LCCA PBC

by Betty Susanti

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LIFE CYCLE COST COMPARISON BETWEEN PERFORMANCE BASED AND TRADITIONAL CONTRACTS FOR ROADS IN INDONESIA

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ABSTRACT: Implementation of Performance-based Contracts (PBC) for road maintenance in Indonesia still requires various studies, especially related to potential long-term cost efficiencies that can be achieved by the road agencies by shifting the application of traditional contracts to PBC. This study assesses the effectiveness of PBC compared to traditional contract implementation based on a case study on one of the PBC pilot projects in Indonesia. The effectiveness of the PBC reviews in terms of project life cycle cost efficiency was calculated. LCC calculations were conducted by considering the influence of the length of contracted road, the initial conditions of contracted road, and the duration of PBC project. The LCC calculation shows that the implementation of PBC generally has the potential to generate LCC efficiency compared to the traditional contract. This study also proved that the implementation of PBC can guarantee the performance of road services during multi-year contracts and also provide other benefits for the road agency and road users.

ABSTRAK: Pelaksanaan Kontrak Berasaskan Prestasi (PBC) untuk penyelenggaraan jalan raya di Indonesia masih memerlukan berbagai kajian, terutama yang berkaitan dengan potensi efisiensi biaya jangka panjang yang dapat dicapai oleh pihak agensi jalan dengan mengalihkan penerapan kontrak tradisional ke PBC. Kajian ini menilai keberkesanan PBC berbanding dengan pelaksanaan kontrak tradisional berdasarkan kajian kes pada salah satu projek perintis PBC di Indonesia. Keberkesanan ulasan PBC dari segi kecekapan kos kitaran hayat projek. Pengiraan LCC dilakukan dengan mempertimbangkan pengaruh panjang jalan yang dikontrak, keadaan awal jalan terkontrak, dan jangka waktu projek PBC. Pengiraan LCC menunjukkan bahawa pelaksanaan PBC secara amnya berpotensi untuk menghasilkan kecekapan LCC berbanding dengan kontrak tradisional. Kajian ini juga membuktikan bahawa pelaksanaan PBC dapat menjamin prestasi perkhidmatan jalan selama kontrak multi-tahun dan juga memberikan manfaat lain untuk agensi jalan dan pengguna jalan raya.

KEYWORDS: *life-cycle cost; maintenance; performance-based contract; road; traditional contract*

1. INTRODUCTION

National road maintenance projects in Indonesia are generally delivered using in-house systems and input-based contracts with a Design-Bid-Build (DBB) method. An in-house system is an approach of self-managed routine maintenance project implementation by a

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road agency. This system is only applied for maintenance of roads in good condition. In the in-house system, the road agency plays its role directly in the process of implementing the physical works of maintenance and project supervision. Meanwhile, the DBB pattern is an approach for implementing the maintenance of road that is contracted to the construction service provider. This pattern is applied on non-routine road maintenance work such as road improvement works, periodic maintenance, and road rehabilitation. Both in-house and DBB systems are generally denoted as part of the traditional contract approach. This traditional approach applies a prescriptive or input-based system. It is performed in a single year with a short maintenance warranty period. The mechanism of road maintenance always applies a corrective approach and it is implemented in the packages of the contract with a small value. Many studies have shown that these traditional contracts generate high costs and inadequate road quality [1,2].

Although traditional contracts remain the most commonly used type of contract in Indonesia, there are currently efforts being made that focus on the application of non-traditional contracts to fund and perform road maintenance projects. This non-traditional contract, or an alternative contract, generally focuses on the output or the outcome of the project. It is performed on a multi-year basis with a long maintenance warranty period. Additionally, the contract integrates various maintenance works in the maintenance project package. There are various types of non-traditional contract for road maintenance namely Design-Build, extended warranty contract, lane rental, cost plus time, and performance-based contract. Some previous studies showed that one alternative to traditional contracts that can overcome a problem related to the high amount of cost and the low road quality is Performance-Based Contract (PBC), as suggested by [3-5].

