Eduvest – Journal of Universal Studies
Volume 4 Number 11, November, 2024
p- ISSN 2775-3735- e-ISSN 2775-3727

Maintenance Costs Optimization Of Light Rail Transit (LRT) Facilities And Infrastructure Based On Life Cycle Cost Analysis (Case Study: South Sumatra LRT)

Atri Ranindita[1], Ayomi Dita Rarasati[2]
[1,2] Fakultas Teknik, Universitas Indonesia, Indonesia
Email: atriranindita11@gmail.com, ayomi@office.ui.ac.id

ABSTRACT

The construction of the South Sumatra Light Rail Transit (LRT) requires a huge development cost, besides that it has quite a large annual operational and maintenance cost. In order for South Sumatra LRT maintenance costs to run efficiently and effectively, it is necessary to optimize maintenance costs for South Sumatra LRT facilities and infrastructure based on Life Cycle Cost Analysis. Life Cycle Cost is an economic analysis method that refers to all costs associated with development, operating and maintaining a construction project over a certain period of time (Heralova, 2017). The research objectives were to analyze the physical condition of Facilities and Infrastructure South Sumatra LRT, evaluate South Sumatra LRT maintenance strategies and develop maintenance cost scenarios based on Life Cycle Cost. Based on data processing using the combined condition index method, the total value of the South Sumatra LRT infrastructure components reached 5,718. The physical condition of the South Sumatra LRT infrastructure reviewed is on a good scale with minor damage so that the option of preventive or time-based maintenance activities can be used. For the Life Cycle Cost of South Sumatra LRT infrastructure, the value obtained is IDR 2,080,482,508,541,480.

KEYWORDS *Light Rail Transit, Maintenance Cost, Life Cycle Cost Analysis*

INTRODUCTION

Railways play an important role in a country's socio-economic development as they provide safe, affordable, efficient, reliable, and environmentally friendly public transportation. Sustainable transportation policies in many countries encourage the movement of passengers and goods from road to rail to reduce

How to cite:	Atri Ranindita, Ayomi Dita Rarasati (2024). Maintenance Costs Optimization Of Light Rail Transit (LRT) Facilities And Infrastructure Based On Life Cycle Cost Analysis (Case Study: South Sumatra LRT). *Journal Eduvest. 4* (11): 10694-10711
E-ISSN:	2775-3727

congestion and the environmental impact of road traffic. Demand for rail transportation capacity, availability, and speed continues to increase.

In Indonesia, urban rail development, especially in South Sumatra, is growing rapidly. One major initiative is the construction of the Integrated Railway (LRT) in Palembang City, which was inaugurated in 2018. The LRT is expected to reduce the use of private transportation and increase the use of public transportation, which will help reduce congestion and improve urban planning.

However, LRT in Palembang faces challenges such as low public interest in public transportation due to lack of convenience, inadequate infrastructure, and network limitations. In addition, although the LRT is operational, it has not been integrated with other modes of transportation, resulting in a decline in passenger numbers after the 2018 Asian Games. Data shows a drastic drop in daily passenger numbers from 3,000 before the COVID-19 pandemic to around 360 passengers in 2020.

Maintenance of LRT infrastructure is critical to ensure proper operation, but it requires substantial investment and operating costs. Challenges in maintenance include complicated budgeting and complex planning. Low revenue from passenger tickets cannot cover operational costs, causing a financial burden to the government.

Research on LRT infrastructure maintenance in South Sumatra using the Life Cycle Cost (LCC) approach is expected to optimize fund allocation and improve maintenance efficiency. This approach aims to evaluate and improve the existing maintenance model to better suit operational needs and the available budget.

Based on the background of this topic, there are several key issues related to the maintenance of the South Sumatra LRT. First, the service life of each infrastructure component has not been considered in the maintenance strategy. Second, the operational cost of the LRT infrastructure is greater than the income from monthly operations. The problem formulations that arise from this identification include questions about the physical condition of the LRT infrastructure, suitable maintenance strategies, and how to optimize maintenance costs using the Life Cycle Cost Analysis (LCC) method.

The purpose of this research is to analyze the physical condition of South Sumatra LRT infrastructure, recommend appropriate maintenance strategies, and optimize maintenance costs effectively and efficiently based on LCC. This research has academic benefits as a study material and increased knowledge about LCC, as well as practical benefits as a reference for LCC planning for the maintenance of LRT infrastructure. This research is limited to the maintenance costs of railways, stations, and LRT operating facilities for a period of 30 years.

Literature Review

Light Rail Transit (LRT) is a rail-based urban transportation mode that provides regular and sustainable public services. LRT has the highest capacity, speed, and reliability performance among all other modes of transportation, with tracks that are completely separated from other modes. Effective LRT systems can influence urban form and contribute to regional growth.

