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Comparative Analysis of Conventional (Financial, Network) and Optimized Mixed Integer Linear Programming Scenarios for Telecom Network Investment Decision Making

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Abstract

The telecommunications industry in Indonesia faces numerous challenges in allocating resources for network development, including network complexity, technological changes, market competition, and customer expectations. To achieve optimal financial outcomes and customer satisfaction, investments must be well-managed, well-placed, and well-executed. This study analyses network investment portfolio selection outcomes at Telkomsel; Indonesia's largest cellular operator, comparing conventional scenarios (financial and network) with an optimized scenario using Mixed Integer Linear Programming (MILP). The research evaluates these scenarios based on total portfolio score, incremental revenue, and Internal Rate of Return (IRR). Financial indicators such as net present value (NPV), IRR, EBIT margin, incremental revenue, and network indicators such as capacity and customer satisfaction (download/upload throughput, latency, packet loss, jitter) assess investment feasibility. The MILP optimization scenario strongly correlates with incremental revenue, NPV, and IRR, indicating higher financial performance. Sites selected in the MILP optimization scenario outperformed others in total score (22% better than the financial scenario, 63% better than the network scenario), incremental revenue (3.5% better than the financial scenario, 90.2% better than the network scenario), and portfolio IRR (4% better than the financial scenario, 70% better than the network scenario).

Keywords: *MILP, CAPEX, OPEX, Optimization, Telecommunication.*

INTRODUCTION

The telecommunications industry in Indonesia is essential to the national economy. However, it is currently in need of improvement. According to official data from the Central Statistics Agency (BPS), the telecommunications industry has slowed to an annual rate of 7.19%. (Selular. id, 2023). This slowdown is also reflected in Average Revenue per User/ARPU (average revenue per user), which measures the health of the telecommunications industry (Suharno, 2023). There are several main problems on the telecommunications industry in Indonesia, which were stated and discussed in the Cellular Business Forum (SBF) in 2023 (Suharno, 2023): relatively cheap data rates, limited and expensive frequency resources, an obligation to build in remote areas but minimal incentives, and policy injustice between cellular operators and providers of OTT (over the top) services. This can create unfairness in the industry. Telecommunications is one of the most investment-driven industries and is a sector that is considered the foundation of capital investment globally. According to the GSMA, mobile operators in Asia Pacific will spend 259 billion dollars during the 2023-2030 period (Intelligence, GSMA, 2023). However, compared to the previous period, the trend CAPEX is estimated to be stable and tends to fall as operators try to maintain the ratio CAPEX to revenue below a certain threshold.

Likewise the cellular operators in Indonesia, where it is expected to maintain the ratio of CAPEX against revenue of CAPEX will likely fall by 2030 to -27% compared with CAPEX 2023.

Network investment decisions are very difficult, optimizing CAPEX and OPEX is the main challenge. Operators must choose the maximum investment and satisfy customers with available CAPEX. Telkomsel's 2022 financial report shows total costs rose 19.6% YoY to 62,827 trillion rupiah, in line with efforts to optimize networks and Digital Business investments. However, revenue per megabyte (RPMB) decreased and the CAPEX to revenue ratio also decreased. (Telkomsel, 2022).

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Cellular operators face various challenges in allocating CAPEX for network development. Some of the main challenges include Network Complexity, Technological Change, Competition and Customer Expectations (pwc, 2020).

For maximum financial results and customer satisfaction, operators must invest in the right time, place and manner. Many operators are starting to use data science to determine the right investments, maximizing impact while adhering to commercial, financial and technical constraints, in the face of stiff competition (Tom Loosen, 2020). The above phenomenon shows that although the telecommunications business is expected to continue growing in revenue but also faces very tight competition.

In choosing a site for an investment portfolio, there are two scenarios, namely conventional and optimization. The financial scenario selects sites based on the largest incremental revenue with CAPEX and OPEX cost limitsyet ignoring network quality. The network scenario selects sites with the highest utilization to improve customer quality, also with limits on CAPEX and OPEX costs. These two scenarios represent the traditional approach. The optimization scenario uses mixed integer linear programming, selecting sites that provide the greatest revenue while considering network quality and cost constraints (Telkomsel, 2023).

In this research the author analyzes and compares the results of selecting an investment portfolio using a conventional scenario and an optimization scenario. Mixed Integer Linear Programming based on financial variables (NPV, IRR, EBIT margin, Incremental revenue) and network variables (Red Capacity Indicator, Competitive Customer Experience Indicator) considering the budget CAPEX and OPEX as a limitation in selecting the portfolio.

Net Present Value (NPV) is the difference between the present value of cash flows and outflows which indicates whether a project is worth accept or not (Sheridan Titman et al., 2018). Meanwhile Internal Rate of Return (IRR) is a financial metric used to evaluate the potential return on an investment (Vipond Team, 2021).

EBIT margin or Profit Margin before Interest and Taxes is a financial ratio that measures a company's profitability without considering the effects of interest and taxes (Ashish Kumar Srivastav, 2021). Whereas, incremental revenue refers to the additional income generated by a company during a certain period due to changes in the number of sales (Abhilash Ramachandran, 2022).

Red Capacity Indicator is a network indicator which describes the condition of the site which experienced a decrease in cell user experience that had reached below the 1.5 Mbps limit due to high capacity utilization. Whereas, Competitive Customer Experience Indicator is a measure of customer satisfaction with a network quality which uses direct measurement data from Telkomsel customers located in each area and compared with other competitors' customer measurements.

There are several previous research results related to methods that can help operators in choosing development investments networks. Buisset (2021) writes about methods that can help operators choose investments that will produce optimal ROI. Riactr in Buisset (2021) created a five-step methodology that can help operators optimize investment network strategies that is listing, profiling, modeling, scoring and selecting. (1) Listing: this process begins by listing all potential candidates for investment using a module machine learning such as SciPy, DBScan, and Geo Pandas which will provide a holistic view of all potential candidates. (2) Profiling: the second step involves creating a profile of the list of candidates who have been selected in the first step which integrates various internal data sources such as network (Call Data Records/CDRs, cell performance, coverage site, etc.) or CRM (existing customer revenue, product details and TAC list). (3) Modeling: the next step involves modeling and scoring each candidate using several predictive algorithms to forecast each site's financial potential over the next few years. (4) Scoring: the fourth step consists of score evaluation (using NPV) for each candidate. (5) Selecting: selection of sites as investment candidates network optimal plan that will maximize the impact of the entire plan within the operator's commercial, financial and technical constraints (Sophie Buisset, 2021).

This research aims to compare conventional scenarios (financial and network) with mixed integer linear programming optimization scenarios in determining investment decisions for developing telecommunications

operator networks at PT. Telkomsel. By considering financial and network variables such as NPV, IRR, EBIT margin, Incremental revenue, Red Capacity Indicator, and Competitive Customer Experience Indicator. This research is intended to answer the question about how the profile of each selected site portfolio with a mixed integer linear programming optimization scenario is, the relationship between network and financial variables with these scenarios, as well as descriptive comparative analysis between the results of portfolio selection from the two scenarios.

METHODS

This research is a quantitative study that uses numerical data and statistical analysis to produce results and conclusions. Through quantitative comparative methods, this research analyzes the relationship between several variables and the results of network investment decision selection. The variables are used include Red Capacity Indicator, Competitive Customer Experience Indicator, Incremental revenue, NPV, IRR, and EBIT margin. Each variable is operationalized and given a score based on the entire site being monitored. This research compares the results of portfolio selection using conventional scenarios with optimization scenarios using Mixed Integer Linear Programming, as well as conducting correlation tests between network and financial variables on the results of selecting network investment decisions using optimization scenarios. This method allows researchers to gain an in-depth understanding of the factors that influence investment decisions in developing telecommunications networks.

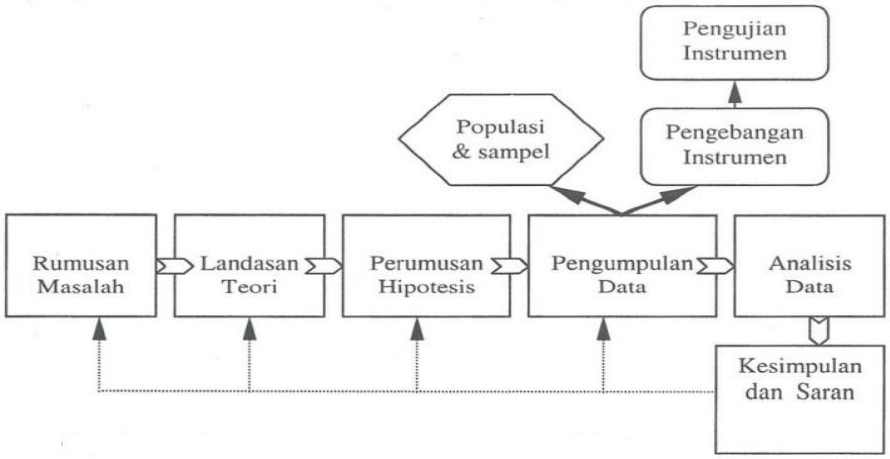

Figure 1. Stages Study Quantitative

(**Source:** Sugiyono, 2022)

This research follows the quantitative research guide by Sugiyono (2022), starting from problem identification to data collection and analysis. The population used was the PT. Telkomsel with purposive sampling method based on certain criteria. Data collection was carried out through literature studies and internal company documentation as well as data from Tutela crowdsources. Data analysis was carried out using descriptive statistics to describe financial and network variables, as well as to see the relationship between variables and the differences between conventional and optimization scenarios.

