculation involves the cost incurred to purchase or lease network infrastructure and serves as an initial capital investment in Year 0, while in subsequent years, it becomes maintenance costs.

Table 3. List of Capex

List of CAPEX	Cost Calculation
Base Band Unit (include UMPT,UBBP)	Rp 382.005.070.620
RRU Module,Three Sectoral	Rp 587.815.543.900
Antenna Sectoral (macro)	Rp 376.329.002.115
Combiner (3 pieces)	Rp 140.675.700.235
Additional Rectifier	Rp 63.943.502.585
Supporting Material Installation	Rp 174.778.900.705
Installation Equipments	Rp 306.928.797.415
Software and License	Rp 4.980.554.045

3.8 Operational Expenditure (OPEX)

In Operational Expenditure, the calculation involves the expenses incurred for operational costs including maintenance costs, site rentals, personnel payments, etc., as explained in the table below:

Table 4. List of OPEX

List of OPEX	Cost Description	Cost
Power Consumption	Power consumption components on gNodeB	Rp 1.149.611.620,00
Transport Fee of gNodeB Optic	Optical transport on gNodeB that is required	Rp 6.707.199.975,00
Consumable Parts	Consumable Parts	Rp 1.814.000.025,00
Operational and Maintenance (5% of CAPEX)	Operation and maintenance	Rp 612.593.370.055,00
Marketing and Advertisement (7% Revenue)	Marketing and advertising	Rp 26.257.758.840,00
Spectrum License	Spectrum license	Rp 29.043.065,00
BHP USO	Components that telecommunication service providers must pay to government (non-tax)	Rp 3.067.495.155,00
BHP for Telecommunication	Components that telecommunication service providers must pay to government (non-tax)	Rp 1.226.998.120,00
Depreciation of Equipments	Depreciation of equipment used	Rp 32.617.927.045,00

The operational cost calculation is carried out to estimate the total components used, and the calculation can be seen in the figure 11.

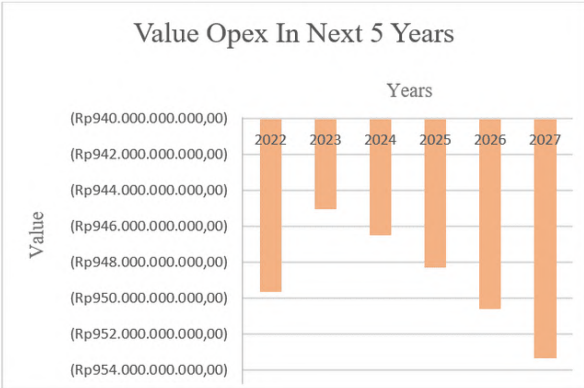

Figure 13. Value Total Opex 5 Years

3.9 Revenue

Revenue calculation is done every year to determine whether the revenue obtained increases or decreases each year. The revenue result is calculated from the first year to the total value of the next five years. The percentage value of the revenue calculation is also depicted in the graph below in the following figure 14 and 15.

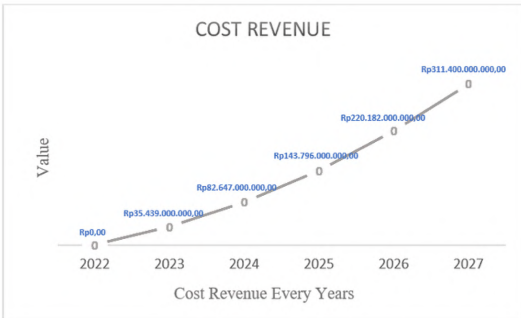

Figure 14. Cost Revenue

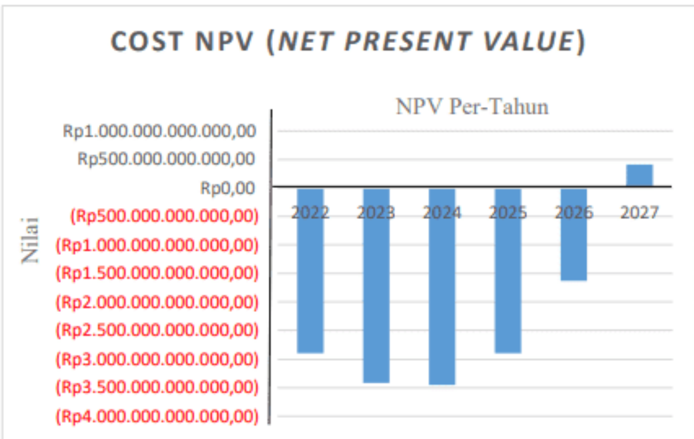

Figure 15. Cost NPV

3.10 Economic Results

3.10.1 Net Present Value (NPV)

Net Present Value (NPV) is the difference between the present value and the net cash income obtained in the future. NPV can be calculated every year for the next 5 years as shown below :