According to Government Regulation of the Republic of Indonesia Number 56 Year 2009, railway is a unified system consisting of infrastructure, facilities, and human resources as well as norms, criteria, requirements, and procedures for the implementation of railway transportation. This infrastructure includes railroad lines, stations, and railroad operating facilities. The railway line includes benefit space, property space, and supervision space, including the top and bottom. Track maintenance includes railways, bridges, tunnels, roadbeds, drainage, level crossings, switches, curves, and construction stability.

A railway station is a place where trains depart and stop, with maintained components such as buildings, electrical installations, water installations, fire extinguishers, and platforms. Train operating facilities include signaling equipment, telecommunications equipment, and electrical installations.

According to Minister of Transportation Regulation No. 18/2019, the Railway Facilities Maintenance Site consists of depots and service centers that carry out daily to annual maintenance. South Sumatra LRT has one depot located in Jakabaring.

Condition assessment of LRT infrastructure can be done by the condition description method based on visual inspection. Condition indices help communicate the suitability of components to support their specific tasks, with categories providing a general classification of the facility's functional deficiencies. The condition measurement process is consistent and repeatable with specific visual or technical criteria.

Operation and maintenance of LRT involves operation and maintenance costs that are usually incurred per specific period, including taxes, insurance, electricity, gas, utilities, employee salaries, maintenance, marketing, administration, and general expenses. Asset maintenance is required to maintain functionality and reduce the risk of cost overruns due to breakdowns.

The legal basis for the operation and maintenance of railway infrastructure is regulated by various government regulations and ministerial regulations, including Government Regulation No. 56 Year 2009 and several regulations of the minister of transportation.

The service life of a building or structure is the time during which the structure is still capable of performing its function and purpose without the need for significant repairs or strengthening. Predicting system reliability and service life helps engineers and owners understand the current and future safety of the structure. The Life Cycle Cost (LCC) approach is used to analyze the total costs associated with building, operating, and maintaining a construction project over a specified period. LCC includes all costs to be evaluated, including initial, operational, maintenance, and demolition costs, and considers the time value of money.

Hypothesis

Hypotheses are temporary answers to the formulation of research problems. The answers given in the hypothesis are temporary because they are only based on relevant theories, not yet based on empirical facts obtained through data collection (Sugiyono, 2013). The hypothesis in this study is shown in Table 1.

Table 1. Hypothesis

H1	The physical condition of integrated cross-rail infrastructure in South Sumatra affects the maintenance of LRT infrastructure
H2	The physical condition of integrated cross-rail infrastructure affects the selection of maintenance strategies
H3	*Life Cycle Cost Analysis* approach can optimize the maintenance cost of integrated rail crossings

Source: Author's Report, 2024

RESEARCH METHOD

This research uses a quantitative descriptive method with various research stages, including identification of research questions, determination of variables, literature study, and use of research instruments such as questionnaires and archival data. Data analysis was conducted to answer various problem formulations, from infrastructure condition assessment to maintenance cost optimization using the Fuzzy Analytical Hierarchy Process method and Life Cycle Cost calculation. The research strategy used helps in identifying the condition of the infrastructure, maintenance strategy, and the most economical financing scheme for the South Sumatra LRT infrastructure.

Research Strategy

This research is descriptive quantitative, combining systematic data collection methods to analyze the facts and nature of the object of research, and interpret the results based on related theories and literature. This research uses several strategies to answer the formulation of problems related to the physical condition, maintenance strategy, and maintenance cost optimization of South Sumatra LRT infrastructure.

Research Stages

The research phase began by identifying research questions based on the problem at hand. This research includes three main questions regarding the condition of LRT infrastructure, maintenance strategies, and maintenance cost optimization. Determination of research variables based on previous literature studies, namely condition assessment, maintenance strategy recommendations, and life cycle cost analysis.

Literature Study and Research Instruments

Literature studies were conducted to collect references from journals, theses, theses, government regulations, and books. The research strategy used was case study, survey, and archive analysis. The research instruments included questionnaires and technical archive data, inventory, and maintenance costs of LRT infrastructure.

Data Analysis

Data analysis was conducted for various purposes, including condition assessment of LRT infrastructure using condition index and Fuzzy Analytical Hierarchy Process method, maintenance strategy based on questionnaire data, and maintenance cost optimization using future value with discount rate. The data analysis approach was tailored to the objectives and research questions.

Answering the Problem Formulation

To answer the first problem regarding the physical condition of the LRT infrastructure, questionnaire data was analyzed with expert validation. For the second problem formulation on suitable maintenance strategies, a questionnaire was developed and tested through a pilot survey, then distributed to respondents to collect data related to infrastructure service time. Finally, the third problem formulation regarding maintenance cost optimization was answered by calculating Life Cycle Cost based on the selected maintenance alternative.

RESULT AND DISCUSSION

Data Collection

Phase I Data Collection - Expert Validation

At this stage, the questionnaire was validated by three experts to identify variables affecting the physical assessment of South Sumatra LRT infrastructure. The profiles of the three experts include postgraduate education and work experience between 10 to 14 years. The questionnaires completed by the experts were then summarized with additional component suggestions.