PBC is perceived as *Output and Performance-based Road Contract* [6]. This contract regulates the road service performance that should be achieved during the contract period in a multi-year contract. Consequently, the road maintenance strategy is preventive. Design works, construction, or road maintenance are carried out in an integrated way by one service provider. The scope of work that is contracted generally includes a relatively long road. With those characteristics stated above, PBCs have the potential to reduce maintenance costs and improve road performance compared to traditional contracts [3,4]. However, various efforts to assess the effectiveness of PBC implementation for road maintenance projects are limited to the assessment of the potential cost savings during the contract period [3,4]. Those approaches have not been based on the assessment of long-term PBC potential cost savings. The appropriate approach to determine cost savings of PBC is to evaluate the actual cost before and after PBC implementation or by making estimates based on road deterioration and life-cycle cost models [7].

Several studies have been conducted regarding the implementation of PBC in Indonesia. Reference [8] identified that the development of methods to estimate the cost efficiency of PBC is required, while [9] emphasized the need to develop PBC quantitative evaluation schemes to justify the claims of efficiency and effectiveness of the use of PBC in national road management in Indonesia. However, quantitative studies assessing the effectiveness of PBC implementation have not been conducted. The objective of this study was to assess the effectiveness of the PBC implementation in road maintenance projects compared to the traditional approach based on a case study of a PBC pilot project in Indonesia. The effectiveness of PBC was reviewed in terms of project's life cycle cost efficiency.

2. CASE STUDY: PBC PILOT PROJECT IN INDONESIA

The implementation of PBC for road maintenance projects in Indonesia started in 2011. Currently, six PBC pilot projects in Indonesia are being carried out (Table 1), all of which are national road improvement works. Of the six projects, five are on roads with high traffic volume and overloads located on Java Island, whereas one project is in the Sei Hanyu–Tumbang Lahung segment on Kalimantan Island, a road with a low volume of traffic. The implementation of PBC is currently more applicable to national roads on Java Island because of the readiness of road agencies and availability of adequate historical data to support PBC implementation.

Table 1: PBC pilot projects in Indonesia

No	Road Segment	Road Length (kilometers)	Contract Period	Project Location
1	Ciasem-Pamanukan	18.50	2011-2015	North coast lane of Java Island
2	Demak-Trengguli	7.68		
3	Semarang-Bawen	22	2012-2019	Central lane of Java Island
4	Bojonegoro-Padangan	11		
5	Padangan-Ngawi	10.70		
6	Sei Hanyu-Tumbang Lahung	50.60	2013-2020	Kalimantan Island

This study was conducted on one PBC pilot project at one section of a national road on the northern coast of West Java, i.e. Ciasem-Pamanukan section (Fig. 1). The contract was completed in 2015. The project was for road improvement work along 18.5 kilometers of road with a pavement width of 14 meters. The type of pavement consisted of flexible and rigid pavements on the fast and slow lanes, respectively. The road agency is the owner of the Karawang-Cikampek-Pamanukan section, whose territory is 74.24 kilometers of the total 273.31 kilometers of the northern coast of West Java Section.

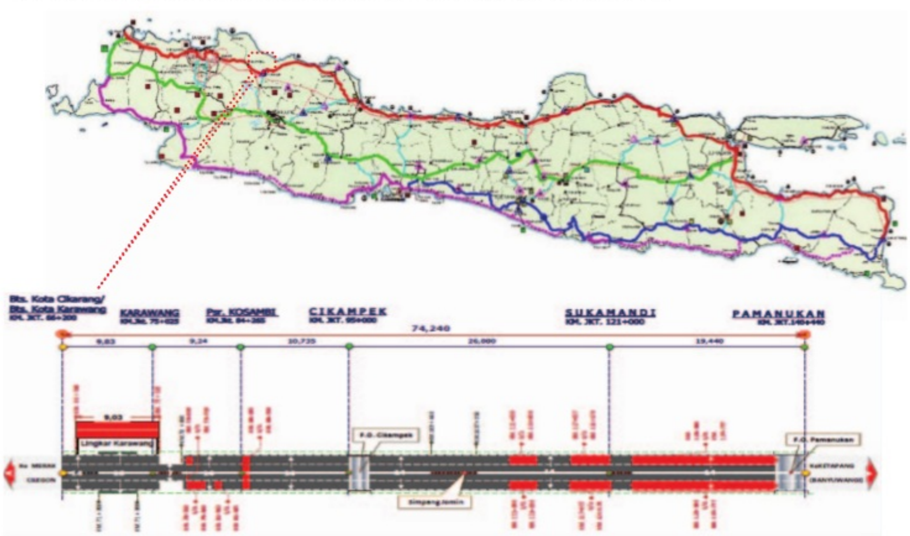

Fig. 1: Location of Ciasem-Pamanukan section.