RESULT AND DISCUSSION

Analysis of Variables in Optimization Scenarios MILP

This research delves further into eight important variables which are divided into three groups: variables network which include RCI score and CX index, financial variables viz incremental revenue, mark NPV, IRR, and EBIT margin, as well as boundary variables (constraints) consisting of CAPEX and OPEX. This analysis aims to gain a more comprehensive understanding of how each variable interacts and influences the telecommunications business context.

Table 1 provides an overview of the distribution of each variable involved in the selection site which is included in the portfolio with optimization scenarios MILP. This is used by researchers to understand the characteristics of each variable site selected using an optimization scenario MILP.

Table 1. Distribution of network and financial variable values for MILP optimization scenarios

	rci_score	cx_index	Incremental Revenue	NPV
mean	0.43	0.73	465,757,500	1,265,950,000
std	0.60	0.55	113,761,300	407,896,800
min	0.00	0.00	168,602,700	177,369,600
perc. 25%	0.00	0.00	373,382,200	941,236,000
perc. 50%	0.00	0.91	457,574,500	1,231,448,000
perc. 75%	0.70	0.98	555,993,500	1,580,526,000
max	3.73	2.57	710,276,000	2,225,011,000

	IRR	EBIT Margin	CAPEX	OPEX
mean	1.28	0.68	217,386,900	76,734,630
std	0.39	0.09	65,611,760	2,317,113
min	0.33	0.10	168,400,000	74,140,460
perc. 25%	0.98	0.63	180,000,000	74,140,460
perc. 50%	1.20	0.69	200,000,000	76,067,040
perc. 75%	1.52	0.74	200,000,000	78,834,820
max	2.67	0.85	405,000,000	79,774,010

(Source: Data processed by the author, 2024)

Variable Analysis Red Capacity Indicator (RCI) Score

Variable network RCI score has a value of 0 to 4 where the higher the value indicates the greater the value site. The Company experienced capacity problems which caused a decline in user experience. RCI score is calculated for each site that goes in set list planning. For example, one site which is in site list planning is in place site 00003 in South Konawe district which is labeled red capacity indicator with a percentile of 17.49% among all sites who experienced red capacity. By using the formula, it is obtained that site 00003 will get an RCI score of 2.349.

The median value (50% percentile) is variable network RCI score, for all sites which are in site list planning, equal to 0 indicates that more than half sites have low value or have no capacity problems. This is natural because of the total site list only 42% are included in the planning site who are experiencing capacity problems (with value RCI score > 0). With an average value of RCI score is 0.43, with quite large variations (standard deviation 0.6). This is normal because not all sites decrease cell user experience which is below the 1.5 Mbps limit due to high capacity utilization.

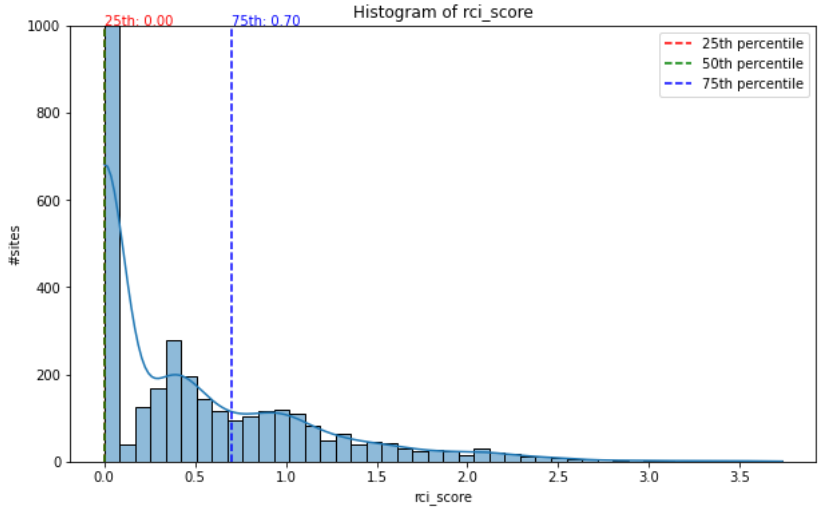

Figure 2. Distribution of RCI variables

(**Source:** Data processed by the author, 2024)

Variable Analysis Competitive Customer Experience Indicator (CX index)

Variable network CX index shows level user experience compared to other competitors. The greater the value CX index the greater the lag behind other competitors. For example in table 2, site 00038 has its own latency, packet loss and jitter which is superior to its best competitors however downlink throughput and uplink throughput is below its best competitor in terms of the five competition parameters site 00038 gets CX index of 1.58.

Table 2. Calculation of CX index per site

Indicator	Telkomsel	Best Competitor	Score	Weighting	Weighted score
DL throughput (Mbps)	2.3	4.9	2.13	40%	0.85
UL throughput (Mbps)	1	2	2.00	20%	0.40
Latency (ms)	40	50	0.80	20%	0.16
Packet loss (%)	1.00%	1.20%	0.83	10%	0.08
Jitter (ms)	35	40	0.88	10%	0.09
				CX index	**1.58**

(**Source:** Data processed by the author, 2024)

The network CX index variable shows the level of user experience compared to other competitors. The greater the CX index value, the greater the lag behind other competitors. For example, in table 4.2, site00038 has superior latency, packet loss and jitter compared to its best competitors, but downlink throughput and uplink throughput are below its best competitors so that from the five competition parameters, site00038 gets a CX index of 1.58.

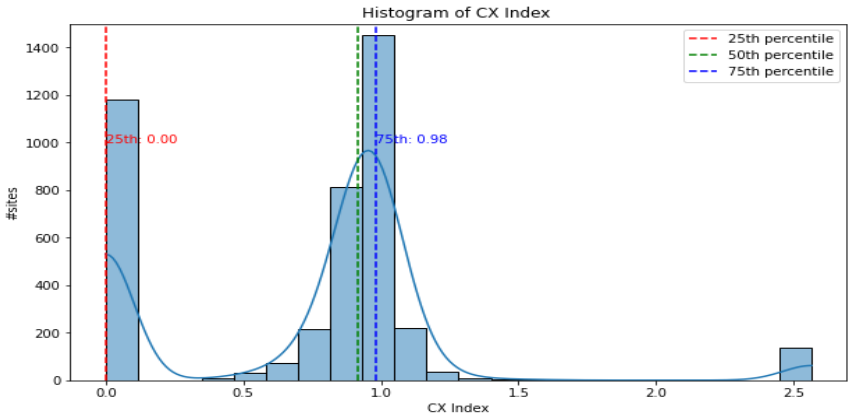

Figure 3. Distribution of the CX index variable

(**Source:** Data processed by the author, 2024)

Variable Analysis Incremental Revenue

Incremental revenue is a prediction of additional revenue generated by a company site on revenue currently accumulated over a one year period. Incremental revenue average of site list included in the planning is around 465.7 million with significant variations (standard deviation 113 million). Median Incremental revenue lower than the average, namely around 457.5 million, indicating that there is site which has incremental revenue very high ones that raise the average. Minimum incremental revenue which was obtained was 168.6 million rupiah, far above the overall median value site included in the planning proposal is 146 million rupiah.

