Jurnal 2

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Techno-Economic 5G New Radio Planning Using 26 GHz Frequency at Pulogadung Industrial Area

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***Abstract*— The Pulogadung industrial area is a widely known developing industrial area that is perfectly ideal for the implementation of 5G technology to help run the Indonesian economy. Nonetheless, it is noteworthy that knowing the level of economic feasibility of an operator is highly crucial before making an investment in a network performance. This study focuses on an analysis of 5G network design in terms of coverage using the Urban Micro propagation model in the Uplink (UL) and Downlink (DL) Outdoor to Outdoor (O2O) Line of Sight (LOS) scenarios. In addition, it also aims to cover the discussion on the economic level of project feasibility using an optimistic scenario assuming 80% users, which is based on the projected increase in population growth of 5G users using the bass growth model method since its implementation in 2021-2030. The economic analysis used the parameters of Capital Expenditure (CAPEX), Operational Expenditure (OPEX), Net Present Value (NPV), Internal Rate of Return (IRR) to determine the feasibility of planning a 5G New Radio network in the Pulogadung Industrial Area. The calculation of Cost Benefit in the optimistic techno-economic scenario shows that each UL O2O LOS NPV scenario resulted in Rp. 28.369.498.095.53 with an IRR of 31.18%, while DL O2O LOS NPV resulted in Rp. 24.862.173.071.28 with an IRR of 26.68%. This result indicates that the performance of the 5G NR network in the Pulogadung Industrial Estate assuming the projections for the next 10 years is feasible.**

Keywords*—5G New Radio, Coverage Planning, CAPEX, OPEX, NPV, IRR

I. Introduction

The newly launched generation technology of 5G mobile communication, which provides services and applications, is grouped into 3 usage scenarios, namely Enhanced mobile broadband (eMBB), Ultra-reliable and low latency communications (URLLC), and Massive machine type-communication (mMTC), which is widely applied to Internet of Things (IoT)[1].In addition, IoT consists of key components for the industrial domain and is very closely related to the fourth industrial revolution (Industry 4.0) for combining several innovative key technologies to produce a system that functions more effectively than the sum of its parts. This particular domain is characterized by its wide array of innovative applications and services of varied interconnected devices as well as new manufacturing operations[2].

It is projected that the 5G technology will be released commercially and can be widely used by the community, since this technology is known to provide some main benefits, including a very high data rates, very low latency, and ability to connect to various devices simultaneously. These advantages make it necessary to maintain the quality of service provided by this 5G technology. As in the previously released generations of 3G and 4G, the 5G technology contains a term of quality determination known as Quality of Service (QoS). The 5G generation has QoS specificity and has an additional quality material that focuses on a service satisfaction known as Quality of Experience (QoE). There has been a number of studies carried out on various kinds of measurement approaches regarding QoS and QoE measurement in 5G technology.[3].

The government constantly encourages the implementation of 5G technology in the Indonesian industrial area sector. This effort is due to the fact that 5G is deemed as more ideal and suitable for the application of industrial areas as technological developments in the area of industrial revolution 4.0 and Indonesian Industry in order to increase economic activity and ensure business operation that requires high data network performance. On this basis, the planning of 5G network implementation is needed to support these economic activities [4].

This research is based on the notions proposed by the previous researches as some main references listed in the followings:

- A previous research entitled *Techno-Economic Analysis on the Implementation of the 5G Wave Frequency Network in the South Sumatra area*. This research is about the design of the 28 GHz-38 GHz 5G mmwave network seen from the coverage the results indicating that the higher the frequency used the NPV, the smaller its output. Conversely, the smaller the frequency used, the higher the NPV value[5].
- A previous research entitled *Techno-Economic Analysis of 4G Long Term Evolution (LTE) Design in Banyumas Regency*. This study discusses the design of the 4G LTE network at 1800MHz frequency in terms of its coverage and capacity based on cost benefit calculations. It resulted in an IRR of 3% and NPV of RP -8,729,606,072. Thus, the design for deploying LTE in Banyumas Regency for 15 years did not lead to a payback period, and thus is deemed as not feasible since it incurred losses[6].

II. Modeling Techno Economic

The first step in techno-economic modeling is technical calculations by calculating the required site search, and projecting its economic potentials.

