Agency cost estimation on flexible and rigid pavement

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Abstract. Flexible pavement is a road pavement type which is commonly used, however rigid pavement is also widely used now days in Indonesia. It has even been used for local roads (managed by local authority), which take in heavy vehicle loads. This rigid pavement is used because it has longer service life and higher durability. The need for a durable road resulted in higher construction costs, whereas the budget for local road design and construction is often limited. This study aims to evaluate the agency costs that must be incurred for flexible and rigid pavement construction. Two alternatives of design life are simulated for each type of pavement, namely design lives of 10+10 year and 20 year for flexible pavement and design lives of 20+20 year and 40 year for rigid pavement. The agency costs of those alternatives are analysed using Life Cycle Cost Analysis (LCCA) program-RealCost 2.5. The results show agency costs for alternative flexible pavement 1 (design life of 10y + 10y) and alternative 2 (design life of 20 y) are $ 1,421,930 and $ 1,061,680 respectively. Furthermore for the rigid pavement, the agency cost for alternative 1 (design life 20y + 20 y) and alternative 2 (design life 40 y) is $. 443,990 and $. 350,870 respectively.

1 Introduction

Flexible pavement is a road pavement type which is commonly used, however rigid pavement is also widely used now days in Indonesia. It has even been used for local roads (managed by local authority), which receive heavy vehicle loads. This rigid pavement is used because it has longer service life and higher durability. The need for a durable road resulted in higher construction costs, whereas the budget for local road design and construction is often limited. Babashamsi, et al. used Life Cycle Cost Analysis (LCCA) to assess the alternative costs efficiency according to the rule of net present value (NPV). It becomes a significant point to act of having cost evaluation in order to get an optimal pavement life cycle cost [1]. The life cycle cost should include those variables controlling future costs; [2]. Life cycle cost analysis becomes a process for assessing the total economic worth of a usable project segment. This is conducted by creating an analysis of initial costs and discounted future costs, namely: maintenance, user costs, reconstruction, and rehabilitation over the life of the project segment [3]. Agency cost comprises the costs related openly to the investments by the operation and maintenance agency to maintain the pavement at the required level of service; [4]. Ram et al. conducted a research of a series of Michigan concrete pavement project by applying LCCA. It has drawn a conclusion that higher levels of sustainability are achieved with increased pavement longevity [5]. Handayani et al. studied user cost of local road using LCCA. It was concluded that the longer the analysis period, the more economical the uses cost [6]. The application of LCCA by Embacher and Snyder was intended to investigate actual maintenance and rehabilitation costs and strategies for concrete and asphalt pavement in two Minnesota counties. The application has documented the impact of differing maintenance strategies on the normalized cost (adjusted for varying traffic levels) of comparable pavement [7].

1.1 RealCost LCCA software

The Federal Highway administration (FHWA) guide approach for performing LCCA considers two main components, namely; agency costs and user costs. The components of agency cost in LCCA methods are construction, maintenance, and rehabilitation. An estimate of the agency cost elements should be taken for the analysis horizon duration for different pavement design alternative. The FHWA's RealCost Software becomes LCCA tool which is widely chosen to be applied in the U.S. for pavement applications. RealCost is basically an MS-Excel® spreadsheet based automated version of the LCCA methodology which is included in the FHWA's LCCA Technical Bulletin [6, 8]. By using both deterministic and probabilistic approaches, the program can be used compute life-cycle costs for agency and work zone user costs which are associated with new construction, maintenance, and rehabilitation activities.

1.2 Research design

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The aim of this research is to assess the agency costs that must be acquired in order to obtain flexible and rigid pavement construction. There are two alternatives of design life which are simulated for each type of pavement, namely design lives of 10+10 year and 20 year for flexible pavement and design lives of 20+20 year and 40 year for rigid pavement. The analysis period in this case means that this study compared the twenty-year life of design alternative 2 against a agency cost of design alternative 1 *plus* agency cost of reconstruction with design alternative 1 in ten years.

Flexible pavement thickness design is based on the Component Analysis Method of Ministry of Public Work [9], furthermore, the rigid pavement thickness design is based on Manual Pavement Design 2013 [10].

The primary data in this study are average annual daily traffic (AADT) and California Bearing Ratio test value. Secondary data in this study are existing road data, traffic growth, work unit prices, vehicle operating costs, and discount rate. Traffic growth and vehicle operating cost are shown in Tables 1 and 2.

This study was conducted based on case of local road construction. Sukowati road of Sragen city is taken as the study case for flexible pavement, meanwhile Hos Cokroaminoto road of Sragen city is taken as the study case for rigid pavement. Agency costs of those alternatives are analysed using life cycle cost analysis program-RealCost 2.5.