Phase II Data Collection - Pilot Survey

After validating the questionnaire, a pilot survey was conducted to clarify the respondents' understanding of the questionnaire questions so as to produce accurate data. The pilot survey involved five respondents with a minimum of one year's experience in LRT operations and maintenance and a minimum of S1 education.

Phase III Data Collection - Respondent Questionnaire

The results of the pilot survey were used to improve the questionnaire. The improved questionnaire was then distributed to respondents who had S1/D4 education and work experience varying from ≤5 years to 10 years in the field of operations and maintenance of South Sumatra LRT infrastructure.

Data Analysis

Phase I Data Analysis

At this stage, a recapitulation of the results of the questionnaires that have been distributed and filled in by experts can be seen in Table 2.

Table 2. Validation of Research Indicators by Experts

Indicator	Expert			Value	Description
	P1	P2	P3		
Condition Assessment					

X1.1	Condition Index	✓	✓	✓	3	Yes
X1.2	Component Importance Weight	✓	✓	✕	2	Yes
Maintenance Strategy						
X2.1	*Service Life*	✓	✓	✓	3	Yes
X2.2	Component Physical Condition	✓	✓	✓	3	Yes
X2.3	Cost	✓	✓	✓	3	Yes
X2.4	Maintenance Schedule	✓	✓	✓	3	Yes
X2.5	Rehabilitation Interval	✓	✕	✓	2	Yes

Source: Author's Report, 2024

From the results of the questionnaire validation conducted by experts, no indicators were omitted. All indicators are considered to meet the criteria because at least 2 (two) out of 3 (three) experts agree with the indicators used.

According to experts, the stability of railroad construction is included in the Rail Road component and does not need to be evaluated separately. In South Sumatra LRT Infrastructure does not use Tunnel Construction so the component is omitted. From the results of the discussion, there are additional components that are recommended to be assessed, namely high-speed *tracks* above the "*foot plate of the engine*" on the Railway component.

Phase II Data Analysis

After the validation stage of the questionnaire, it is important to ensure that the sentences used are easily understood by prospective respondents. The following is a recapitulation of the *pilot survey* results on 5 (five) sample respondents which can be seen in Table 3.

Table 3. *Pilot Survey* Results

Respondent Sample	**Suggestions for other LRT Infrastructure components that are important to assess**	**Sentences that are difficult to understand**	**Time taken to complete the questionnaire**
SR1	None	None	5 minutes
SR2	None	None	5 minutes
SR3	High-speed inspection at the rear of the train	None	6 minutes
SR4	None	None	5 minutes
SR5	High-speed *track* above the "*foot plate of the engine*"	There is. The assessed components	6 minutes

Respondent Sample	Suggestions for other LRT Infrastructure components that are important to assess	Sentences that are difficult to understand	Time taken to complete the questionnaire
		need to be described to make it easier for officers to fill out the questionnaire.	

Source: Author's Report, 2024

After obtaining the results of the *pilot survey*, it was concluded that the *sample* respondents could understand the sentences in the questionnaire. There are several suggestions from *sample* respondents, one of which is the addition of other LRT Infrastructure components that are important to assess and input to provide descriptions of the components being assessed. To answer the questionnaire, the *sample* respondent takes ± 5 minutes. After re-discussion with the expert, the *Track* component with high speed above the "*foot plate of engine*" was finally added to be assessed.

Phase III Data Analysis

The data that has been obtained is then sought for the average value and standard deviation of the Condition Index data using *Microsoft Excel* Application. Then data analysis was carried out using the *Fuzzy AHP* method for the component weight assessment questionnaire and using the mode value for the service time questionnaire on each component of the South Sumatra LRT infrastructure.

Discussion of Research Problem I

After respondents filled out the questionnaire on the importance of the South Sumatra LRT infrastructure components, the questionnaire was processed by taking the geomean value of each comparison. The values obtained are then organized into a pairwise comparison matrix as in Table 4.

Table **Error! No text of specified style in document.**. Pairwise Comparison Matrix

Component	Railway Line	Railway Station	Train Operating Facility	Maintenance Place for Railway Facilities (Depot)
Railway Line	1	0,288	0,421	0,340
Railway Station	3,478	1	0,540	0,573

Component	**Railway Line**	**Railway Station**	**Train Operating Facility**	**Maintenance Place for Railway Facilities (Depot)**
Train Operating Facility	2,378	1,85	1	0,837
Maintenance Place for Railway Facilities (Depot)	2,942	1,75	1,195	1
Total	**9,798**	**4,883**	**3,156**	**2,750**

Source: Author's Report, 2024

Next, each matrix entry is divided by each of its column totals and each row of results is summed. The average value of each row of the new matrix is the priority factor.