3.10.2 Playback Period (PP)

In the Payback Period (PP), it is an estimate of the time period or the duration in which a design that will be implemented by the company will return the initial investment that has been made. The shorter the time period obtained in the payback period, the better in network planning calculations. In this calculation, the result is approximately around a duration of 4 years.

3.10.3 Internal Rate of Return (IRR)

In the Internal Rate of Return (IRR) calculation, it functions to determine the rate at which the present value of future expected cash flows equals the initial investment outlay and operational costs. In this study, the IRR value obtained is 10%, which is considered feasible because the IRR value is greater than the interest rate of 3.20%. Therefore, IRR in this study is considered feasible.

3.10.4 Return On Investment (ROI)

Return on Investment (ROI) functions to analyze from a financial report to calculate a rate of return on a company's operations, which is done to calculate within a company to achieve an effective operational level. ROI value is calculated every year as shown in the following table:

Table 5. ROI Value

Years	ROI Value (%)
2023	2,1%
2024	4,8%
2025	8,3%
2026	12,8%
2027	18,1%

3.11 Cost and Economic Structure Analysis

3.11.1 Cost Feasibility Analysis

According to the calculation of the cost structure based on Capex, Opex, and Revenue. The calculation results where Capex and Opex are calculated over the next 5 years to determine the amount of expenses incurred each year for the purchase of goods and operational expenses, while Revenue is the income obtained each year. Cost structure calculation on Capex is only done in Year 0 (2022) because in Capex, the capital expenditure is used to purchase devices, installation necessities, etc. Whereas in Opex, the expenses for operations are always present every year, so the cost in Opex is calculated every year, and after entering the calculation process, the expenses in Opex incurred an increase every year, this is also influenced by the increasing number of 5G customers built from the first year, to the second and so on the number of users continues to increase, therefore the operational expenses incurred increase every year, and in revenue, the value is obtained every year from the first year to the next five years. Revenue is the income value to cover the amount spent by Capex and Opex. The results for cost structure calculations are obtained.

3.11.2 Economic Feasibility Analysis

The calculation of the economic structure is calculated using NPV and PP, in this calculation, it is also calculated with a projection of the next 5 years. The results obtained in the first 4 years of NPV show negative values, and in the 5th year, a positive value/profit is obtained. In PP, it is the time period where the value obtained in NPV also shows how long the initial investment can return the capital, in this calculation, it takes 4 years to return the initial capital, so the parameter in the payback period of the investment is considered feasible if PP.

4. Conclusion

Based on the data collection, planning, simulation results, and analysis of the final project entitled "Technical and Economic Analysis in 5G NR Non-Standalone Network Planning in Yogyakarta City Using 2300 MHz Frequency," it can be concluded that, In the Coverage Planning simulation results in Yogyakarta City with an area of 32.5 km^2, 47 sites were obtained. The SS-RSRP result from the simulation was -47.97 dBm, categorized as Very Good. The SS-SINR result was 20.09 dB, categorized as Good, and the Throughput value was 243,947.8 Kbps. In the Capacity Planning simulation results in Yogyakarta City with 14 districts, a total of 43 sites were obtained. The SS-RSRP result from the simulation was -50.17 dBm, classified as Very Good. The SS-SINR result was 20.66 dB, classified as Good, and the Throughput value was 256,913.8 Kbps.