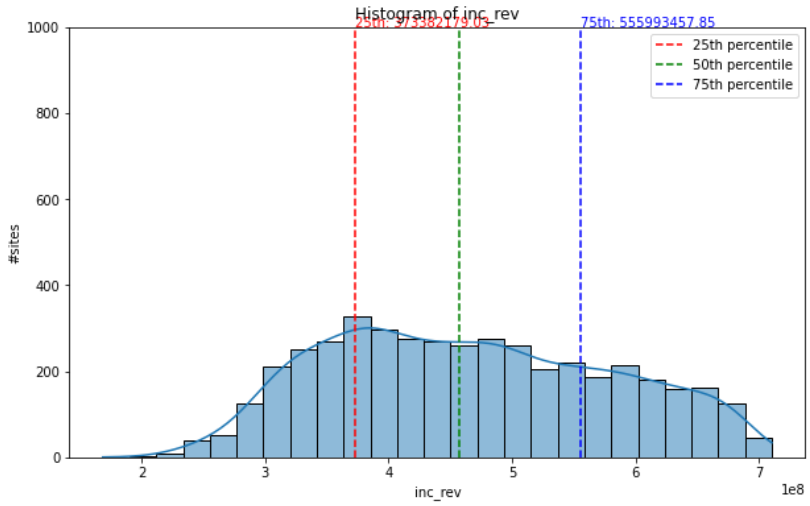

Figure 4. Distribution of the Incremental revenue variable per site

(**Source:** Data processed by the author, 2024)

Variable Analysis NPV

From the financial side, variables such as NPV and IRR show investment performance, temporary EBIT margin depicts operational profitability. NPV is calculated for each site proposed in development planning. It can be seen in one site 00002 in Bombana district which is planning development LTE 2300 8T8R 40 MHz with CAPEX amounting to 250.7 million rupiah and OPEX 76.06 million rupiah with incremental revenue amounting to 103.58 million rupiah in year first and 228.72 million rupiah in year second to seventh. By WACC which has been set by the company at 10.12% is obtained NPV during site the amount is 274.6 million rupiah.

Site : Citi00002

Regency : Bombana

Development plan : LTE2300 8T8R 40MHz

CAPEX : IDR 250,700,000

OPEX : IDR 76,070,000

Table 3. Calculation of NPV per site

	formula	Year 0	Year 1	Year 2 - 7
Additional full year revenue predicted	a		103,582,564	228,729,683
Opex	b		76,067,040	76,067,040
EBITDA	c = a - b		27,515,524	152,662,643
Capex	d	250,700,000		
Depresiasi	e = d/7		35,814,286	35,814,286
EBIT	f = c - e		(8,298,761)	116,848,358
EAT	g = f * (1- tax)		(8,298,761)	91,141,719
Net Cash Flow	h = g + e	(250,700,000)	27,515,524	126,956,005
WACC	i	10.12%	10.12%	10.12%
Discount Factor	$j = 1 / (1+i)^t$	1.00	0.91	[0.82, 0.75, 0.68, 0.62, 0.56, 0.51]
PV	k = i * j	(250,700,000)	24,986,855	500,351,873
NPV	∑ k	274,638,727		

(**Source:** Data processed by the author, 2024)

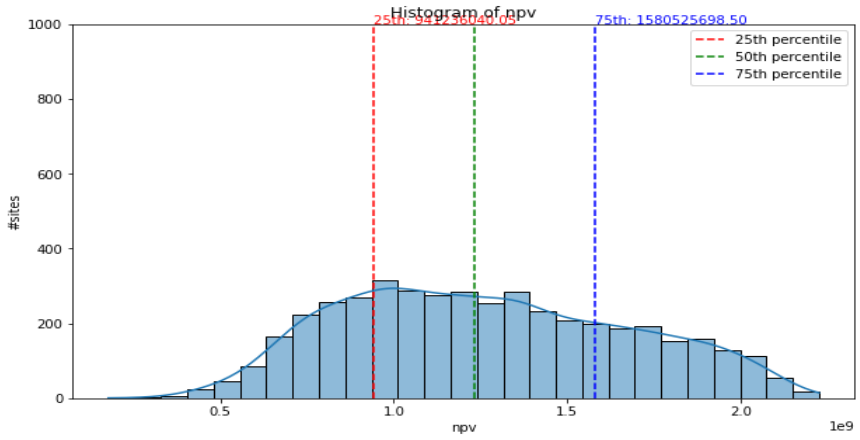

Figure 5. Distribution of NPV variables per site

(**Source:** Data processed by the author, 2024)

This analysis illustrates that NPV sites which are included in the portfolio selected using the optimization scenario MILP have an average value of around 1.26 billion rupiah. However, the variability is high that can be seen from the standard deviation of around 407.8 million rupiah. NPV has a minimum value that remains positive 177.4 million rupiah, which shows the overall site which is included in the portfolio selected using the optimization scenario MILP is worth the investment.

Variable Analysis IRR

IRR is calculated based on interpolation with iteration to determine the resulting value NPV=0. Financial calculations include IRR calculations is conducted by using a Python script as in Figure 6 below.

```python
def compute_finance_metric(
    metric_df, wacc, gap_time_arr, sensitivity_arr, capex_portion, tax, useful_life, months=12):
    temp_df = metric_df.copy()
    temp_df['revenue_from_investment'] = temp_df['incremental_revenue'].apply(lambda x: np.array(x) * 1 * 1)

    # Step 2: Compute annual opex
    temp_df['annual_opex'] = temp_df['opex'].apply(np.array) * 1

    # Step 3: Compute ebitda
    temp_df['ebitda'] = temp_df['revenue_from_investment'] - temp_df['annual_opex']

    # Step 4: Compute depreciation
    temp_df['full_capex'] = temp_df['capex'] / 1
    temp_df['depreciation'] = (temp_df['full_capex'] / useful_life)

    # Step 5: Compute EBIT
    temp_df['ebit'] = temp_df['ebitda'] - temp_df['depreciation']

    # Step 6: Compute tax to be paid
    temp_df['tax_paid'] = temp_df['ebit'].apply(lambda arr: np.maximum(arr * tax, 0))

    # Step 7: Compute EAT
    temp_df['eat'] = temp_df['ebit'] - temp_df['tax_paid']

    # Step 8: Compute net cashflow
    temp_df['net_cf'] = temp_df.apply(lambda x: np.hstack([-x['full_capex'], x['eat'] + x['depreciation']]), axis=1)

    # Step 9: Compute NPV
    temp_df['npv'] = temp_df['net_cf'].apply(lambda x: npf.npv(wacc, x))

    # Step 10: Compute IRR
    temp_df['irr'] = temp_df['net_cf'].apply(irr)

    # Step 11: Compute profitability
    temp_df['profitability'] = temp_df.apply(lambda x: x['ebit'][0] / np.abs(x['revenue_from_investment'][0]), axis=1)

    return temp_df
```

```
def irr(values, guesses=[0.1, -0.5, -1.1, -1.5], tol=1e-12, maxiter=100):
    values = np.atleast_1d(values)
    if values.ndim != 1:
        raise ValueError("Cashflows must be a rank-1 array")

    # If all values are of the same sign no solution exists
    # we don't perform any further calculations and exit early
    same_sign = np.all(values > 0) if values[0] > 0 else np.all(values < 0)
    if same_sign:
        return np.nan

    npv_ = np.polynomial.Polynomial(values)
    d_npv = npv_.deriv()

    for guess in guesses:
        x = 1 / (1 + guess)
        for _ in range(maxiter):
            x_new = x - (npv_(x) / d_npv(x))
            if abs(x_new - x) < tol:
                return 1 / x_new - 1
            x = x_new

    return np.nan
```

Figure 6. IRR calculation per site

(**Source:** Author, 2024)

Site00002 in Bombana district in one of the IRR calculations with CAPEX, OPEX, incremental revenue from the first year to the seventh year, Net Cash flow as in the NPV calculation above, produces an IRR calculation of 34.05%.

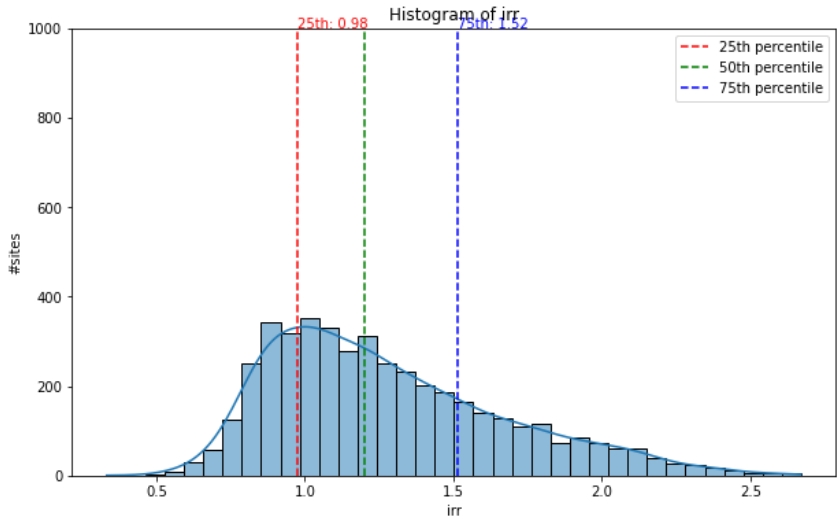

Figure 7. Distribution variable IRR per site

(**Source:** Data processed by the author, 2024)

The IRR average of all sites which are included in the portfolio selected using the optimization scenario MILP was 128%, with quite wide variation (standard deviation 39%). There is no value IRR all over site included in the portfolio, with a minimum IRR 33%, which represents the overall investment of each site it is profitable.

Variable Analysis EBIT Margin

In calculations of EBIT margin on one site 18987 in Probolinggo City, with CAPEX amounting to 180 million rupiah, OPEX 78.8 million rupiah and incremental revenue amounting to 116 million rupiah in first year obtained positive EBIT margin 10.02% as seen in the calculations in table 4.