A. Planning 5G New Radio (NR) at MilimeterWave

Fig. 1 flowchart planning based on techno economy 5G NR at 26 GHz frequency mmWave is described in the following.

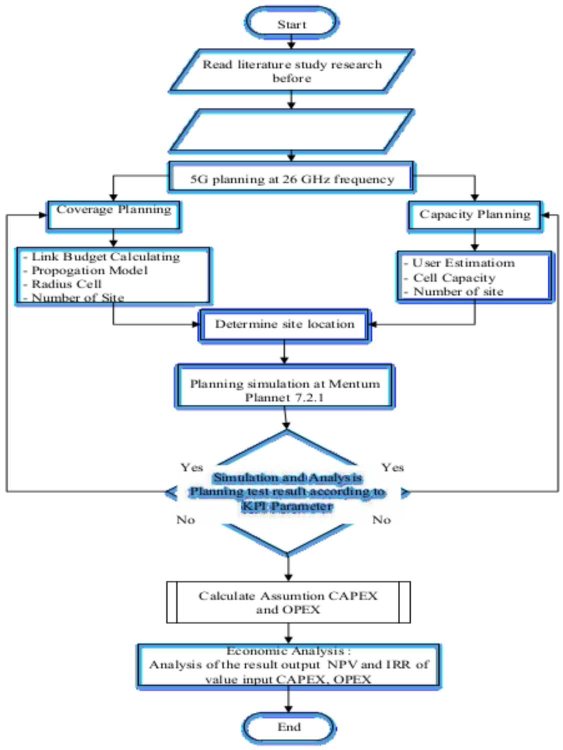

Fig. 1. Flowchart techno economic

To measure the feasibility of the technology as a way to find out that the planning of the technology gains or losses with the NPV and IRR methods, this study uses an optimistic scenario based on projected customer growth in the Pulogadung industrial area. In the calculation of the Net Present Value (NPV) the calculation of present value with the following formula:[6].

$$NPV = \sum_{t=1}^{n} \frac{CFt}{(1+K)^t} = Io \qquad (1)$$

t = Times of Year
n = Number of Year
Cft = Cashflow
Io = Intial Investasion
K = Rate of Return

Internal Rate of Return (IRR) is a method of finding the interest rate where the present value of future expected cash flows or cash receipts equals initial investment expenditures and operating costs[6].

$$Io = \sum_{t=1}^{n} \frac{CFt}{(1+IRR)^t} \qquad (2)$$

t = Times of Years
n = Number of Year
Io = Initial Investasion
CF = Cashflow
IRR = Internal Rate of Return

B. Planning The Number of Sites Based on Their Coverage

1) Link Budget

There was no difference in the basic concept in the calculation of the link budget factor on 5G and 4G, but 5G introduces the influential factors in terms of body block loss, foliage loss and rain/show attenuation, especially for millimeter Wave frequencies[7].

TABLE I. LINK BUDGET PARAMETERS [7][8][14]

Parameter	Uplink	Downlink
gNodeB Transmiter Power (dBm)	35	
Resource block	132	
Subcarrier quantity	1584	
gNodeB antenna gain (dBi)	3 (omnidirectional)	
gNodeB cable loss (dBi)	0	
Penetration loss (dB)	12.23	
Foliage loss (dB)	5	
Body block loss (dB)	15	
Interference margin (dB)	0.5	1
Rain/Ice margin (dB)	3	
Slow fading margin (dB)	7	
UT antenna gain (dB)	omnidirectional	
Bandwidth (MHz)	100	
Konstanta boltzman (mWs/K)	1.38×10^{-20}	
Temperature (Kelvin)	293°	
Thermal noise power (dBm)	-153.93	
UT noise figure (dB)	7	
Demodulation threshold SINR (dB)	-1.1	

2) Urban Micro

Based on the 3GPP 36,873 the propagation model on 5G New Radio (NR) is used at 0.5 to 100 GHz. UMi with Base Station O2O (Outdoor to Outdoor). The UMi propagation model formula uses the Line of Sight (LOS) scenario[8].