National road sections on Java Island have a higher traffic volume and traffic loads compared to roads on other islands, especially on the north coast lane of Java. Reference [10] showed that the average daily traffic on Ciasem-Pamanukan section in 2011 or first year of contract was more than 46 million vehicles in both directions, where the traffic volume is distributed mostly on the fast lane with flexible pavement. Approximately, 60% of heavy vehicles are distributed in the fast lane [11].

3. LIFE CYCLE COST (LCC) ANALYSIS

The LCC analysis refers to the models that have been developed [12-14]. In line with the PBC concept that is applied for road maintenance works, the scope of work reviewed in this study was limited to road maintenance works, which consist of routine maintenance, periodic maintenance, and road betterment. The LCC analysis simply considered the cost components of the road agency. They are the total cost that should be spent by the government as the road agency to implement all works related to the road maintenance project [15]. The component of road agency cost for each contract approach that is considered in this study is shown in Table 2. The type of pavements reviewed were flexible pavements as most of the traffic volume was distributed on these.

Table 2: The components of road agency costs

Type of road works	**Road Agency Cost for Traditional Contract Approach**	
	Delivery System	**Road agency costs components**
Routine maintenance	In-house	Routine maintenance cost
Periodic maintenance	D-B-B	Periodic maintenance cost Contractor procurement cost Design cost Designer procurement cost Supervision cost Supervisor procurement cost
Road improvement	D-B-B	Road improvement cost Contractor procurement cost Design cost Designer procurement cost Supervision cost Supervisor procurement cost
Type of road works		Road Agency Cost for PBC
	Delivery System	Road agency costs components
Design and road maintenance (integrated)	D-B-O-M	Integrated procurement costs (for designer and contractor) Integrated costs for design and road works Procurement cost for external supervision Supervision cost

This study applied the LCC method with a deterministic approach. To overcome the uncertainty associated with an estimated present value of LCC, we applied deterministic sensitivity analysis techniques in order that the estimation indicate the variability of LCC for road maintenance projects performed using different types of contracts. According to [3] and [4], the characteristics of a project applying a PBC scheme—such as the length and initial condition of the road, the duration of the contract, the number and type of activities comprised in the contract package, the extension or addition of contract period, and the performance indicators applied—affects its cost-efficiency.

In this study, a deterministic sensitivity analysis associated with the length and initial condition of the road contracted and duration of the PBC project was performed on 48 scenarios, 36 of which were for PBC projects, and 12 for traditional projects. Three overall scenarios were designed, each with varying road lengths: the first scenario used a road length complying with the scope of the case study project; the contracted road in the second scenario was extended to road networks under the authority of the owner of Karawang-Cikampek-Pamanukan Sections; and the contracted road in the third scenario was extended to the northern coast lane of West Java. For each of these scenarios of different road lengths, the initial road conditions were simulated as being good, fair, minor damage, and heavy damage. For each initial road condition, the PBC project durations were simulated to follow the existing practical implementations of PBC in Indonesia—4 and 7 years—and forthcoming PBC projects—10 years. A summary of all the scenarios used in the LCC calculations are shown in Table 3.

Table 3: Scenarios used in the LCC Analysis

Road Length (kilometers)	Initial Road Condition	LCC of Traditional Projects	Duration of PBC Projects	LCC of PBC Projects
			4-years	LCC PBC-1
18.5	Good	LCC TC-1	7-years	LCC PBC-2
			10-years	LCC PBC-3
			4-years	LCC PBC-4
	Fair	LCC TC-2	7-years	LCC PBC-5
			10-years	LCC PBC-6
			4-years	LCC PBC-7
	Minor Damage	LCC TC-3	7-years	LCC PBC-8
			10-years	LCC PBC-9
			4-years	LCC PBC-10
	Heavy Damage	LCC TC-4	7-years	LCC PBC-11
			10-years	LCC PBC-12
			4-years	LCC PBC-13
74.24	Good	LCC TC-5	7-years	LCC PBC-14
			10-years	LCC PBC-15
			4-years	LCC PBC-16
	Fair	LCC TC-6	7-years	LCC PBC-17
			10-years	LCC PBC-18
			4-years	LCC PBC-19
	Minor Damage	LCC TC-7	7-years	LCC PBC-20
			10-years	LCC PBC-21
			4-years	LCC PBC-22
	Heavy Damage	LCC TC-8	7-years	LCC PBC-23
			10-years	LCC PBC-24
			4-years	LCC PBC-25
273.31	Good	LCC TC-9	7-years	LCC PBC-26
			10-years	LCC PBC-27
			4-years	LCC PBC-28
	Fair	LCC TC-10	7-years	LCC PBC-29
			10-years	LCC PBC-30
			4-years	LCC PBC-31
	Minor Damage	LCC TC-11	7-years	LCC PBC-32
			10-years	LCC PBC-33
			4-years	LCC PBC-34
	Heavy Damage	LCC TC-12	7-years	LCC PBC-35
			10-years	LCC PBC-36