Table 5. Results of Matrix Division with Total Columns

Component	**Railway Line**	**Railway Station**	**Train Operating Facility**	**Maintenance Place for Railway Facilities (Depot)**	**Total**	**Prioritization Factor**
Railway Line	0,102	0,059	0,133	0,124	0,418	0,104
Railway Station	0,355	0,205	0,171	0,208	0,939	0,235
Train Operating Facility	0,243	0,379	0,317	0,304	1,243	0,311
Maintenance Place for Railway Facilities (Depot)	0,300	0,357	0,379	0,364	1,400	0,350

Source: Author's Report, 2024

To get the value of the total weight factor, the priority factor value is multiplied by the pairwise comparison matrix. Furthermore, to get the priority weight value (*eigenvalue*), the total weight factor obtained is divided by the priority factor of the component being assessed, the results are obtained as in Table 6.

Table 6. Results of Priority Weight Value (*Eigenvalue*)

Component	***Eigenvalue***

Railway Line	1,023
Railway Station	1,147
Train Operating Facility	0,981
Maintenance Place for Railway Facilities (Depot)	0,962

Source: Author's Report, 2024

After obtaining the priority weight value (*eigenvalue*) of each component, then look for the value of λ_{maks} (maximum eigen), *Consistency Index (*CI) and *Consistency Ratio* (CR).

λ_{maks} = (9,798 x 0.104) + (4,883 x 0.235) + (3,156 x 0.311) + (2,750 x 0.350)

=4 ,1132

$$CI = \frac{\lambda maks - n}{n-1} = \frac{4,1132-4}{4-1} = 0,038$$

$$CR = \frac{CI}{RI} = \frac{0,038}{0,90} = 0,042$$

The Consistency Ratio (CR) result is 0.042 where CR ≤ 0.1 then the matrix is declared consistent. Furthermore, the same test was carried out on the South Sumatra LRT infrastructure sub-criteria.

The next step is to convert the AHP linguistic scale into a *Triangular Fuzzy Number* (TFN) consisting of l (*lower)*, m (*middle*) and u (*upper*). These TFN components are then summed horizontally. The summation results are tabulated in Table 7.

Table 7. Result of TFN Summation Horizontally

Component	**∑l**	**∑m**	**∑u**
Railway Line	2,697	3,876	5,506
Railway Station	6,446	9,143	12,245
Train Operating Facility	6,480	10,014	14,004
Maintenance Place for Railway Facilities (Depot)	7,497	11,331	16,126
Total	23,119	34,364	47,881

Source: Author's Report, 2024

Next, the *Triangular Fuzzy Number* (TFN) summation value is calculated.

$$\left[\sum_{i=1}\sum_{j=1} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i-1}^{n} u_i}, \frac{1}{\sum_{i-1}^{n} m_i}, \frac{1}{\sum_{i-1}^{n} l_i}\right)$$

$$= \frac{1}{47,881}, \frac{1}{34,364}, \frac{1}{23,119}$$

= (0,021; 0,029; 0,043)

Then look for the calculation value of *fuzzy* synthesis (Si)

$$S_i = \sum_{j=1} M_{gi}^{i} \times \left[\sum_{i=1}\sum_{j=1} M_{gi}^{j}\right]^{-1}$$

An example calculation is as follows.
Si=2 .697 x 0.021
=0 ,056

The calculation results are then tabulated in table 8.

Table 8. *Fuzzy* Synthesis Value Results

Component	l	m	u
Railway Line	0,056	0,113	0,238
Railway Station	0,135	0,266	0,530
Train Operating Facility	0,135	0,291	0,606
Maintenance Place for Railway Facilities (Depot)	0,157	0,330	0,698

Source: Author's Report, 2024

After obtaining the results of the *fuzzy* synthesis value, the *Degree of Possibility is* then calculated with the formula

$$V(M_2 \geq M_1) = \begin{cases} 1; jika\ m_2 \geq m_1 \\ 0; jika\ l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} \end{cases}$$

Table 9. *Degree of Possibility* Calculation Results

Component	Railway Line	Railway Station	Train Operating Facility	Maintenance Place for Railway Facilities (Depot)	Minimum Value
Railway Line		0,403	0,365	0,273	0,273
Railway Station	1		0,940	0,854	0,854
Train Operating Facility	1	1		0,921	0,921
Maintenance Place for Railway Facilities (Depot)	1	1	1		1
Total					**3,049**

Source: Author's Report, 2024

The last step of this *fuzzy AHP* calculation is defuzzification or weight normalization. The *Degree of Possibility* value obtained is then normalized to get a non-fuzzy number for the weight value of the main criteria. Furthermore, it is also done for the weight value of the sub-criteria of each component.

$$\text{CRISP } (d_i) = \frac{d'_1}{\sum_{i=1}^{n} d'_1} = \frac{0{,}273}{3{,}049} = 0{,}09 = 9\%$$

This study uses the condition index from USACERL to assess the condition of the South Sumatra LRT infrastructure components on a scale of 1 to 7 and representations of damaged to excellent. Data obtained from the South Sumatra LRT infrastructure questionnaire which was distributed and filled in by respondents, namely South Sumatra LRT infrastructure operations and maintenance officers. Furthermore, the data was processed by calculating the *mean* value and standard deviation of each component of the South Sumatra LRT infrastructure. The results of this condition index analysis were then multiplied by the weight of the importance of the South Sumatra LRT infrastructure obtained.