$$PL = 32.4 + 21 \log_{10} (d_{3D}) + 20 \log_{10} (fc) \qquad (3)$$

PL = Pathloss Value (dBm)
d_{3D} = Resultant of Distance h_{BS} and h_{UT} (m)
d'BP = Distance of Break Point (m)
fc = Frequency (GHz)
h_{BS} = Height dari gNB (m)
h_{UT} = Height dari UT (m)

$$Radius\ cell\ (d2D) = \sqrt{(d_{3D})^2 - (h_{BS} - h_{UT})^2} \qquad (4)$$

$$Coverage\ area = 1{,}95 \times 2.6 \times d^2. \qquad (5)$$

3) Synchrnization Signal Reference Signal Received Power (SS-RSRP)

SS-RSRP is the average level of the received secondary synchronization signal. RSRP makes it possible to compare the signal strength of individual cells in a 5G network. SS-RSRP is equivalent to the RSRP parameter used in LTE systems[9].

4) Synchrnization Signal Signal to Interference Noise Rasio (SS-SINR)

SS-SINR is defined as the mean of the power contribution (in [W]) of the resource elements carrying the secondary synchronization signal divided by the linear average of the noise and noise power contributions (in [W])[9].

C. Techno-Economic Planning

Table II portrays the number of productive age population in the Pulogadung Industrial Estate based on the data from the previous 5 years (2013-2017) on the number of productive age population of 15-64 years as a way to calculate the growth constant of productive users. Table III is the population prediction using equation (6) to calculate population growth using the following equation [4][10] :

$$Pt = Po(1+r)^t \qquad (6)$$

Pt = Traffic Prediction
t = Time
r = Constanta (Rate of Growth) (0,017).

TABLE II. POPULATION AGE 15-64 IN 2013-2017 [3]

Year	Population (15-64 Tahun)
2013	191.665
2014	192.508
2015	189.291
2016	207.092
2017	207.092

TABLE III. POPULATION PREDICTION OF PULOGADUNG 2020-2030

Year	t	r	Traffic Prediction
2020	0	0.017	265.901
2021	1	0.017	270.421
2022	2	0.017	275.018
2023	3	0.017	279.694
2024	4	0.017	289.284
2025	5	0.017	299.203
2026	6	0.017	209.463
2027	7	0.017	325.515
2028	8	0.017	342.400
2029	9	0.017	360.161
2030	10	0.017	385.284

Table IV is this result was derived from the equation (10) where an optimistic user scenario of 80%, resulted from the data, indicates that in the 10th year, namely 2030 the predicted population of the Pulogadung area will be 385,284 inhabitants. By using the Bass Growth Model method, the prediction of growth in the number of 5G subscribers in the Pulogadung area[11]:

$$B(t;M;ts;\Delta t;s;v) = M\frac{1-\left(1+\frac{v}{s(1-v)}\right)^{\frac{t-ts}{\Delta t}}}{1+\left(\frac{1}{s}-1\right)\left(1+\frac{y}{s(1-v)}\right)^{\frac{t-ts}{\Delta t}}} \qquad (7)$$

M = Market Capacity
ts = Product Time Point to Introduction (ts=<t)
Δt = Time Duration of Product Characteristic
s = Sigmoidal Parameter, $0 < s \leqslant 1$
v = Time point of Penetration (ts + Δt, 0 =< v < 1)

TABLE IV. USER PREDICTION 5G 2021-2030

Year	Product Point	Market Capacity	User 5G
2020	0	68.922	0
2021	1	70.093	0
2022	2	71.285	98.439
2023	3	72.497	100.167
2024	4	74.982	103.602
2025	5	77.554	107.154
2026	6	80.213	110.828
2027	7	84.374	116.577
2028	8	88.750	122.624
2029	9	93.354	128.985
2030	10	99.866	137.982

1) CAPITAL EXPENDICTUR (CAPEX)

The Capital Expendicture (CAPEX) aspects discussed in the Radio Access Network (RAN) side of CAPEX are calculated as the total cost of the base station construction (BS cost), base station installation (BS inst), transmission backhaul construction costs (BHL) and frequency usage fee (BHP), which can be calculated using the following formula [12]:

$$CAPEX_{Total} = BS(cost) + BS_{INST} + BHL + SPLicense \qquad (8)$$

TABLE V. CAPEX'S COMPONENT [5][6]

Parameter	Value	Per tahun
Inflation	3%	Per NE
gNodeB +Software/License	140.000.000	Per NE
Instalation	10.000.000	Per tahun
Interest Rate	9.95%	Tahun
Pay Back Period	5	Per tahun
Loan	60%	
Own Capital	40%	