Table 4. Calculation of EBIT margin per site

	formula	Y0	Y1
Additional full year revenue predicted Y1	a	-	116,191,919
Opex	b	-	78,834,817
EBITDA	c = a - b	-	37,357,102
Capex	d	180,000,000	-
Depresiasi	e = d/7	-	25,714,286
EBIT	f = c - e	-	11,642,816
MARGIN EBIT	m = f / a	10.02%	

(**Source:** Data processed by the author, 2024)

The EBIT margin average of all sites which entered the selected portfolio using an optimization scenario MILP was 68% with very small variations (standard deviation 9%). There are no negative values on the EBIT margin, showing the overall possibility that those selected experience operational benefits.

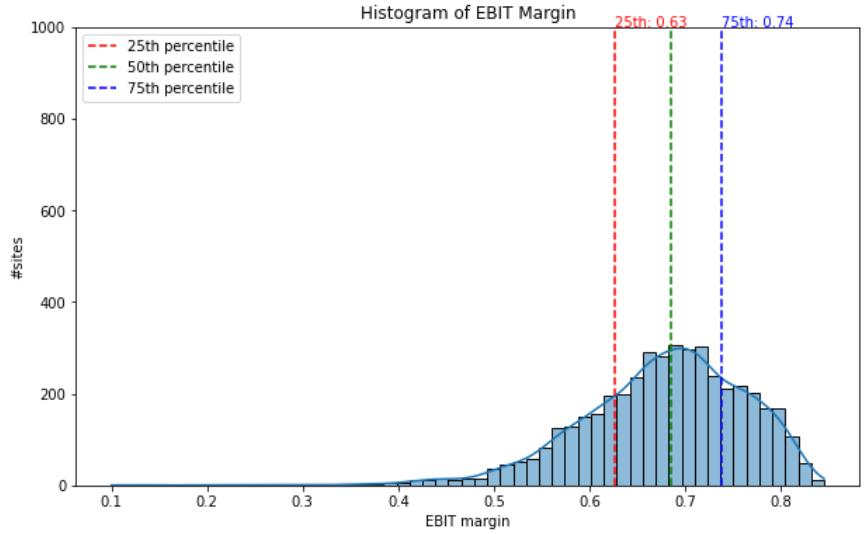

Figure 8. Distribution of EBIT margin per site

(**Source:** Data processed by the author, 2024)

Variable Analysis CAPEX and OPEX

The constraint variables, CAPEX and OPEX, provide an overview of the site development costs. An average CAPEX of 217.3 million indicates large capital expenditures, while consistent OPEX between sites indicates stable operational costs. This analysis is important for understanding the impact of investment and portfolio decisions. CAPEX variations are smaller (standard deviation 65.6 million) with the majority below 200 million rupiah, while OPEX is relatively stable (standard deviation around 2.3 million), depending on the solution per site.

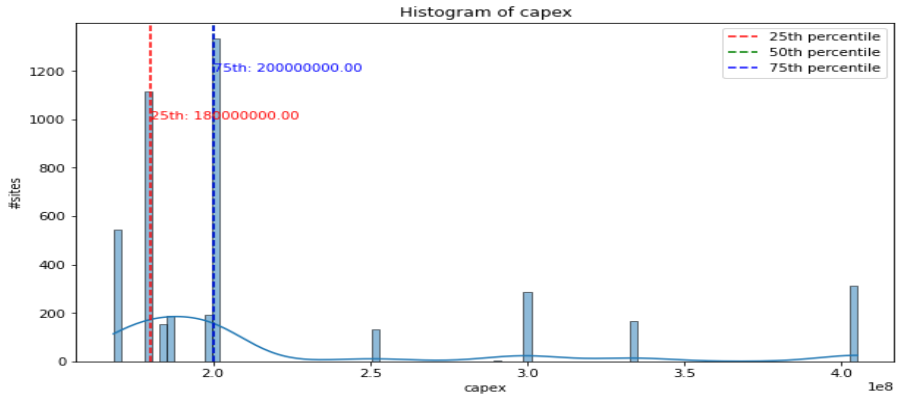

Figure 9. CAPEX distribution per site

(**Source:** Data processed by the author, 2024)

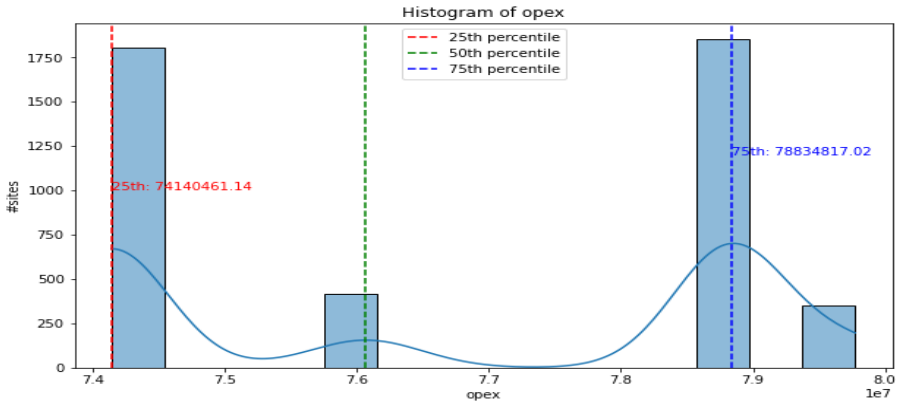

Figure 10. OPEX distribution per site

(**Source:** Data processed by the author, 2024)

Analysis of the Relationship/Correlation Between Variables with Optimization Scenarios MILP

Correlation Analysis Between Variables

In this analysis, the correlation between variables network, finances, and boundaries are examined to see how they relate and influence each other. Correlation between variables is good network, financial and constraints seen in the following table.

Table 5. Pearson correlation of network variables

	rci_score	cx index	Incremental Revenue	NPV	IRR	EBIT Margin	CAPEX	OPEX
rci_score	1.00	-0.12	0.13	0.12	-0.01	0.03	0.12	-0.19
cx index	-0.12	1.00	-0.16	-0.15	-0.02	-0.07	-0.14	0.03
Incremental Revenue	0.13	-0.16	1.00	0.99	0.67	0.76	0.37	-0.05
NPV	0.12	-0.15	0.99	1.00	0.76	0.80	0.25	-0.05
IRR	-0.01	-0.02	0.67	0.76	1.00	0.78	-0.40	0.11
EBIT Margin	0.03	-0.07	0.76	0.80	0.78	1.00	0.06	-0.03
CAPEX	0.12	-0.14	0.37	0.25	-0.40	0.06	1.00	-0.11
OPEX	-0.19	0.03	-0.05	-0.05	0.11	-0.03	-0.11	1.00

(**Source:** Data processed by the author, 2024)

From table 5, it can be seen RCI score and CX index has a low negative correlation (-0.12) which shows that sites which have high capacity utilization are in areas where Telkomsel is dominant so they have CX index or low competition. Whereas sites which have the highest CX index are in areas that have high competence where Telkomsel already has capacity that has not been fully filled. This data indicates that sites with high capacity are often located in areas with low competition. This shows the dynamics between capacity and competitiveness in the telecommunications business.

The RCI score is positively correlated with financial variables, indicating that an increase in the RCI score slightly increases incremental revenue, NPV, and EBIT margin, indicating increased capacity improves financial performance. The CX index tends to have a weak negative correlation with financial variables, indicating that sites with a high CX index have low or unidentified financial potential. The very strong and positive correlation between incremental revenue, NPV, and IRR shows that increasing incremental revenue increases NPV and IRR significantly. Incremental revenue below 136 million per year tends to produce negative IRR, but the MILP optimization scenario selects sites with positive IRR, although some are still below the company's target of 13.35% IRR.

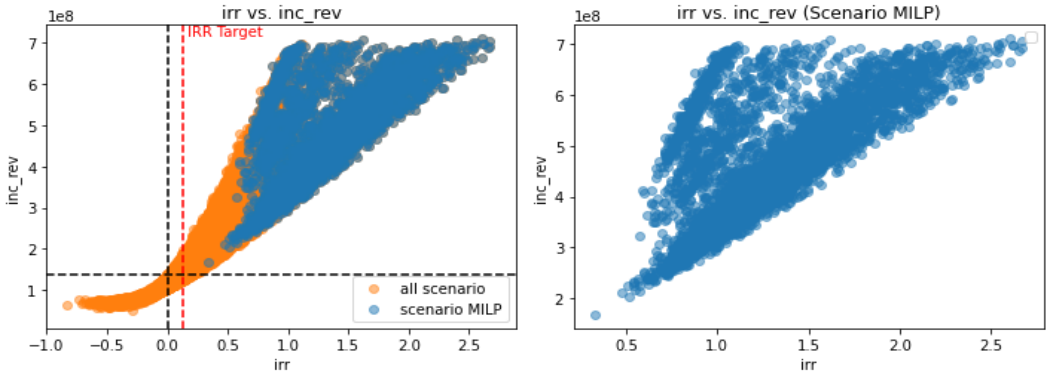

Figure 11. Correlation of IRR vs incremental revenue

(**Source:** Data processed by the author, 2024)

Meanwhile, in Figure 12, it can be seen incremental revenue per year under 180 million tends to give NPV negative. Thus, to get NPV positive and IRR above the company target, a site with incremental revenue 191 million per site is required.