The overall value of the South Sumatra LRT Infrastructure component is 5.718 which is stated to be in good condition. There are components in the depot public facilities that are rated poorly and require little improvement. The combined condition value of the South Sumatra LRT Infrastructure component can be seen in Table 10.

Table 10. South Sumatra LRT Infrastructure Combined Condition Index

No.	Component	Sub-component	Condition Index	Component Weight	Total Condition Value (Cn)x(Wn)
1	Railway Line	Rail Road	6	0,159	0,951
		Bridge Construction	6	0,049	0,293
		Road Body	6	0,029	0,176
		Drainage	6	0,016	0,098
		Level crossings, switches, arches	7	0,182	0,912
		High-speed track above the "foot plate of the engine"	5	0,018	0,127
2	Railway Station	Building	6	0,020	0,12
		Electrical Installation	6	0,013	0,076
		Water Installation	5	0,013	0,065
		Fire Fighting	6	0,083	0,498
		Platform	6	0,071	0,426
3	Train Operating Facility	Signaling Equipment	7	0,008	0,054
		Telecommunication Equipment	6	0,011	0,066
		Electrical Installation	6	0,009	0,054

4	Maintenance Place for Railway Facilities (Depot)	Pathway for Maintenance	6	0,052	0,312
		Main building for maintenance	6	0,017	0,102
		Building for auxiliary equipment	6	0,074	0,444
		Office building	5	0,186	0,93
		Public facilities	4	0,004	0,014

Source: Author's Report, 2024

Discussion of Research Problem II

Respondents to the questionnaire who are South Sumatra LRT infrastructure operations and maintenance officers were asked to fill out a questionnaire in accordance with the situation in the field to determine the *service life of* each component of the South Sumatra LRT infrastructure. The results of the questionnaire that has been filled in are then processed by taking the mode value on each question given. The results of the questionnaire can be seen in Table 11.

Table 11. Service Time of South Sumatra LRT Infrastructure Components

No.	Component	Activities	Service Time
1.	Railway Line	Fastening Fasteners	Seven Days
		Railroad grinding and straightening	One Year
		Money Order Maintenance	One Year
		Bearing Maintenance	Six Months
		Ballas Maintenance	Six Months
		Drainage Dredging	Six Months
2.	Railway Station	Building Maintenance	Six Months
		Electrical Installation Maintenance	One Year
		Water Installation Maintenance	Six Months
		Fire Extinguisher Maintenance	One Year
		Platform Maintenance	One Month
3.	Train Operating Facility	Signaling Equipment Maintenance	One Month
		Telecommunication Equipment Maintenance	One Month
		Electrical Installation Maintenance	Three Months
4.	Maintenance Place for Railway Facilities (Depot)	Path Maintenance for Maintenance	One Year
		Maintenance Main building for maintenance	One Year
		Building Maintenance for auxiliary equipment	One Year
		Office Building Maintenance	One Year
		Maintenance of public facilities	Six Months

Source: South Sumatra Light Railway Management Center, 2024

From the data obtained, the South Sumatra LRT Infrastructure Maintenance strategy is grouped into daily periodic maintenance, twice-yearly periodic maintenance and annual periodic maintenance. Daily periodic maintenance is carried out on fastening railroad ties. Periodic maintenance is carried out once every three months for maintenance of electrical installations in train operating facilities. Routine maintenance twice a year is carried out for bearing maintenance, ballast maintenance, drainage dredging, building maintenance, maintenance of water installations at train stations and maintenance of public facilities at depots. Annual periodic maintenance activities are carried out for grinding and straightening of railways, maintenance of switches, maintenance of electrical installations, maintenance of fire extinguishers at railway stations, maintenance of bridge construction, maintenance of main buildings for maintenance, maintenance of buildings for auxiliary equipment, maintenance of office buildings and maintenance of lines for maintenance at depots.

After review, the physical condition of the South Sumatra LRT infrastructure is assessed to be in good condition with minor damage so that as an option preventive or time-based maintenance activities can be carried out to keep it in good condition.

Discussion of Research Problem III

After the maintenance strategy is selected, the next step is to estimate the *life cycle cost* for 100 years based on the planned life of the South Sumatra LRT Infrastructure. The South Sumatra LRT Infrastructure was completed in 2018 and immediately operated to support the 2018 Asian Games held in Palembang.

Development Cost

From the data obtained by the South Sumatra Light Railway Management Center, the cost of building the South Sumatra LRT infrastructure is Rp. 10,612,290,650,312.

Maintenance Cost

Periodic maintenance costs consist of daily maintenance costs, monthly maintenance costs and annual maintenance costs. The maintenance cost of South Sumatra LRT infrastructure based on the data obtained is Rp. 20,269,010,252.