2) OPERATIONAL EXPENDICTUR (OPEX)

Parameter consist of Operational & Maintenance cost, rent site cost, Backhaul cost, payment resoursh human, Interconnection, Marketing, General & Administartive dan BHP Frequency. Operational & Maintenance cost it is assumed Rp. 6.000.000 rent site assumed is Rp. 150.000.000, Backhaul cost Rp. 50.000.000 and BHP frequency Rp. 1.200.000.000.000 [12]:

$$OPEX\_annual = OAM\_(cost) + MA \qquad (9)$$

OPEXannual = Operational Expendicture
OAMcost = Maintenance and Operational Cost
MA = Marketing and Advertisement

TABLE VI. OPEX'S COMPONENT ASUMTION [5]

Parameter	Value
Operational & Maintenance	Rp. 6.000.000
Site Rent	Rp. 150.000.000
Backhaul Cost	Rp. 50.000.000
BHP Frequency	Rp. 1.200.000.000.000.

III. Research Methodology

The Pulogadung industrial area covered the total area of 15.61 Km2 with a percentage of 8.30%. Then in 2016, the area remained 15.61 Km2 with a percentage of 8.30%. Administratively, the Pulogadung sub-district consists of seven villages.[4]

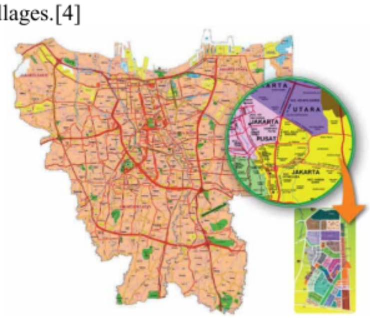

Fig. 2. Pulogadung Industrial Area Map[13]

Table VII demonstrates the mapping of techno-economic modeling scenarios using an optimistic scenario using a technical calculation to find the number of sites needed with outdoor to outdoor scenario based on uplink and downlink line of sight.

TABLE VII. SCENARIO TECHNO ECONOMIC

Optimis Scenario	
Outdoor to Outdoor	
Uplink Line of Sight	Downlink Line of Sight

IV. Scenario Simulation Results

A. Simulation Planning Based on Coverage

The 5G network is projected to be implemented in the Pulogadung industrial area[13]. After the implementation, the plan is simulated using Mentum Plannet ver 7.3.0 software using New Radio (NR) technology [15].

1) Simulation Scenario of Uplink Outdoor to Outdoor Line of Sight (LOS).

The scenario based on the calculation results in a total number of 19 sites. The placement of the gNodeB site was done using the Automatic Site Planning (ASP) method which has Mentum software. The ASP settings was done by entering the cell radius and the number of sites that have been calculated.

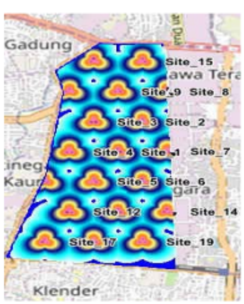

Fig. 3. ASP Scenario UL O2O LOS SS-RSRP

Meanwhile, the SS-RSRP simulation results on the coverage side in Table VIII indicate that the minimum power produced by SS-RSRP is -109.21 dBm, while the maximum is -61.06 dBm. Then, the average power produced by SS-RSRP is -109.21 dBm. RSRP of -61.06 dBm.

TABLE VIII. SIMULATION RESULTS OF SS-RSRP

SS-RSRP Value	**Percentage**	**Color**
-109,21 s/d -102,33 dBm	3,29 %	
-102,33 s/d -95,46 dBm	20,84 %	
-95,46 s/d -88.58 dBm	39,33 %	
-88.58 s/d -81.70 dBm	20,3 %	
-81.70 s/d -74.82 dBm	9,52 %	
-74.82 s/d -67.94 dBm	4,93 %	
-67.94 s/d -61,06 dBm	1,79 %	

Table IX and Fig. 4 present that the simulation results of SS-SINR parameters indicate the obtained maximum value of 21.03 dB, while the minimum value that SS-SINR has is -7.90 dB. Thus, the average value is 6.07 dB.