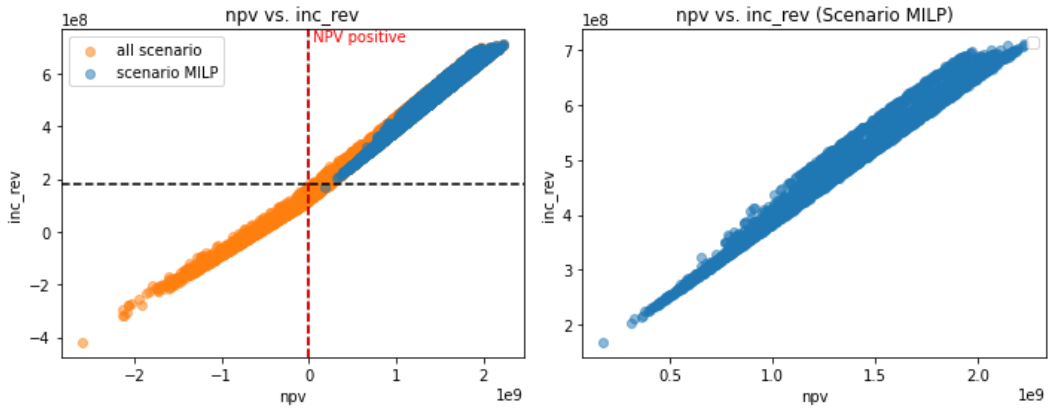

Figure 12. Correlation of NPV vs incremental revenue

(**Source:** Data processed by the author, 2024)

Incremental revenue has a moderate correlation with EBIT margin and a very weak positive correlation with CAPEX and OPEX which can be seen in table 5. Figure 13 shows that the higher incremental revenue is correlated with higher EBIT margin, but only has a small influence on capital expenditure/CAPEX and operational costs/OPEX. EBIT margin tends to be negative when incremental revenue under 133 million.

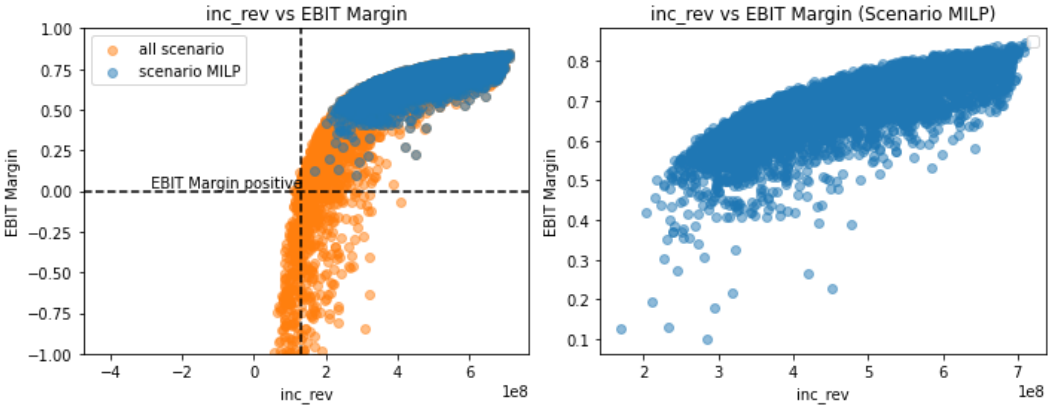

Figure 13. Correlation of incremental revenue vs EBIT margin

(**Source:** Data processed by the author, 2024)

In figure 14, NPV has a fairly strong correlation with EBIT margin, indicating that the value of NPV is often associated with increased profitability. From figure 14, it can also be seen that NPV has a negative tendency when EBIT margin below 10.8%.

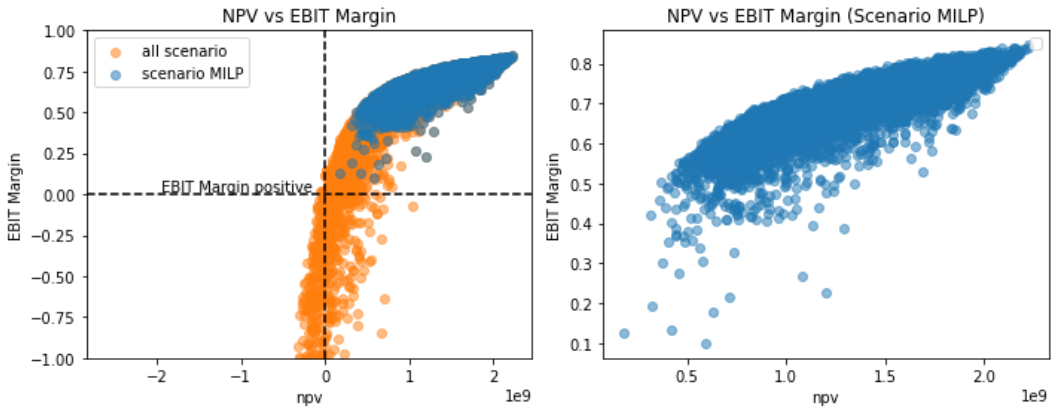

Figure 14. Correlation of NPV vs EBIT margin

(**Source:** Data processed by the author, 2024)

Overall, this correlation matrix shows that financial variables such as incremental revenue, NPV, and IRR are very closely related to each other. On the other hand, variables such as RCI score and CX index appear to have a more limited and inconsistent influence on other financial and operational variables.

Correlation Analysis between Variables and Targets for Financial Scenarios, Network and Optimization MILP

Correlation between variables network and financials against various scenarios offers a broader view of how these variables influence decisions in different scenarios. Correlation between variables is good network, financial to financial scenarios, network and optimization MILP seen in the following table

Table 6. Correlation of input variables and targets for each scenario

	Scenario		
	Optimasi MILP	finance	network
rci_score	0.14	0.16	0.83
cx index	-0.10	-0.13	-0.07
Incremental Revenue	0.65	0.70	0.20
NPV	0.64	0.66	0.19
IRR	0.75	0.70	0.11
EBIT Margin	0.02	0.01	0.01

(**Source:** Data processed by the author, 2024)

Site selected by the optimization scenario MILP has a very strong positive correlation with incremental revenue (0.65), NPV (0.64), and IRR (0.75). This shows that the site selected by the optimization scenario MILP really gives a high weight to the financial aspect and has the potential to provide incremental revenue, NPV and IRR higher. This analysis found that in this scenario IRR has a very high correlation and is the highest compared to other scenarios, this indicates that the optimization performance is based on the search target IRR portfolio works fine.

Site selected financial scenarios also have a strong positive correlation with incremental revenue (0.70), NPV (0.66), and IRR (0.70). This analysis found that in the financial scenario, there is a very strong correlation with incremental revenue, NPV, and IRR, indicating a focus on financial aspects in the election site. This is very closely related to the financial scenario mechanism which prioritizes based on incremental revenue.

Sites selected by scenario networks have a very high correlation with RCI score (0.83) indicates that scenario networks give high weight to RCI score in election sites. Scenario network also has a positive relationship with incremental revenue, NPV and IRR, but not as strong as the relationship with RCI score. This may indicate

that the site selected by the scenario network also affects income and financial performance, but not as strongly as it does RCI score. This indicates that the financial aspect is not in the priority capacity network.

Figure 15 represents unselected site and the selected one are selected based on the comparison between IRR and NPV in three different scenarios.

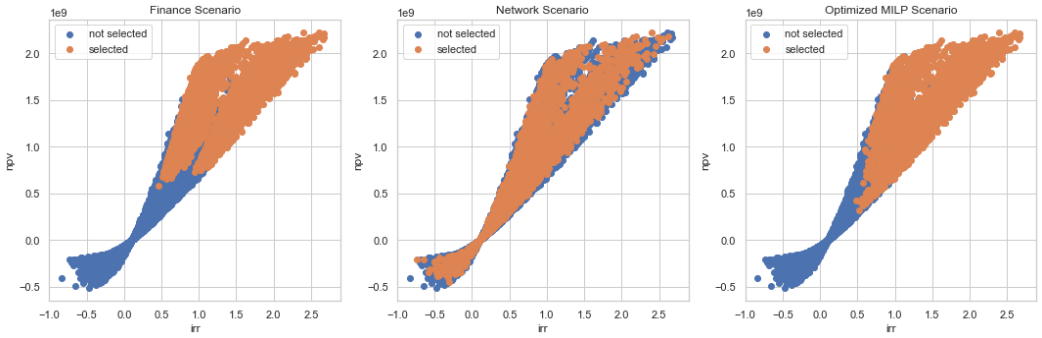

Figure 15 Correlation of IRR vs NPV

(**Source:** Data processed by the author, 2024)

In all scenarios, for the most part, the chosen one has NPV positive and IRR which is positive, although there are some exceptions, especially in the scenarios network. While the whole site is selected using an optimization scenario, MILP owns IRR positive and NPV positive. This shows the optimization performance MILP which works well.