Replacement Cost

Replacement cost is the cost incurred for the replacement of South Sumatra LRT infrastructure components that have reached the end of their useful life. Based on data obtained from the South Sumatra Light Railway Management Center, the replacement cost for South Sumatra LRT infrastructure is Rp. 561,982,220.53.

Operation Cost

Operating costs obtained from the South Sumatra Light Railway Management Center with the annual operating value of the South Sumatra LRT Infrastructure can be seen in Table 12.

Table 12. Operating Costs of South Sumatra LRT Infrastructure

Cost	Volume	Service Time	Unit Price	Amount (Rp)
Implementation of South Sumatra LRT Pioneer Train Transportation	1	1	83.361.601.186	83.361.601.186

Provision of Station Labor Services	1	1	40.124.324.151	40.124.324.151
Implementation of South Sumatra LRT Feeder	1	1	8.090.711.411	8.090.711.411
South Sumatra LRT Electricity Subscription	1	1	60.631.890.354	60.631.890.354
Total				**192.208.527.102**

Source: South Sumatra Light Railway Management Center, 2024

Destruction Cost

Unused railway infrastructure in Indonesia has until recently been left alone. Factors influencing this include the high cost of demolition including the physical cost of demolition, material removal, and potential compensation to the relevant parties involved. These costs can be a major factor in considering whether it is better to repair or demolish existing LRT infrastructure. Even if the condition of the LRT infrastructure is not optimal, there is still consideration for retaining usable infrastructure if repair or rehabilitation can be done at a lower cost than demolition and rebuilding. Decisions regarding whether to retain or remove LRT infrastructure may also be influenced by community support, public transportation needs, and the socio-economic impacts of the decision.

Total *Life Cycle Cost* is the sum of all annual partial costs required by a building over its planned life. Since costs spent at different times have different Present Value (PV), future costs are converted to a consistent present value of rupiah by adjusting future costs using a *discount rate*, and then summing the results over T years, with the equation:

$$\textit{Total Operation and Maintenance Cost} = \sum_{t=0}^{T} C_t \ x \ (1 + r)$$

Description:
C = $_t$ Year-t cost
r = *discount rate*

Discount rates can reflect the opportunity value of time and are used to calculate the effect of inflation and discounting. The *discount rate* used is 6.25%. In this study, the initial construction cost is calculated at year 0, while year 1 is the current value. The associated costs are then calculated by considering the *discount rate*. to calculate the *Present Value* (PV) value obtained from the costs associated with the South Sumatra LRT infrastructure throughout its planned life. *Discount rates are* used to adjust future values to present values, given the value of money over time and taking into account the effects of inflation and the opportunity value of time. The total cost of operation and maintenance of the South Sumatra LRT infrastructure for 100 years is Rp. 2,080,482,508,541,480. This value was then added to the construction cost of the South Sumatra LRT infrastructure and obtained a total *Life Cycle Cost of* Rp2,091,094,799,191,800.

CONCLUSION

This research is an initial form in the form of analysis and calculation of maintenance activity plans on the South Sumatra LRT infrastructure that has been built in order to allocate existing funds more effectively. Based on the results of the discussion in this study, the following conclusions can be drawn. 1. From the results of calculations using the combined condition index method, the overall value of the South Sumatra LRT infrastructure components reaches 5, 718 , which gives an overview of the South Sumatra LRT infrastructure in good condition, but with some functions of public facility components in the depot that are not good and require minor repairs. 2. The physical condition of the South Sumatra LRT infrastructure reviewed is on a good scale with minor damage so that preventive or time-based maintenance activities can be used as an option. The South Sumatra LRT infrastructure maintenance strategy consists of several final points taken, namely daily periodic maintenance, twice-yearly periodic maintenance and annual periodic maintenance. Daily periodic maintenance is performed on the fastening of railroad ties. Periodic maintenance is carried out once every three months for maintenance of electrical installations in train operating facilities. Routine maintenance twice a year is carried out for bearing maintenance, ballast maintenance, drainage dredging, building maintenance, maintenance of water installations at train stations and maintenance of public facilities at depots. Annual periodic maintenance activities are carried out for grinding and straightening of railways, maintenance of wires, maintenance of electrical installations, maintenance of fire extinguishers at train stations, maintenance of bridge construction, maintenance of main buildings for maintenance, maintenance of buildings for auxiliary equipment, maintenance of office buildings and maintenance of lines for maintenance at depots. 3. Based on the results of the analysis, the *Life Cycle Cost of the* South Sumatra LRT infrastructure is Rp2,091,094,799,191,800. The influencing factor is the incomplete Operation and Maintenance Cost data obtained, so there is a possibility of costs that are not calculated. Incompleteness is found in the maintenance costs, replacement costs and rehabilitation of South Sumatra LRT infrastructure.