The LCC considers all initial and future costs. All costs included in this LCCA are adjusted to the cost of project implementation for both contract approaches, as shown in Table 2. This LCCA input consists of the historical data of road maintenance costs; surface roughness at the beginning of contract year, number of modified structures on the road, and the cumulative equivalent single axle load (CESAL) value for predicting the road pavement performance; design and construction supervision costs; and administration costs for procuring planning service provider, contractor, and project supervisor.

A schematic diagram of the LCC analysis procedure is shown in Fig. 2. The initial step to calculate the project's LCC is to determine the road condition and maintenance works required (Fig. 2). Initial road conditions were varied to represent good, fair, minor damaged and heavily damaged conditions.

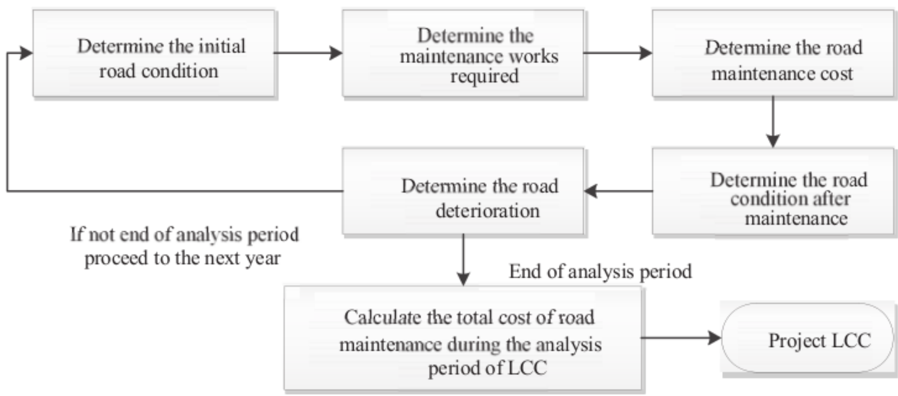

Fig. 2: LCC calculation procedure.

In line with the performance indicators set in the PBC project, the road conditions were measured based on the road's functional performance using a roughness indicator (International Roughness Index, IRI). The road conditions were assumed to be uniform and were expressed using a single IRI value. The Public Works Ministry Regulation on Procedures for Road Maintenance and Surveillance [16] was used to determine the type of maintenance works suitable for the road condition (Table 4). Table 4 is also used to determine the road's conditions after maintenance based on IRI values.

Table 4. Guidelines for determination of road maintenance works

Road Condition	IRI Value Range	IRI Value Used	Required Works	IRI Value after Maintenance
Good	$0 \leq IRI \leq 3.5$	1.75	Routine (preventive) maintenance	Same as initial IRI
Fair	$3,5 \leq IRI \leq 6$	4.75	Routine (corrective) maintenance	Previous IRI – 0,5
Minor Damage	$6 \leq IRI \leq 8$	7	Periodic maintenance	3,00
Heavy Damage	$IRI \geq b$	9	Betterment	3,00

PBCs and traditional approaches have different road maintenance strategies. The maintenance works under a PBC scheme are conducted throughout the year by considering the road conditions and the project's performance indicators, which in this project case study was IRI ≤ 4 m/km. The maintenance work applied to the PBC project may be higher than what is required by regulation (Table 4). For example, good road conditions require only routine preventive maintenance, but if this action is implemented, the deterioration prediction for the coming year would exceed the performance indicators set out in the PBC project; and higher maintenance works in this case routine corrective maintenance should be applied. In traditional projects, road maintenance is conducted every year and only considers the road conditions. In general, preventive maintenance strategies are applied to the PBC scheme, which delays and prevents widespread damage to the roads; whereas in traditional projects, corrective maintenance strategies are applied in an attempt to repair damages that have already occurred. In this study, those two contract approaches are set by applying the same performance indicator for the road that will be contracted. Thus, the implication of the LCC difference between both types of contract is simply on the mechanism of project implementation.