There is a visible relationship between NPV and IRR in all scenarios, with sites that have a high positive IRR tending to also have a high NPV. This is consistent with the financial understanding that projects with higher rates of return often also create greater value.

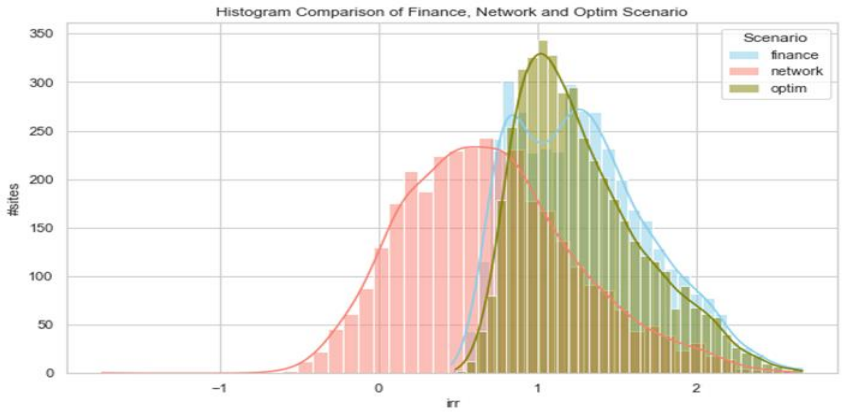

Figure 16. IRR distribution per site for each scenario

(**Source:** Data processed by the author, 2024)

In financial and optimization scenarios MILP, all chosen sites has positive IRR and NPV . Selected sites by the optimization scenario MILP have distribution IRR slightly better than the financial scenario, as seen in figure 16. Optimization scenarios MILP owns a site with a minimum IRR 33% while in the financial scenario it has a site with a minimum IRR 30%. This is because the algorithm in the optimization scenario choose the site which produces the best IRR portfolio.

It is different from the scenario network who chose some site which has negative IRR or NPV. This is normal because the scenario network does not consider financial factors at all and only focuses on RCI score.

Profile Site and Portfolio Comparison between Scenarios

Comparison of Each Scenario's Portfolio

Election site which is included into portfolio, which involves financial scenarios, network as well as optimization mixed integer linear programming (MILP), has limitations CAPEX and OPEX taken from site list development proposal network the same one. In this research, using site list development proposal network of Telkomsel on first quarter in 2023 as a reference. These three scenarios are carried out the following budget constraints with CAPEX amounting to 1 trillion Rupiah and OPEX 350 billion Rupiah.

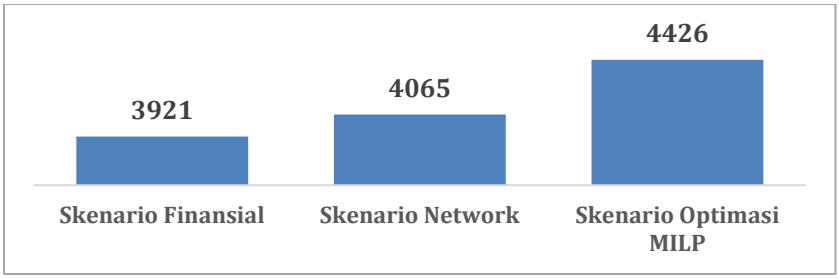

Figure 17. Comparison of the number of sites selected by each scenario

(**Source:** Data processed by the author, 2024)

With the same CAPEX and OPEX budget constraints, it can be seen that the financial scenario accommodates the fewest number of sites compared to other scenarios with 3921 sites. Followed by a network scenario with 4065 sites and optimization scenarios MILP with 4426 sites. This shows that the optimization scenario MILP is able to provide the widwer site which is 13% more compared to the financial scenario, confirming the superiority of the optimization approach MILP in managing resources more efficiently in tight budget conditions.

Absorption Comparison CAPEX and OPEX in the Portfolio of Each Scenario

Optimization Scenario MILP is leveraging advanced optimization techniques to maximize network efficiency and performance in the face of tight budget constraints. This scenario successfully selects the amount site the most, namely 4,426, which shows a strong commitment to wider network coverage expansion and significant capacity increases.

According to data from Figure 18, although accommodating the most site, optimization scenarios MILP continues to succeed in maintaining efficiency in managing funds by using CAPEX which is 4% lower compared to the other two scenarios, indicating a very high effectiveness of capital use. Average CAPEX per site in an optimization scenario MILP is 217.47 million Rupiah, which is lower than the average financial scenario CAPEX per site amounting to 255 million Rupiah and scenarios network with 246 million Rupiah.

Efficiency in selection sites reflects a more careful and measured approach to allocating financial resources, with a focus on achieving maximum returns from the investments made.

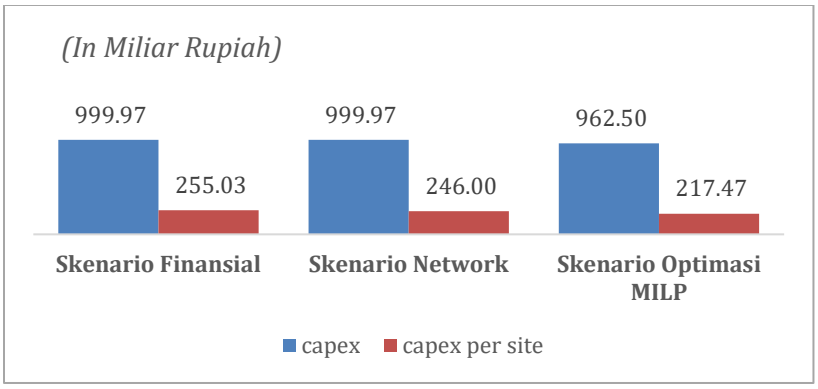

Figure 18. Comparison of CAPEX usage for each scenario

(**Source:** Data processed by the author, 2024)

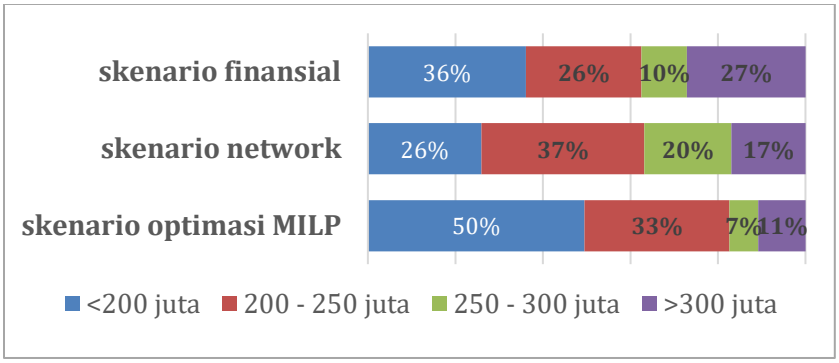

Figure 19. Comparison of CAPEX distribution per site for each scenario

(**Source:** Data processed by the author, 2024)

Optimization scenarios MILP take a lot of sites requiring low CAPEX, namely under 200 million Rupiah. From a comparative analysis of distributions of CAPEX per site in Figure 19, it can be seen that even though the optimization scenario MILP covers more sites, CAPEX cost per site remains lower, namely 17% lower than the financial scenario and 13% lower than the scenario network. This shows higher efficiency in capital utilizationwith the most site, the optimization scenarios MILP possibility offers the best network coverage and capacity which is critical in meeting increasing data demands and ensuring customer satisfaction.

This efficiency in site selection reflects a more careful and measured approach in allocating financial resources, with a focus on achieving maximum results from the investments made.