In connection with the various studies that have been presented in this research up to the conclusion of the research, several points can be taken that can be suggestions for the development of research in similar subjects. 1. It is recommended for further research on similar topics to be able to assess the performance of the instrumentation components of the South Sumatra LRT infrastructure, because as has been described based on the situation in the field there are often *errors* and damage to these components. So that the results presented in the future can be more optimal. 2. This research only takes the example of certain LRT infrastructure and similar research can be done on other LRT infrastructure. It is recommended to conduct research and comparison of different LRT infrastructure. 3. It is recommended to develop a *Life Cycle Cost* scheme not only with variations in LRT infrastructure maintenance costs, but also LRT facility maintenance costs. So that the discussion in research can develop and be more diverse in the future on related topics.

REFERENCES

Amani, N., M., A. N., & Samat, R. a. (2012). Infrastructure Component Assessment Using the Condition Index System: Literature Review and Discussion. KICEM Journal of Construction Engineering and Project Management. https://doi.org/10.6106/JCEPM.2012.2.1.027

American Public Transit Association, *Glossary of Transit Terminology*, American Public Transit Association, Washington DC, USA, 1994.

Anggraini, I. A. (2021). Penilaian Kondisi Bendungan dan Optimasi Biaya pemeliharaan Berdasarkan *Life Cycle Cost Analysis*. Universitas Indonesia.

Arliansyah, J., Kadarsa, E., & Melania, R. (2022). *Desain Noise Barrier Light Rail Transit (Lrt)Palembang Untuk Mengurangi Tingkat Kebisingan*. Publikasi Penelitian Terapan Dan Kebijakan, 5(2). https://doi.org/10.46774/pptk.v5i2.504.

Boomen, M. V. D., Schoenmaker, R., & Wolfert, A. R. M. (2018). A Life Cycle Costing Approach for Discounting in Age and Interval Replacement Optimisation Models for Civil Infrastructure Assets. Structure and Infrastructure Engineering, 14.

Chang, D.-Y. (1996). Applications of The Extent Analysis Method on Fuzzy AHP. *European Journal of Operational Research*, *65*. https://doi.org/10.1016/0377-2217(95)00300-2.

Corder, Antony. 1996. Teknik Manajemen Pemeliharaan. Jakarta: Erlangga.

D. Bruckmann, A. Bomhauer-Beins, and U. Weidmann, "*A qualitative model to evaluate the financial effects of innovations in the rail sector*," Transportation Research Procedia, vol. 10, pp. 564–573, 2015.

Dananjoyo, R. A., Aminullah, A., Nugroho, A. S. B. (2020). Penerapan Metode *Life Cycle Cost* dalam Perhitungan Evaluasi Ekonomi Jembatan untuk Penentuan Prioritas Penanganan Jembatan.

El-Akruti, K., Zhang, T., Dwight, R. (2016). Developing an Optimum Maintenance Policy by *Life Cycle Cost* Analysis – a Case Study

Fuller, S., 2010. *Life-cycle Cost Analysis (LCCA)*. Whole Building Design Guide.

Giunta, M., Bressi, S., & D'Angelo, G. (2018). *Life cycle cost assessment of bitumen stabilised ballast: A novel maintenance strategy for railway track-bed. Construction and Building Materials, 172, 751–759.* doi:10.1016/j.conbuildmat.2018.04.020.

Goh, K. C., Goh, H. H., Chong, H. (2018). Integration Model of Fuzzy AHP and Life-Cycle Cost Analysis for Evaluating Highway Infrastructure Investments.

Heralova, R. S. (2017). Life Cycle Costing as an Important Contribution to Feasibility Study in Construction Projects. Procedia Engineering, 196.

Heralova, R. S. (2014). *Life Cycle Cost* Optimization Within Decision Making on Alternative Designs of Public Buildings. Procedia Engineering, 85, 454463. https://doi.org/10.1016/j.proeng.2014.10.572

Huang, M., Dong, Q., Ni, F., Wang, L. (2020). LCA and LCCA based multi-objective optimizationof pavement maintenance.

Herdian, Rozi. (2019). *Pengembangan Situs Light Rail Transit (LRT) Palembang Berbasis Analytical Customer Relationship Management (CRM)*. Universitas Sriwijaya. Palembang.

Hudoyo, C. P. (2018). *Pengembangan standar WBS Berbasis Risiko Untuk Meningkatkan Perencanaan Estimasi Biaya Pada Proyek Konstruksi Pelabuhan Laut.* Universitas Indonesia.

Illankoon, I. M. C. S., Tam, V. W. Y., Le, K. N., & Wang, J. Y. (2018). Life Cycle Costing for Obtaining Concrete Credits in Green Star Rating System in Australia. Journal of Cleaner Production, 172. https://doi.org/10.1016/j.jclepro.2017.11.202

J. Liang and Z. Liu, "*Analysis of urban rail transit operation cost control*," International Journal of Business and Social Science, vol. 5, no. 5, pp. 140–142, 2014.

Kementerian PPN/Bappenas. (2015). Draft Final Business Case / Draft Kajian Akhir Prastudi Kelayakan Report Penyiapan Dokumen Transaksi Proyek Kerjasama Pemerintah Swasta Sumatra Selatan Monorail.