Table 1. Traffic Growth

	2011-2020	>2021-2030
Arterial and Urban (%)	5.0	4.0
Rural (%)	3.5	2.5

Source: The Ministry of Public Work and Public Housing (Directorate of Highway)

Table 2. Vehicle Operating Cost

Vehicle type	Vehicle Operating Cost (IDR)		
	Bandung	Semarang	Surabaya
Car	213,500	243,820	217,560
Utility	213,890	243,340	217,560
Small Bus	414,490	420,080	418,370
Large Bus	670,150	677,960	667,370
Light Truck	326,320	327,070	303,840
Heavy Truck	673,560	673,560	615,110

Source: The Ministry of Public Work and Public Housing (Directorate of Highway)

2 Result and discussion

2.1. Flexible pavement

AADT for each vehicle type collected from traffic survey on flexible pavement is shown in Table 3. The CBR value obtained from Dynamic Cone Penetrometer test is 6%. The estimate results of the thickness of the flexible pavement layer found using the Component Analysis method are 14.86 cm for the 10 years-design life and 18.86 cm for the 20 years-design life. The budget plan estimates of flexible pavement cost with the 10 years-design life and 20 years are $ 873,036,000 and $ 1061,682,000 respectively. Figure 1, 2, and 3 show the result of LCCA analysis with Realcost 2.5 program.

Table 3. AADT of vehicle type of case study flexible pavement

Vehicle type	AADT (vehicle/day/2lanes)
Car	9120
Bus	320
Small Truck	1120
Medium Truck	150
Heavy Truck	20
Total	10730

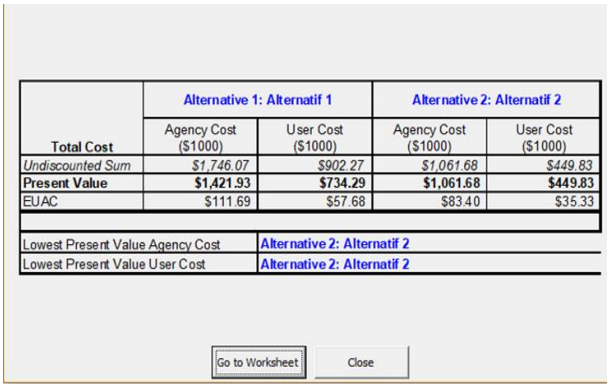

Fig. 1. Deterministic results with RealCost 2.5

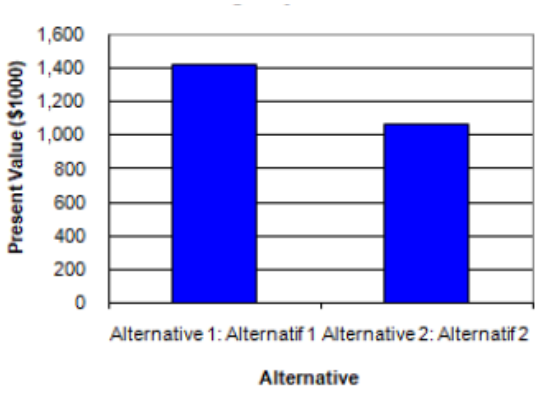

Fig. 2. Agency cost deterministic result

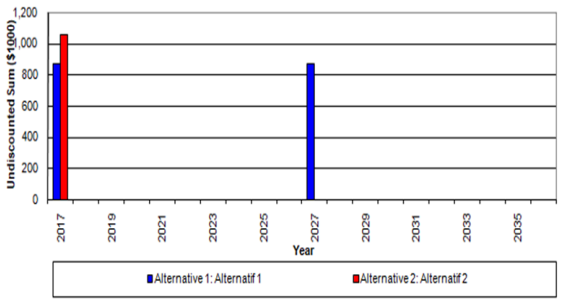

Fig. 3. Expenditure stream: agency cost

The following table indicates the recapitulation of LCCA analysis results:

Table 4 The estimate result of the thickness, budget plan and LCCA of the flexible pavement

	Alternative 1 10 years' design life	Alternative 2 20 years' design life
Thickness of flexible pavement	14,86 cm	18,86 cm
Budget plan	$ 873,036,000	$ 1,061,682,000
Agency cost	$ 1,421,290	$ 1,061,680

The above information mentioned in Table 1 indicates the alternative 1 has a smaller cost budget than the alternative 2. This is so for a reason that the pavement thickness is planned to be thinner. Meanwhile, the deterministic result of the RealCost 2.5 program indicates that alternative 1 needs a more agency cost than alternative 2. This is due to the design alternative with shorter design life. When the design life has been expanded, agency cost of reconstruction will be reestimated and added to total agency cost.