The next step in the LCC calculation procedure is to determine the road maintenance cost. The cost for each type of road maintenance work was estimated based on historical cost data of road projects contracted using traditional contracts during the years 2003-2011. The historical data was collected from the same road segment and vicinity as the one reviewed in this study. The unit cost estimation was carried out for the year 2011 and was used as a baseline of the LCC calculation (Table 5). Unit cost of PBC project not including the cost of service provider procurement and supervision works.

Table 5: Unit cost estimate of road maintenance works

Type of Works	Project Unit Cost (Rp/km)
Routine (preventive) maintenance	98,054,957
Routine (corrective) maintenance	11,738,118
Periodic maintenance	2,116,526,108
Betterment	8,735,724,931

Note: 1 USD = Rp. 14,500.

In traditional approach, routine maintenance works are always carried out under an in-house system in which the planning and supervision are carried out by in-house staff and the maintenance work is conducted using equipment available at *Balai Pelaksanaan Jalan Nasional*. The total cost of in-house works consists only of material costs and wages of field workers. Periodic maintenance and betterment on the traditional approach are carried out under the DBB delivery system. The road agency expenditures include costs for design, construction, and supervision, as well as the cost of procuring service providers for each of those works.

PBC projects differ from traditional projects in that PBC projects are organized under a Design-Build-Operate-Maintain (DBOM) project delivery system, as stated in [4,5,7]. The road agency expenses encompass the costs for design, construction, and maintenance, all in an integrated manner [4]. In this case study project, there was also a cost for the activities of an independent supervisor that were meant to ensure that the project quality assurance was performing adequately. Procurement costs in PBC projects consist of service provider procurement of both the contractor and supervisor.

This study determined the LCC project based on deterioration of the road. This study uses the Indonesian Integrated Road Management System (IIRMS) method to estimate the deterioration of flexible pavements, which is expressed in the following equation:

$$IRI_t = e^{0.023.t}[IRI_o + 263\ (1+SNC)^{-5}.NE_t] \quad \text{Eq. 1}$$

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where IRI_t is the road deterioration prediction after 1 year of maintenance, IRI_o is the IRI value immediately after maintenance, t is the time of evaluation (t=1 as the maintenance work is to be conducted every year), SNC is the structural number capacity of the pavements, and NE_t is the cumulative equivalent single axle load (CESAL) at time t (per 1 million ESAL). SNC and CESAL data are obtained from [15]. The CESAL value in 2011 was 18,785,729 with a growth rate set to 7.5% per year. In this study, the SNC values were assumed to be influenced by the roads' functional performance where SNC values for roads with good and fair conditions were each set at 6.10 and 3.32, with a condition factor of 0.92 and 0.5, respectively.

Results of the deterioration evaluation of the current year were used as input to assess the initial road conditions for the following year and, based on these predictions, the required maintenance works for the following years were identified. This process was carried out throughout the period of analysis.

The project LCC is the present value of the total cost of road maintenance during the analysis period. Based on the IIRMS guideline that becomes the pavement management system for the road network in Indonesia, the service life of the road for improving the existing road is established for 10 years. The IIRMS guideline also the flexible pavement is designed to be able to serve traffic for 10 years. Based on the considerations above, this study decided that the service life of roads was 10 years. Considering that the longest service life of roads reviewed was 10 years, the LCC analysis period in this study was also set for 10 years. However, as the contract duration of the PBC projects is 4 or 7 years, identification of the required maintenance works and their cost during the 4 or 7 years was conducted in accordance with the PBC maintenance strategy. After the end of the PBC contract period, road maintenance is assumed to be delivered using a traditional approach until the end of the LCC analysis period. Therefore, identification of the required maintenance works and calculation of road maintenance costs for the rest of the analysis period was conducted using a traditional scheme.