In the cost calculation, Capital Expenditure (CAPEX) was required for expenses in Year 0 (2022) for component costs, installation, and others. Operational Expenditure (OPEX) was calculated as annual expenses in operational costs, and the total Revenue was obtained each year from the first year to the fifth year. In the economic calculation, the Net Present Value (NPV) was Rp412,007,923,481.78 with a rate of 3.20%, which is considered feasible. The Payback Period (PP) value with a parameter of PP < 5 years resulted in a Payback Period (PP) of 4 years, which is considered feasible. The Internal Rate of Return (IRR) value was 10%, which is considered feasible because the Internal Rate of Return (IRR) value exceeds the interest rate of 3.20%. The Return On Investment (ROI) value is considered feasible because the Return On Investment (ROI) value has a percentage above 0 and an average percentage value of 9.22%. The financial parameters of profit are chosen because through this method, one can determine and analyze the profits and losses in the design of a 5G NR Non-standalone network in Yogyakarta city with a frequency of 2300. It is profitable because the cost and economic calculations can be recouped in approximately 4 years in the design phase, thus making it deemed feasible for network implementation.

References

[1] U. M. D. E. C. D. E. Los, “Kota Yogyakarta Dalam Angka 2023”, [Online]. Available: data bps/Kota Yogyakarta Dalam Angka 2023.

[2] Sophia Antipolis, “3GPP Technical Report: Study on channel model for frequencies from 0.5 to 100 GHz (3GPP TR 38.901 version 16.1.0 Release 16),” 3GPP Tech. Rep., vol. 3GPP TR 38, no. 16, 2020.

[3] K. Khotimah et al., “Analisis Key Performance Indicator (Kpi) Jaringan Telekomunikasi Gsm Pada Pt .Hutchison 3 Indonesia (H3I),” 1999, [Online]. Available: https://media.neliti.com/media/publications/191284- ID-analisis-key-performance-indicator-kpi-j.pdf

[4] U. Aryanto, “Bab III - Metode Penelitian Metode Penelitian,” Metod. Penelit., pp. 32–41, 2018.

[5] S. B. Barutu, A. Hikmaturokhman, and M. P. K. Praja, “Planning of 5G New Radio (NR) mmWave 26 GHz in Karawang Industrial Area,” 2020 IEEE Int. Conf. Commun. Networks Satell. Comnetsat 2020 - Proc., pp. 42–49, 2020, doi: 10.1109/Comnetsat50391.2020.9329010.

[6] P. Jogja, “Peta Administrasi Kota Yogyakarta,” 2023, [Online]. Available: https://dokumen.tips/documents/peta-jogja.html?page=1

[7] R. Desi, “Analisis Tekno Ekonomi Perencanaan Jaringan 5G Menggunakan Frekuensi 26 GHZ Di Daerah Kawasan Industri Pulogadung,” 2021, doi: 10.1109/ISRITI51436.2020.9315455.

[8] F. K. Karo, A. Hikmaturokhman, and M. A. Amanaf, "5G New Radio (NR) Network Planning at Frequency of 2.6 GHz in Golden Triangle of Jakarta," in 2020 3rd International Seminar on Research of Information Technology and Intelligent Systems, ISRITI 2020, 2020, pp. 278–283. doi: 10.1109/ISRITI51436.2020.9315504.
[9] Huawei Technologies Co., "5G Link Budget: Best Partner for Innovation," pp. 1–15, 2018.
[10] B. P. Statistik Yogyakarta, "Kota Yogyakarta Dalam Angka 2022," vol. 4, no. 1, pp. 64–75, 2022.
[11] H. Yuliana, F. M. Santoso, S. Basuki, and M. R. Hidayat, "Analisis Model 91 Propagasi 3GPP TR38 . 900 Untuk Perencanaan Jaringan 5G New Radio (NR) Pada Frekuensi 2300 MHz di Area Urban Analysis of Propagation Model 3GPP TR38 . 900 for 5G New Radio (NR) Network Planning at 2300 MHz in Urban Areas," Telekontran, Vol. 10, No. 2, Oktober 2022, vol. 10, no. 2, pp. 1–8, 2022, [Online]. Available: https://ojs.unikom.ac.id/index.php/telekontran/article/download/8233/3321
[12] M. I. Nashiruddin, P. Rahmawati, and M. A. Nugraha, "Assessment of 5G Non-Stand Alone Network Deployment Using 700 MHz for Urban Scenario," *2022 10th Int. Conf. Inf. Commun. Technol. ICoICT 2022*, pp. 299–304, 2022, doi: 10.1109/ICoICT55009.2022.9914879.