2.2 Rigid pavement

AADT for each vehicle type collected from traffic survey on rigid pavement is shown in Table 5. The CBR value obtained from Dynamic Cone Penetrometer test is 10.5%. The rigid pavement plan has been conducted with Manual of Road Pavement Design of 2013 with the result of thickness of pavement on Alternative I (20 years' design life) of 20 cm and Alternative II (40 years' design life) of 25 cm.
The budget plan estimates of flexible pavement cost with the 20 years' and 40 years' design life are $ 318,204 and $ 350,870 respectively.
After the analysis is conducted with the program, the output of the program is reflected in a deterministic result. The following figures including Figures 4, 5, and 6 shows Deterministic Results (Agency Cost & User Cost).

Table 5. AADT of vehicle type of case study rigid pavement

Vehicle type	AADT (vehicle/day/2lanes)
Motor Cycle	6910
Car	630
Bus	10
Small Truck	200
Medium Truck	270
Heavy Truck	360
Total	8380

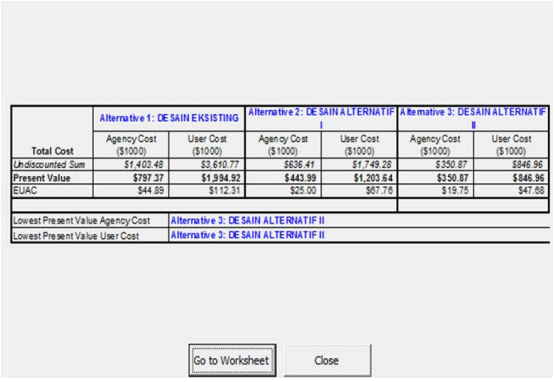

Fig.4. Deterministic results

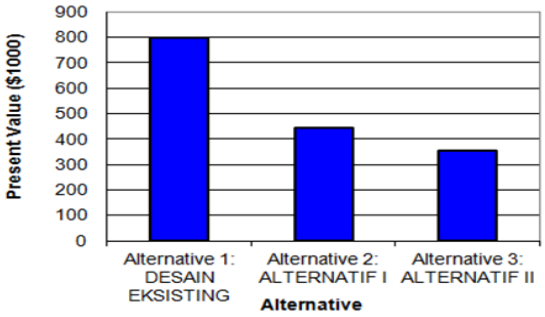

Fig. 5. Agency cost chart

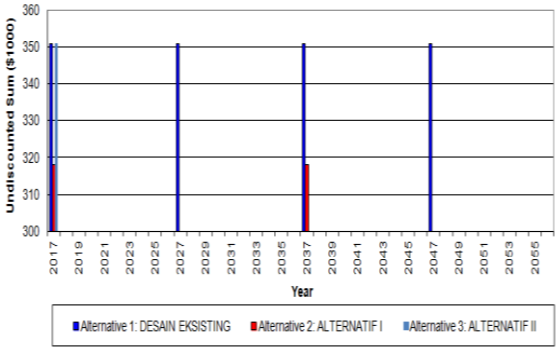

Fig. 6. Expenditure steam: agency cost

The following table indicates the recapitulation of LCCA analysis results:

Table 6. The estimate result of the thickness, budget plan and LCCA of the rigid pavement

	Alternative 1 20 years' design life	Alternative 2 40 years' design life
Thickness of rigid pavement	20 cm	25 cm
Budget plan	$ 318,204	$ 350,870
Agency cost	$ 443,990	$ 350,870

According to the information mentioned in Table 2 above, Alternative 1 has a smaller cost budget than the second alternative. This is so for a reason that the pavement thickness is previously planned to be thinner. Meanwhile, the deterministic result of the RealCost 2.5 program indicates that alternative 1 needs a higher agency cost than alternative 2. This is because of the design alternative with shorter design life. When the design life has been exceeded, agency cost of reconstruction will be recalculated and added to total agency cost, over an analysis period.

3 Conclusion

The results indicate that agency cost of flexible pavement construction of 10 years and 20 years' design life are US$ 1,421,930 and US$ 1,061,680 respectively. Moreover, agency cost of rigid pavement construction of 20 years and 40 years' design life are US$ 443,990 and US$ 350,870 respectively. The estimate using the LCCA method show that planning with a longer design life results in more economical value. This is due to the design alternative with shorter design life. Agency cost of reconstruction will be recalculated and then added to total agency cost if the design life has been exceeded, over an analysis period.

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