As the PBC project reviewed in this study was implemented in 2011, the baseline of the LCC calculation and estimation of the LCC present value were set for the year 2011. LCC calculation was done using an average discount rate during 2005-2014. The discount rate used here was 7.97%.

4. PROJECT LCC EFFICIENCY

In general, the results of this calculation show that PBC projects generate a lower LCC compared to traditional projects, as shown in Fig. 3. The LCC calculation for all scenarios shows that the PBC application has potential in generating an LCC efficiency of 9.4% compared to the application of the traditional contract. For all contract duration scenarios and the initial conditions of the road to be contracted, the implementation of PBC generates lower LCC compared to the implementation of traditional contracts. The longer the duration of PBC contracts, there is a tendency for the LCC project to decline. This is due to the low administrative costs for multi-year contract management as in PBC projects compared to single-year contracts on traditional projects, as indicated by [17].

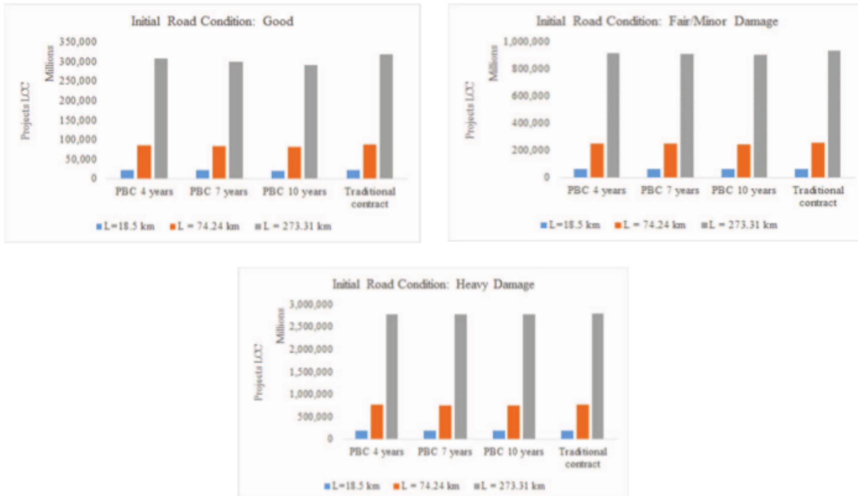

Fig. 3: LCC of PBC and traditional projects.

LCC projects increase as the length of contracted roads increases; however project costs per kilometer of road decrease by 1.9%, as shown in Fig. 4. This is consistent with [18] and [19], thus, working on longer road lengths has the potential to generate lower LCC. Implementation of PBC for the maintenance of long roads can potentially generate a higher LCC efficiency due to the economies of scale in unit cost of road maintenance. There is also a benefit in the form of ensuring road performance on a long road network.

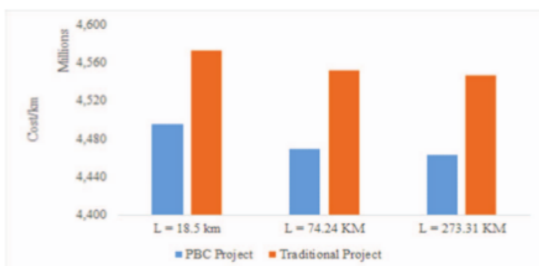

Fig. 4: Project cost comparison per kilometer of road.

The LCC calculation results also show that the implementation of PBC has the potential to generate a lower LCC by as much as 6.4% under the traditional contract for each of the same road conditions, as shown in Fig. 5. Implementation of PBC also has the potential to generate a low LCC if the roads contracted are in good condition. The lower the initial road conditions, the higher the LCC of PBC projects due to the high cost of road maintenance needed in the early years of the contract to meet the required performance indicators, and vice versa. This is consistent with [20-22]. Implementation of PBC on roads with a heavily damaged condition and high traffic loads will encourage contractors to perform road betterment works in the early years of the contract because of the high levels of uncertainty associated with the pavement structural condition.

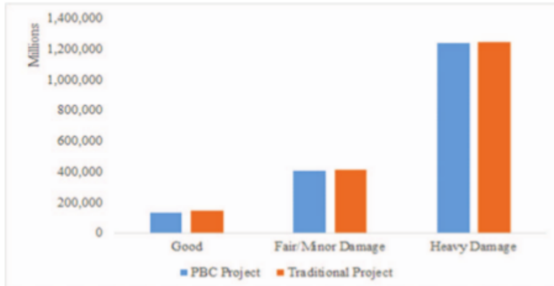

Fig. 5: Project cost comparison for different road condition.

