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Evaluation of Life Cycle Cost (LCC) of Flexible Pavement and Rigid Pavement on Bhayangkara Road Section, Samarinda City

Hendra Gunawa*, Risma Marleno, Retno Hastijanti

Magister Teknik Sipil, Universitas 17 Agustus 1945 Surabaya

Coressponding author: bagungun@gmail.com

Abstract: The development of irrigation infrastructure is an important factor in supporting the agricultural sector, particularly in areas that rely on irrigation systems to improve agricultural productivity. One of the main challenges in implementing irrigation projects is selecting the appropriate construction method to achieve time This research evaluates the life cycle cost (LCC) of flexible and rigid pavement alternatives for Jalan Bhayangkara, Samarinda, to determine the most economical pavement type over the design life. A quantitative LCC analysis based on Net Present Value (NPV) at a 6% discount rate was performed for a 20-year planning period. Cost components included initial construction, routine maintenance, periodic maintenance, rehabilitation, and salvage value. Data sources comprised field surveys, technical documents, maintenance records, and budget estimates. The total LCC for flexible pavement was calculated at IDR 11.19 billion, while rigid pavement yielded a lower total LCC of IDR 10.19 billion. The cost difference of IDR 999.76 million (approximately 8.9%) indicates that rigid pavement is more cost-effective over the analysis period, primarily due to lower maintenance demands and higher structural resilience in the wet, heavy-traffic conditions typical of Samarinda. Consequently, rigid pavement is recommended as the more economical and sustainable option for Jalan Bhayangkara when considering long-term lifecycle costs.

Keywords: life cycle cost (LCC); Net Present Value (NPV); flexible pavement; rigid pavement; maintenance cost.

INTRODUCTION

Road infrastructure development not only considers the initial cost, but also all costs incurred during the service life, including routine maintenance, periodic maintenance, rehabilitation, and salvage value [Arifin et al, 2021]. The Life Cycle Cost (LCC) concept is becoming an increasingly used approach to assess the efficiency of a construction design, especially in areas with heavy environmental and traffic pressures such as Samarinda City. In the context of public infrastructure, LCC analysis is crucial because it provides a comprehensive picture of long-term costs, so that decisions are made not only based on initial costs, but also on sustainability and efficiency over the design life [Hermawan, 2019]

The Bhayangkara Road section is a key corridor that plays a crucial role in supporting community activities and the distribution of goods. Humid environmental conditions, frequent rainfall, and increasing traffic volumes result in significant road maintenance costs if pavement design is not appropriate. Therefore, an in-depth evaluation of the cost-efficiency between flexible and rigid pavements using the LCC approach is necessary to enable local governments to choose the most economical and sustainable alternative [Fahmi, 2022; Kusnadi, 2023].

Flexible pavements generally have lower initial costs but require more frequent maintenance due to their susceptibility to deformation and cracking. Conversely, rigid pavements have higher initial costs but provide better structural stability, longer service life, and lower maintenance costs. By using the Net Present Value (NPV) approach, all cost components over the 20-year design life can be calculated more objectively to determine the most efficient pavement type to be applied to Bhayangkara Road.

This Life Cycle Cost evaluation is expected to provide a comprehensive overview of the long-term costs of each pavement type, which can inform decision-making in road infrastructure planning and development [Setiawan, 2019; Wiwoho, 2020]. This research is crucial to ensuring that government investment in the Bhayangkara Road section not only meets technical requirements but also provides maximum economic benefits and supports sustainable development in Samarinda City.

RESEARCH METHOD

Types and Approaches of Research

This study uses a quantitative-analytical approach through the Life Cycle Cost Analysis (LCCA) method. This comparative study aims to assess the cost differences between flexible and rigid pavements over the design life.

Location and Time of Research

The research was conducted on the Bhayangkara Road section, Samarinda City, with data collection referring to the availability of technical documents and budget.

Data Types and Sources

- Primary Data
    - Survey road conditions to determine maintenance needs.
    - Interview with the technical team regarding maintenance costs.
- Secondary Data
    - RAB (Cost Budget Plan) for initial construction.
    - Routine and periodic maintenance costs rehabilitation.
    - Planned age and salvage value data
    - Discount rate data, used 6%.

Data collection technique

1. Collection of budget documents from the PUPR Service.
2. Literature study on LCC standards and cost parameters.
3. Field survey to determine actual conditions that affect maintenance needs.

Data Analysis Techniques

A. Identification of Cost Components

Cost components are calculated for a 20-year design life, including:

- Initial construction costs.
- Routine maintenance costs.
- Periodic maintenance.
- Rehabilitation.
- Salvage value at the end of the planned life.

B. Life Cycle Cost (LCC) Calculation

The Net Present Value (NPV) approach is used with a discount rate of 6%.

General formula:

$$NPV = \sum_{t-1}^{n} \frac{R_t}{(1+i)^t} - Initial\ Investment$$

Where:

Rt = Net cash inflow-outflows during a single period t

i = Discount rate or return that could be earned in alternative investments

t = Number of timer periods

n = Total number of periods

Salvage value is calculated by:

$$Annual\ Depreciation = \frac{Cost\ of\ Asset - Salvage\ Value}{Useful\ Life}$$

C. Comparison of Flexible vs. Rigid Pavement LCC

- Compile a comparative table of total costs over 20 years.
- Determine cost difference and efficiency percentage.
- Assess the most economical pavement options to implement.

D. Interpretation of Results

The calculation results are analysed to determine the pavement type with the lowest LCC value and the reasons for the cost differences.