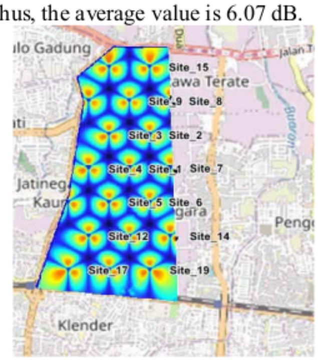

Fig. 4. ASP Scenario UL O2O LOS SS-SINR

TABLE IX. SIMULATION RESULTS OF SS-SINR

SS-SINR Value	**Percentage**	**Color**
-7,90 s/d -3,03 dB	3,45 %	
-3,03 s/d 1,82 dB	26,9 %	
1,82 s/d 6,69 dB	28,29 %	
6,69 s/d 11,56 dB	20,05 %	
11,56 s/d 16,4 dB	13,58 %	
16,4 s/d 21,30 dB	7,73 %	

2) Simulation Scenario of Downlink Outdoor to Outdoor Line of Sight (LOS).

The scenario based on the calculation results in a total number of 20 sites. The placement of the gNodeB site used the Automatic Site Planning (ASP). ASP enters the cell radius and the number of sites that have been calculated. Thus, the ASP will automatically place the site in its planning area.

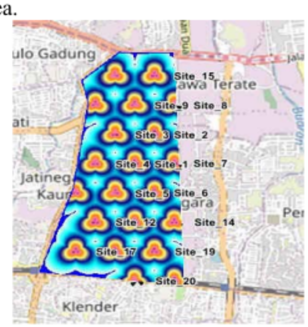

Fig. 5. ASP Scenario DL O2O LOS SS-RSRP

Based on the SS-RSRP simulation results on the coverage side, Table X shows the results that the minimum power generated by SS-RSRP is -110.96 dBm, while the maximum is -62.15 dBm. Thus, the average power produced by SS- RSRP is of -95.16 dBm.

TABLE X. SIMULATION RESULTS OF SS-RSRP

SS-RSRP Value	Percentage	Color
-110,96 s/d -103,99 dBm	7,82 %	
-103,99 s/d -97,02 dBm	44,01 %	
-97,02 s/d -90,04 dBm	25,71 %	
-90,04 s/d -83,07 dBm	12,44 %	
-83,07 s/d -76,10 dBm	5,81 %	
-76,10 s/d -69,13 dBm	2,95 %	
-69,13 s/d -62,15 dBm	1,26 %	

Table XI and Fig. 6 portray that the simulation results of the SS-SINR parameters result in the obtained maximum value of 52.80 dB, while the minimum value that SS-SINR has is -3.63 dB. Thus, the average value is 11.39 dB.

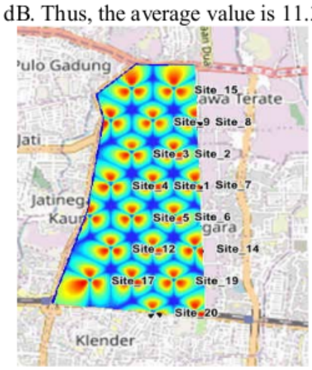

Fig. 6. ASP Scenario DL O2O LOS SS-SINR

TABLE XI. SIMULATION RESULT OF SS-SINR

SS-SINR Value	Percentage	Color
-3,63 s/d 5,77 dB	3,45 %	
-3,03 s/d 15,17 dB	26,9 %	
15,17 s/d 24,58 dB	28,29 %	
24,58 s/d 33,99 dB	20,05 %	
33,99 s/d 43,39 dB	13,58 %	
43,39 s/d 52,80 dB	7,73 %	

V. COST BENEFIT ANALYSIS

A. Revenue

To calculate future revenue predictions, we need to know the minimum revenue value for the previous 5 years from an operator being used.

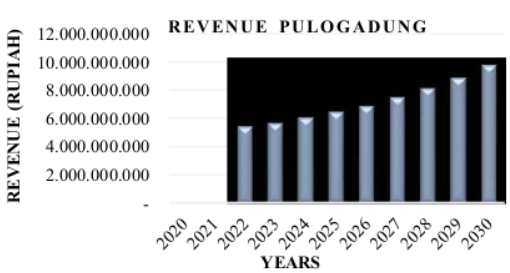

Fig. 7. Revenue of Pulogadung

Fig. 7, namely the projection on Pulogadung Revenue was calculated based on the number of subscribers. The graph shows that it continues to increase and the projection of 5G in the Pulogadung area constantly generates revenue with an average growth of around 3% because the population of the Pulogadung area is projected to continuously increase from 2020-2030.