The LCC analysis also showed that the implementation of PBC with a duration of 10 years generated an LCC efficiency of 2.5% compared to the shorter contract duration, as shown in Fig. 6. This result is in line with the findings of [3] and [4]. Although long contract durations require a significantly higher initial cost, they can ensure road performance over a long period of time. Other benefits of a long contract duration include less bureaucracy for the road agencies due to the assurance of available funding of road maintenance for several years, allowing the agency to focus on efforts to increase their role and expertise in the areas of asset management. Roads maintained at good conditions provide benefits for road users, such as reducing the vehicle operating costs, accident rate, and travel time, as also demonstrated by [7].

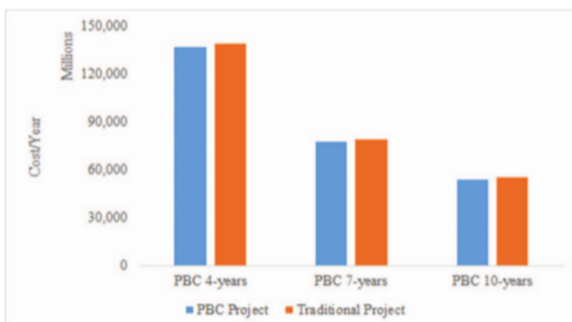

Fig. 6: Project cost comparison for different contract duration.

Implementation of PBC should be based on the consideration of its effectiveness rather than LCC efficiency alone. To determine a viable PBC project, a PBC effectiveness assessment is required on various project scenarios. PBC effectiveness is expressed as the ratio between the traditional LCC project to the PBC LCC project for the same project scenario. A project scenario with a LCC ratio of more than 1 is considered feasible to be contracted under PBC scheme. The results of the PBC effectiveness assessment on this case study project are shown in Fig. 7. The effectiveness of PBC increases when implemented to projects with longer contracted road, good road conditions, and long contract duration. This is in line with the study conducted by [3] and [4].

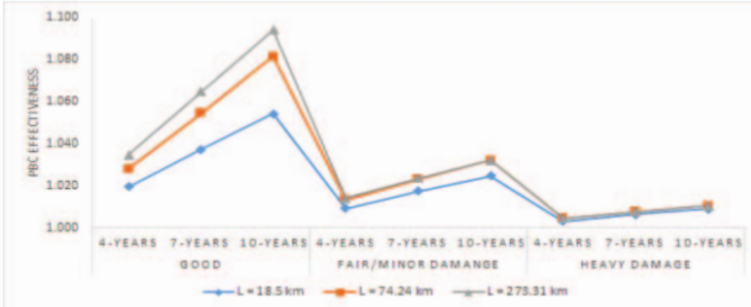

Fig.7: PBC effectiveness for different contract scenarios.

5. CONCLUSION

This study conducted LCC calculation and analysis of a PBC pilot project on national roads in Indonesia with high traffic volumes and overloads. The LCC calculation showed that implementation of PBC for road maintenance has the potential to generate lower LCC compared to the implementation of traditional approaches. Preventive treatment on PBC projects could delay and restrict road deterioration, thereby reducing the long-term cost compared to implementation of corrective treatments with traditional contracts.

This study contributes to the determination of an accurate PBC scheme based on the indicator of LCC efficiency. The results showed that PBC projects are highly effective on roads with good conditions and long-term contract duration. These findings are specifically for projects that are similar to this case study; however, the principles of LCC assessment and PBC effectiveness assessment presented in this study can be applied in general. Furthermore, this study has proven that PBC implementation may decrease the road maintenance cost and also provide other benefits that may not be easily reflected in monetary value.

The LCC calculations in this study used a deterministic approach and did not take into consideration the uncertainty of LCCA input variables that can affect the results of LCC efficiency potential. The sensitivity of LCC in this study was limited to the initial conditions and length of the road contracted, and the contract duration of the PBC project. There are various other variables that can affect the variability of LCC, such as the structural condition of roads and vehicle load that might influence the performance deterioration significantly.

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