Margaretha, T. N. (2023). *Evaluasi Kinerja Pelayanan Light Rail Transit di Kota Palembang*. Universitas Islam Indonesia.

Marliansyah, J. (2014). Analisis Rencana *Life Cycle Cost* Gedung Hostel pada Kawasan Rumah Sakit Jimbun Medika Kediri.

Muda, D. (2021). *Analisis Pengaruh Keamanan, Kenyamanan, Dan Aksesibilitas Terhadap Minat Masyarakat Pengguna Mrt Jakarta*. Forum Studi Transportasi Antar Perguruan Tinggi, 1(2), 4–6.

Pambudi, A. S., & Hidayati, S. (2020). *Analisis Perilaku Sosial Pengguna Moda Transportasi Perkotaan: Studi Kasus Mass Rapid Transit (MRT) DKI Jakarta*. Bappenas Working Papers, 3(2), 143–156. https://doi.org/10.47266/bwp.v3i2.74.

Pangestu, Y. (2015). *Pemilhan Pemasok Bahan Baku Kayu Handle Raket Dengan Menggunakan Metode Fuzzy Analitycal Hierarchy Process*. Jurnal Teknik Industri, Vol. 16, No. 1, Februari 2015, pp. 31-42. ISSN 1978-1431 print / ISSN 2527-4112 online

Perwitasari, D., Rahman, H. Z., Petroceany, J. S., Andreas, A. (2017). Optimasi Kerjasama Pemanfaatan Aset Dalam Pembiayaan Operasional dan Pemeliharaan Stasiun Palmerah.

Plebankiewicz, E., Meszek, W., Zima, K., Wieczorek, D. (2019). Probabilistic and Fuzzy Approaches for Estimatingthe Life Cycle Costs of Buildings under Conditionsof Exposure to Risk.

Putri, Dianyta. (2019). *Faktor-Faktor Yang Mempengaruhi Minat Masyarakat Dalam Menggunakan Transportasi Light Rail Transit (LRT) di Palembang*. Universitas Sriwijaya. Palembang

Rosyad, F., & Yandi, J. (2019). *Analisis Persepsi Pengguna Layanan LRT Kota Palembang*. Tekno, 16(1), 421–435.

Saaty, T. L. (1993). *Pengambilan Keputusan Bagi Para Pemimpin: Proses Hirarki Analitik untuk Pengambilan Keputusan dalam Situasi yang Kompleks.* Pustaka Binaan Pressindo.

Setiono, Koosdaryani, Suryoto, & Ulyanisa, N. (2020). Selera Masyarakat dalam Menentukan Perumahan di Kabupaten Sukoharjo dengan Metode Fuzzy AHP. *e-Jurnal Matriks Teknik Sipil, 8*. https://doi/org/10.20961/mateksi.v8i2.44178

Sitohang, D. T. R. T. (2018). *Pengembangan Standar WBS Untuk Meningkatkan Perencanaan Penjadwalan Pada Proyek Konstruksi Pelabuhan Udara Berbasis Risiko.*

Spickova, M., & Myskova, R. (2015). *Costs Efficiency Evaluation using Life Cycle Costing as Strategic method*. Procedia Economics and Finance 34.

Sugiyono. (2013). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D*. Alfabeta

Sun, Y., Carmichael, D. G. (2017). *Uncertainties Related to Financial Variables Within Infrastructure Life Cycle Costing: a Literature Review*.

Taufik & Arliandi, M. (2020). *Sistem Informasi E-Ticketing Lrt Kota Palembang*. Bina Darma Conference on Computer Science. e-ISSN: 2685-2683p-ISSN: 2685-2675.

V. R. Vuchic, *Transportation Engineering and Planning*, EOLSS Publisher/UNESCO, Oxford, UK, 2009.

Wayangkau, H. G. (2021). *Analisis Manajemen Risiko pada Proyek Pembangunan bendungan (Studi Kasus : Bendungan Titab di Bali, Bendungan Jatibarang di Kabupaten Semarang Dan Bendungan Diponegoro di Semarang)*. Universitas Diponegoro. Semarang.

Wongkar, Y.K., Tjakra, J., Pratasis, P. A. K. (2016). Analisis *Life Cycle Cost* Pada Pembangunan Gedung (Studi Kasus: Sekolah St. URSULA Kotamobagu).

Y. Zhu and M. Diao, "*The impacts of urban mass rapid transit lines on the density and mobility of high-income households: a case study of Singapore*," Transport Policy, vol. 51, pp. 70–80, 2016.

Yahya, I. N. (2011). *Pengelolaan Risiko Proyek Pembangunan PLTU 10.000 MW Dalam Rangka Peningkatan Kinerja Biaya*. April.

Zhou, Q., Mao, B., Peng, S., Huang, J., Tian, P. (2023). *Analysis of the Impacts of Passenger Demand on the Profitability of Different Types of Urban Rail Transit*. Promet – Traffic&Transportation. 2023;35(1):71-86. https://doi.org/10.7307/ptt.v35i1.4185 .