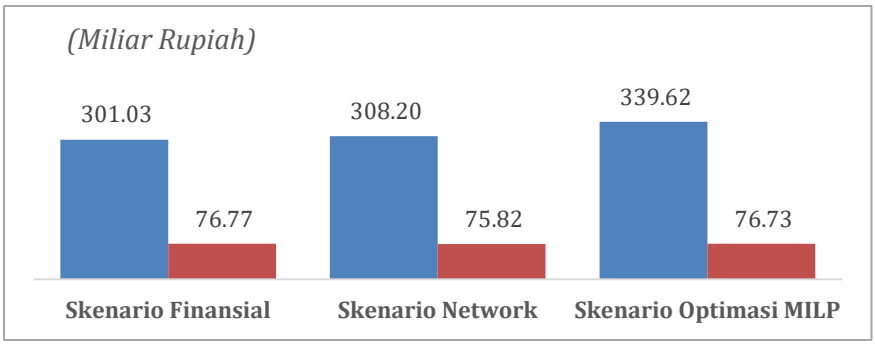

Figure 20. Comparison of OPEX usage for each scenario

(**Source:** Data processed by the author, 2024)

From a usage perspective OPEX, based on Figure 20, it can be seen that the optimization scenario MILP have uses OPEX which is higher, namely 339.62 billion Rupiah, compared to the financial scenario and network each of which has a use OPEX amounting to 301.03 billion rupiah and 308.20 billion rupiah. However, the MILP optimization scenario handles a larger number of sites. This results in OPEX per site that is quite competitive and similar to financial and network scenarios.

The height OPEX in an optimization scenario MILP indicates more substantial investment in maintenance, operations, and service improvements, which result in increased network quality and capacity. Although at first glance it looks more expensive, it increases in OPEX use. This is actually justified by the additional site which can ultimately offer better coverage and connectivity for users.

Therefore, although nominally an optimization scenario MILP seems to be using larger OPEX, but from the perspective of the value obtained per site, this investment can be considered efficient. Taking into account the higher quantity site that can be accommodated, OPEX incurred in the optimization scenario MILP demonstrated optimal budget utilization, by prioritizing wider network expansion without sacrificing overall operational cost efficiency. This strengthens the argument that the optimization scenario MILP, although with higher OPEX is a superior strategy in the long term to achieve the goal of continuous growth and improvement of network services.

Comparison of Total Score Portfolio

From the histogram in Figure 21, it shows the distribution of the total scores for each site, we can clearly observe how each financial scenario, network, and optimization MILP in making elections site. Through this histogram, we can see the different approaches and priorities used in each scenario.

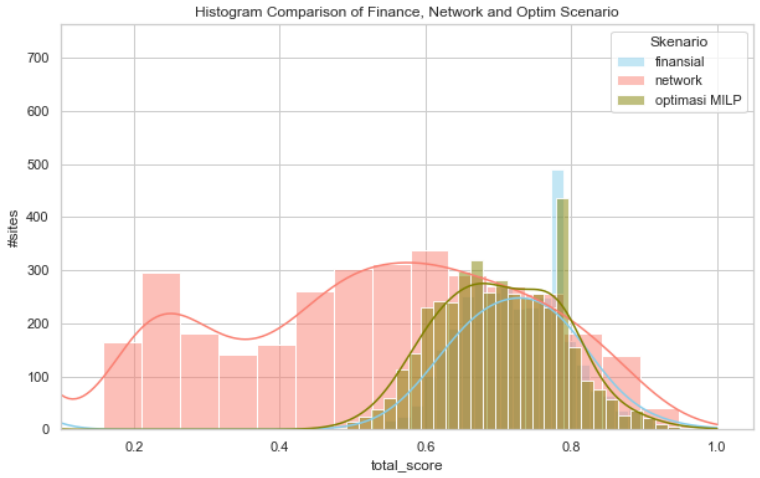

Figure 21. Distribution of total scores per site for each scenario

(**Source:** Data processed by the author, 2024)

The financial scenario stands out with the spread site who has a high score. This can be explained by the dominant weight of financial variables in determining scores, namely 70%, compared to variable networks which is only 30%. In line with its focus on finances, this scenario tends to be a selective site which gives the highest incremental revenue, which is reflected in the abundance site with a higher total score.

On the other hand, optimization scenarios MILP shows a slightly wider distribution than the financial scenario, although it has similar median values. This may indicate that the optimization scenario MILP combines various factors in the assessment site, not only financial, but also additional variables or considering more flexibility in the selection site.

Meanwhile, scenario networks have quite significant variations between sites, with most sites congregating around lower values. This could be the result of RCI. The score is the determining factor in the scenario network, where the variable network has a lower weight compared to financial variables. This indicates that the scenario network focuses more on factors such as quality network or potential synergies, which may not be directly correlated with high revenues but are considered important for long-term and operational sustainability.

Furthermore, the score distribution in the scenario network indicates that the selection decision site in this scenario is influenced by strategic and technical considerations than by direct financial. This scenario may be better considering various aspects such as service coverage, network capacity, and improving the quality of service for customers. This represents a more comprehensive approach in considering the operational future and development of the network as a whole.

Thus, the differences between these three scenarios reflect different priorities and strategies in investment decision making, where the financial scenario is more oriented towards direct profit, optimization scenarios MILP combining various factors for a more balanced approach, and scenarios network more emphasis on long-term strategic considerations and service quality.

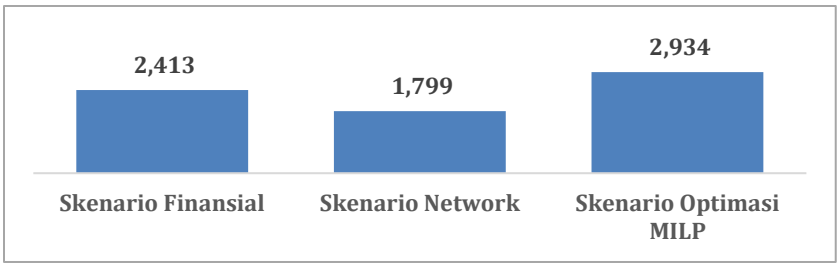

Figure 22. Comparison of total portfolio scores for each scenario

(**Source:** Data processed by the author, 2024)

From Figure 22 which compares the total portfolio scores for the three scenarios, namely financial, network, and optimization MILP, we can see that optimization scenario MILP excelled by providing the highest total portfolio score reaching 2934. This indicates the effectiveness of the optimization method MILP in choosing a combination site or the project that overall provides the best value.

The financial scenario, with a total portfolio score of 2413, shows competitive results, although not as high as the optimization scenario MILP. This illustrates that, although the main focus is on financial aspects, this scenario is able to identify portfolio sites which resulted in significant scores, reaffirming the importance of financial aspects in determining scores.

Meanwhile, scenario network, which has a total portfolio score of 1799, is the lowest among the three. While this value may seem lower, it is important to remember that this scenario may prioritize other aspects such as quality network or potential synergies that may not be directly reflected in financial value.

The differences between the optimization scenarios are striking MILP with other scenarios, which provides an increase in the total portfolio score of 22% compared to the financial scenario and 63% compared to the scenario network, indicates that the integration of various factors is carried out by optimization MILP not only able to produce superior results quantitatively but also more balanced in considering various aspects of the assessment. The use of optimization models MILP in the latter scenario appears to provide a more holistic strategy in valuation, allowing companies to identify portfolios that are not only high performing financially but also overall according to various criteria considered important in the overall assessment.

This can include factors such as risk, sustainability and future growth potential. Thus, the optimization scenario MILP provides a more comprehensive and balanced approach, allowing companies to achieve the best results by taking into account multiple important variables simultaneously. This shows that the optimization approach

of MILP not only focuses on short-term profits but also considers long-term sustainability and growth, creating a portfolio that is stronger and adaptive to changing market conditions and technology.

Comparison Incremental revenue Portfolio

Based on Figure 22 which shows the distribution of incremental revenue per site for each scenario, it can be seen that the financial scenario has the highest peak and is furthest to the right. This indicates that there is project concentration with high incremental revenue in that scenario. Thus, it can be concluded that the sites in the financial scenario, in general, generate higher incremental revenue than the other two scenarios, and show higher consistency in the portfolio's financial performance.

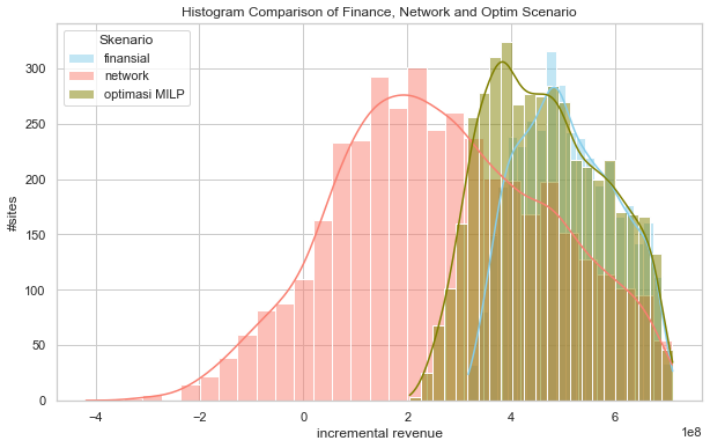

Figure 23. Distribution of incremental revenue per site for each scenario

(**Source:** Data processed by the author, 2024)

The distribution of incremental revenue in the scenario network shows significant variations between sites, with most site clusters around the lower value. However, there are also some sites who reach incremental revenue which is quite high, indicating the presence of several site flagships that perform well in this scenario.