B. Projected Capital Expenditure (CAPEX)

Capital Expenditure is the infrastructure of capital expenditure of the installation costs required in planning a cellular network. The gNodeB investment costs incurred by PT. Telkomsel are based on the calculation of the coverage scenario for Uplink and Downlink Outdoor to Outdoor Line of Sight.

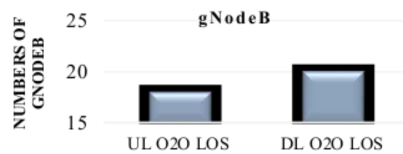

Fig. 8. gNodeB Scenario UL and DL O2O LOS

C. Projected Operational Expenditure (OPEX)

OPEX includes the assumption of Operational Maintenance costs, Backhaul Leases, Telkomsel's annual report data to calculate Interconnection, Pulogadung HR, Pulogadung Administration, Marketing, and BHP Frequency. The followings are projections from 2020 to 2030 based on Telkomsel's annual report.

Fig. 9. OPEX Scenario Projected UL and DL O2O LOS

Based on Fig. 9, at the beginning of the first investment in 2021, the amount was Rp. 8.866.33.168.61, the amount was Rp. 8,702,333,168.61. However, in the following years after the projection begins with the implementation of 5G, there will be an increase of customers per year which will affect the value of revenue and will reduce OPEX expenses since the projections have started running.

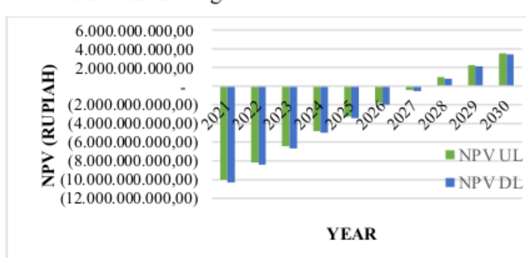

Fig. 10. Acumulative NPV Scenario UL and DL O2O LOS

Fig. 10 shows the results of the accumulative NPV calculations in the Uplink and Downlink scenarios from the graph. The NPV values in both scenarios are almost the same. The projection of the 5G New Radio (NR) performance which was carried out from 2021-2030 in the first year 2021-2026 shows negative results with the gradual decrease in negative number. Hence, it continues to experience an increase or net income starting from 2028. From Table XII the results of the overall accumulative NPV and IRR calculations based on the company's free cash flow, the NPV value of the 5G NR network planning in the Pulogadung Industrial Area shows NPV> 0 and positive output of IRR. the NPV and IRR outputs on the Uplink O2O LOS side are higher than the Downlink O2O LOS side, because they are influenced by the projected cost of the number of sites and the rental sites for DL LOS is higher than UL LOS.

TABLE XII. COST BENEFIT SCENARIO UPLINK AND DOWNLINK OUTDOOR TO OUTDOOR (O2O)

Cost Benefit	Net Present Value	Internal Rate of Retrun
Uplink Line of Sight	28.369.498.095,53	31,18 %
Downlink Line of Sight	24.862.173.071,28	26,68 %

VI. CONCLUSION

The simulation for the Downlink scenario Line of Sight shows that the power value of Synchronization Signal Reference Signal Received Power and Synchronization Signal Signal to Interference Noise Ratio is better than Uplink Line of Sight. This condition makes the downlink side as a better choice to apply in planning the 5G New Radio network. In terms of the economic calculation, the Cost Benefit in the techno-economic optimistic scenario indicates that in each scenario, the UL LOS NPV is Rp. 28,369,498,095.53 with an IRR of 31.18%, while the DL LOS NPV is of Rp. 24,862,173,071.28 with an IRR of 26.68%. This result shows that the 5G NR network performance in the Pulogadung Industrial Area is feasible, assuming that the calculation of projections for the next 10 years is implemented by an operator.

VII. FUTURE WORK

It is necessary that further research calculate the capacity to find the number of sites per year so that the required annual increase in traffic capacity is more accurate in proportion to the population growth of 5G New Radio users for the next 10 years. It is assumed that the price of capital and operational expenditures must be close to real data regarding 5G, by referring to countries that have implemented 5G NR.

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