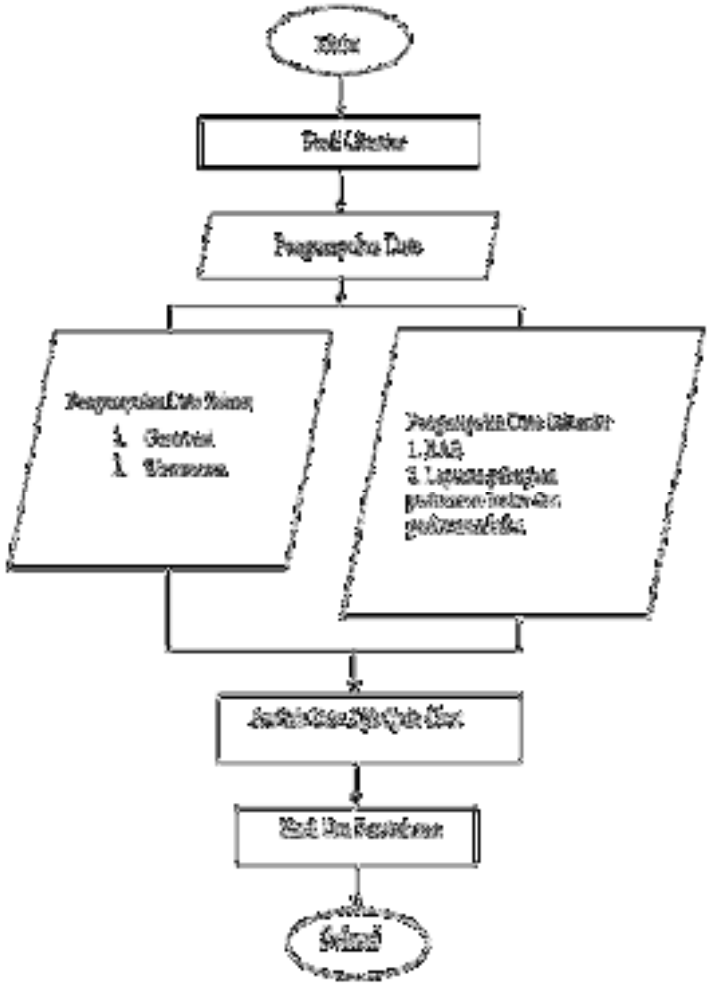

Figure 1. Reseearch Flow cart

RESULTS AND DISCUSSION

Life Cycle Cost (LCC) Calculation Results

The analysis was conducted over a 20-year planning period with a discount rate of 6%.

1. Flexible Pavement Cost Components
    - Initial construction costs: high, but still below rigid pavements.
    - Routine maintenance: annual, including patching and sealing.
    - Regular maintenance: overlay in the 8th and 15th years.
    - Rehabilitation: required in the 15th year.
    - Salvage value: low due to considerable structural damage.

    Total LCC of flexible pavement = Rp. 11.19 billion.
2. Rigid Pavement Cost Components
    - Initial construction costs: higher than flexible pavement.
    - Routine maintenance: minimal, only joint maintenance.

- Periodic maintenance: small-scale in the 12th year.
- Rehabilitation: insignificant before the 19th year.
- Salvage value: higher.

Total LCC of rigid pavement = IDR 10.19 billion.

LCC Comparison

Pavement Type Total LCC (20 Years)

Flexible Pavement Rp 11.19 billion

Rigid Pavement Rp 10.19 billion

Cost difference = Rp 999.76 million (± 8.9%), with rigid pavement being more economical over the design life.

Discussion

1. Structural Differences Affecting LCC

   Flexible pavement requires:

   - More frequent maintenance,
   - Periodic overlays,
   - High rehabilitation costs approaching the 15th year.

   In contrast, rigid pavements:

   - Have high structural strength,
   - Are more resistant to weather and water,
   - Require limited maintenance,
   - Have a high salvage value.

   This difference is what causes a cost difference of almost IDR 1 billion.

2. The Influence of Local Conditions on Bhayangkara Road

   Local factors that influence LCC are:

   1. Heavy traffic volume (high LHR) → puts great stress on flexible pavement.
   2. High rainfall → accelerates damage to the asphalt layer.
   3. Drainage is still not good in some parts → increases maintenance costs.

   This condition increases the cost of flexible pavement compared to rigid pavement.

3. Economic Feasibility of Pavement Selection

   Based on the analysis:

   - Rigid pavement is more economical and efficient in the long term.
   - Although the initial cost is higher, the long-term savings are significant.
   - Suitable for roads with heavy traffic and humid environments like Samarinda.

CONCLUSION

Based on the results of the Life Cycle Cost (LCC) evaluation over the 20-year design life with a 6% discount rate, several key conclusions were obtained:

1. The total LCC of flexible pavement is IDR 11.19 billion, contributed by annual routine maintenance costs, periodic overlays, and rehabilitation costs in year 15. The high maintenance requirements increase the total cost over its service life.
2. The total LCC of rigid pavement is IDR 10.19 billion, lower than that of flexible pavement. This is influenced by the lower maintenance requirements, the absence of large overlays, and the higher salvage value at the end of the design life.
3. There is a cost difference of IDR 999.76 million, or approximately 8.9%, indicating that rigid pavement is more economical for the conditions of Jalan Bhayangkara.
4. Based on the results of the economic analysis, rigid pavement is recommended as a more efficient and sustainable option, because it provides lower total life cycle costs, less maintenance requirements, and better structural resistance to heavy traffic conditions and high rainfall in Samarinda City.

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