For optimization scenarios MILP, distribution incremental revenue shows that site in this scenario generally have more consistent results with incremental revenue which ranges from higher values than the scenario network. This indicates that the quality of the project was selected through an optimization process MILP tends to be better at incremental revenue, reflecting the efficiency of the optimization approach used.

Based on figure 24, the total incremental revenue of the portfolio per year of the financial scenario is recorded to have a higher total than the scenario network, namely 1991.1 billion Rupiah. This indicates that the financial scenario is more effective in generating income from the selected site. The networks scenario has a total incremental revenue portfolio of 1083.74 billion Rupiah, which is the lowest amount among the three scenarios. This data is in line with the histogram showing a wider distribution with most projects converging on the lower values.

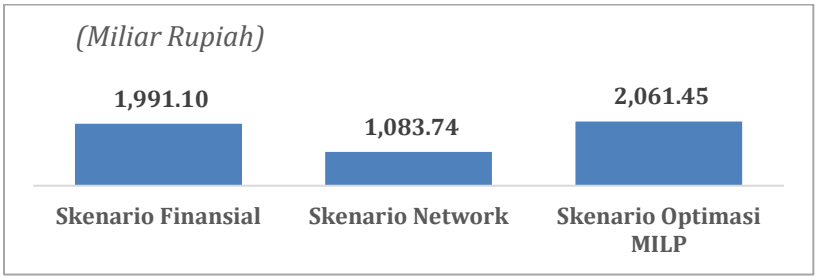

Figure 24. Comparison of incremental revenue portfolio for each scenario

(**Source:** Data processed by the author, 2024)

Optimization scenarios MILP shows the total incremental revenue of the highest portfolio, namely 2061.45 billion Rupiah. This value is 3.5% higher than the financial scenario portfolio and 90.2% higher than the scenario network. This shows that although the amount of sites that generate high revenue may be fewer in an optimization scenario MILP, the optimization approach used tends to produce portfolios with greater overall returns. Thus, the optimization approach MILP proved to be superior in maximizing the total incremental revenue portfolio.

Comparison IRR Portfolio

From a histogram showing the distribution IRR of each site, we can see what the financial scenario is like, network, and optimization. MILP chooses sites based on IRR.

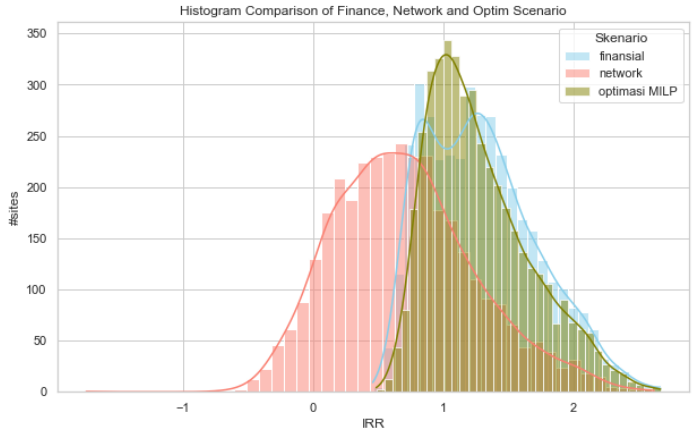

Figure 25. IRR distribution per site for each scenario

(**Source:** Data processed by the author, 2024)

Financial scenario: choose a site which has an IRR which is quite high in the range of 45% to 260% with a median value of 120%. This is in line with the profile incremental revenue, where the financial scenarios are selected based on the order site with the highest incremental revenue according to budget CAPEX and OPEX allocated.

The distribution of IRR for network scenarios, which has is low peak in IRR value and includes negative values, indicating that this scenario includes projects that have the potential for lower returns and even losses. Network scenario owns IRR site ranged from -170% to 260% with the median value at 66%. This approach can be interpreted that network scenario is not solely focused on financial profits but also on other aspects such as infrastructure development, strengthening network, and strategic objectives that may have value that is not immediately visible in financial returns.

Optimization scenarios MILP shows distribution IRR which is at a relatively high value and a higher peak than the network and financial scenarios. Optimization scenarios MILP million did not vote site with IRR negative, indicating that the optimization approach tends to avoid high-risk projects that could result in losses. With a fairly wide distribution, this scenario also covers site-site with very high returns, indicating that this scenario successfully balances risk and expected return.

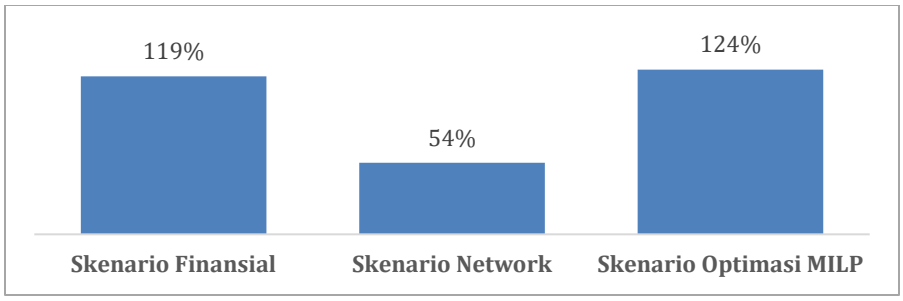

Figure 26. Comparison of portfolio IRR for each scenario

(**Source:** Data processed by the author, 2024)

The IRR Portfolio graph displays an interesting comparison between the three scenarios, namely financial, network, and optimization MILP. With optimization scenarios MILP occupied the top position with an IRR portfolio of 124%, this indicates that the optimization approach applied in this scenario succeeded in producing a combination of investment projects that was very efficient in terms of financial returns. This figure is 4% ahead of the financial scenario which is already quite high at 119%, a difference that may seem small but is still significant in the context of investment returns.

On the other hand, the network scenario has a much lower portfolio of IRR, namely 54%, less than half of the financial and MILP optimization scenarios. This reflects differences in approach, where network scenarios may prioritize network development or long-term benefits that are not directly linked to financial returns. The 131% difference in IRR confirms the effectiveness of the MILP optimization strategy. This illustrates how MILP can be a tool for better results compared to traditional methods of portfolio management and investment decision making. The MILP optimization scenario offers maximum added value for investors seeking growth and efficiency, while the network scenario may be suitable for organizations focused on building future capabilities and infrastructure.

CONCLUSION

The results of research regarding the comparison of conventional scenarios (financial and network) and optimization scenarios mixed integer linear programming in determining development investment decisions network telecommunications operators came to the following conclusions:

Financial variables on selected site in the portfolio in the optimization scenario MILP are dominated by high variable values sites. Meanwhile for variables network, only there are 24% site which has CX index greater than one (which indicates that there is area where competitors are superior) and 47% site which has RCI score more than 0 (which indicates high utilization and capacity). From the side variable financial, 100% site own incremental revenue above the overall median value of 25 thousand sites included in the planning proposal, 100% site own NPV, IRR, EBIT Margin positive with IRR average 128% and EBIT Margin average 68%. This happens because of the algorithm created in the optimization scenario MILP gives financial variables a 60% higher weight than network variables 30%.

There is a very strong and positive correlation between incremental revenue, NPV and IRR which shows that when incremental revenue increases, value NPV and IRR tends to increase significantly. On the other hand, network RCI score has a positive correlation with financial variables, which shows RCI score High ones tend to have a higher impact on financial variables. But the case is different. The CX index has a negative correlation with financial variables which shows that in areas where competitors are dominant, have lower financial potential or are not identified.

Selected site by the optimization scenario MILP has a very strong positive correlation with incremental revenue (0.65), NPV (0.64), and IRR (0.75), which indicates that the optimization scenario MILP gives high weight to financial aspects. IRR site in optimization scenarios MILP highest compared to other scenarios, which indicates that the optimization performance has worked well based on the search target IRR highest portfolio. Whereas site selected financial scenarios have the highest positive correlation with incremental revenue (0.70), which is

very closely related to the financial scenario mechanism that prioritizes based on incremental revenue. A site selected by a scenario network has a very high correlation with RCI score (0.83) indicates that the scenario network runs according to its mechanism by prioritizing based on utilization and RCI score.

Selected site in the optimization scenario MILP has overall better results than the other two scenarios from the side total score (22% better than financial scenario and 63% than scenario network), incremental revenue portfolio (3.5% better than financial scenario and 90.2% than scenario network), IRR portfolio (4% better than financial scenario and 70% than scenario network). On the other hand, the optimization scenario MILP uses total CAPEX and average CAPEX lowest compared to the other two scenarios, but can accommodate the number site more portfolio. This indicates the effectiveness of the optimization method MILP in choosing a combination site or projects that overall provide the best value and demonstrate optimization mechanisms MILP which works well based on the target total score, incremental revenue portfolio and IRR portfolio.

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