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The delay factor of road maintenance against vehicle operating cost

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Abstract

The rapid increase in the number of vehicles and the lack of additional road networks resulted in high traffic volume and increase the load of road structure then causing road damage. Road deterioration can be caused by road traffic load and impact of drainage system deviation. The impact of road distress result is reduced the speed of vehicles, causing queues and can cause damage to vehicles. Delays in road repairs will increase further damage. The distress gets worse along with the traffic density. This can lead to larger and ineffective financing. This study aims to determine the increase in vehicle operating cost due to delayed road maintenance. The results showed that if the road improvements are not implemented immediately will lead to increased vehicle user costs so that the total maintenance costs will increase. Delays in maintenance for 3 months resulted in an increase in VOC weight to 74.86% of total maintenance costs. And if the delays in maintenance for 1 year resulted in an increase in VOC weight to 96.28% of total maintenance costs. It is expected that the results of this study can be a reference for decision makers in implementing a sustainable road maintenance program.

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Keywords: delay factor; road maintenance; vehicle operating cost; traffic load

1. Introduction

Roadways contribute to improving the quality of human life by becoming a means of distributing goods and services (Hamdi et al., 2017). Current growth in vehicle use in several developing countries follows a similar trend experienced by developed countries. Private vehicle ownership and its use continue to grow at a pace that increases with increasing personal income and the desire to enjoy faster and more modern transportation technology (Sinha, 2003). The rapid growth in the number of vehicles is not supported by the growth of adequate road construction, so that the traffic load that arises has an impact on decreasing road pavement services. This causes damage to the road and causes a decrease in vehicle speed.

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Nomenclature

VOC	vehicle operating costs
IRI	international roughness index
VT59000	serial of the roadpod (tools of traffic counter from metrocount)
FV	future value
v	speed (km/h)
v_{min}	minimum speed (km/h)
v_{max}	maximum speed (km/h)
$v_{average}$	speed average (km/h)
IDR	indonesian currency (rupiah)
SNI	indonesian standard
Pd T-15-2005-B	code of SNI
HDM-4	highway development and management release 4
KM	positioning
lkpp	office of government commerce

To maintain road quality and comfort of road users, regular maintenance or rehabilitation activities are needed throughout the life of the road. The frequency of road works required may depend on different factors such as material quality, traffic level, vehicle overload and type of road. After the road construction process or new road surface has been completed, a variety of damage begins to occur due to traffic loads combined with weathering effects. The condition of the pavement which is getting worse at this time is the accumulation of various types of distress which have resulted in not only increasing agency costs but also user costs. (Islam and Buttlar, 2012).

The operating costs and maintenance of vehicles include fuel consumption, tire usage, oil consumption, maintenance and repair, depreciation of vehicles and operator wages. Travel delay due to traffic flow due to: intersections, construction zones due to road repairs, detours, and speed reduction due to road damage (Curtis et al., 1997). The vehicle operating cost model can be formulated empirically or mechanically, deterministically or probabilistically. In the past, vehicle operating costs have been formulated based on deterministic-empirical relationships which were derived using classical regression analysis of historical information. The main weakness for the empirical model is that it requires intensive data to be formulated and usually requires significant data collection with a sophisticated model calibration. Empirical-based models also have the disadvantage of inference for analysis in different place and time conditions.

In developing countries such as Indonesia, road maintenance is carried out based on budget availability. Where the budget can be lowered through a parliamentary approval process that requires considerable time. Road damage that is left over as time increases will get worse, resulting in additional costs for repairs. Additional construction costs due to delays in repair and maintenance of the road have relatively no significant effect on budget availability. However, the operational costs of vehicles that burden users have increased dramatically. Even in research conducted in the United States (Islam and Buttlar, 2012) stated that the composition of construction costs compared to road user costs is 96: 4.

2. Purpose of Study

This study uses an analytical approach based on Indonesian National Standards SNI Pd T-15-2005-B (Oetojo and Pangihutan, 2005) adopted from the VOC, HDM-4 developed by the World Bank model to estimate vehicle operating costs. The HDM-4 model has been used to estimate vehicle operating costs and the results have been validated by researchers conducted in several countries (Ranawaka and Pasindu, 2017). The purpose of this study is to determine the cost of road maintenance due to considering vehicle operating costs.

3. Literature Study

(Zaabar and Chatti, 2012) recommend models to estimate the effects of pavement conditions on vehicle operating costs. The recommended model to be applied to road and vehicle technology in the United States. Model development by integrating external costs including emissions and time loss (Prevedouros and Mitropoulos, 2016).

4. Methodology

The location of this study is the Trans Sumatera road in Lampung province, Indonesia. The research was conducted by field survey method to get the velocity of vehicle that passed the road. There are 6 location points for collecting data surveys with various conditions of road distress. To get a data survey, this study uses a speed meter called MetroCount Roadpod VT 59000. Besides getting speed data, this tool can also detect the type and class of vehicles that pass through the survey area.

Fig. 1. The Roadpod VT59000

Placement of tools at the survey point is done by designing locations with the type of severty level, namely: good, fair and poor. And the placement of the tube is placed in the condition leading to damage, close to damage and after damage. The type of distress that greatly affects is the type of pothole. For more explanation, it will be shown in table 1.

Table1. Design of the roadpod tube placement

Location	Road Conditions			RoadPod VT59000 Placement		
	Good	Fair	Poor	Towards	Near	Far
1	√				√	
2			√		√	
3		√		√		
4			√		√	
5			√	√		
6		√				√

Furthermore, the tool was installed according to the location along the 5.35 km from the position of KM 41 + 550 to KM 46 + 000. At location # 2 the tool is placed close to the point of distress with the level of poor distress as illustrated in figure 2.

Fig 2. Placement of tools and tubes in location # 2

To validate the speed of the results of the tool Roadpod VT59000 used speed gun as a comparison as shown in figure 3. The results obtained from the speed gun are relatively the same and close to the results of Roadpod. After the survey data is collected, it is then presented in the description as presented in table 2.

Fig 3. Speed validation using speed gun

Table2. Design of the Roadpod tube placement

Location	V_{min}	V_{max}	$V_{average}$	IRI	Condition
1	15.5	52.2	36.5	2	Good
2	15.2	30.7	21.5	9	Poor
3	15.5	48.1	28.7	5	Fair
4	15.3	41.9	24.5	9	Poor
5	12.0	28.6	20.1	9	Poor
6	14.5	43.5	32.5	5	Fair

IRI data in table 2 is obtained from secondary data from the measurement results of the Department of Public Works using a roughmeter. From the table above, it can be seen that the low speed on the road with a high level of damage with the IRI value is also high. While high speed on roads with low damage and low IRI values.

Table 3. Calibrated Indonesian Standard SNI Pd T-15-2005-B for calculating vehicle operating costs

Name	Description	Unit
Vehicle Operating Cost (VOC)	$= B_iBBM_j + BO_i + BP_i + BU_i + BB_i$	IDR/km
B_iBBM_j	Fuel Consumption	IDR/km
B_iBBM_j	$= KBBM_i \times HBBM_j$	IDR/km

$KBBM_i$	Fuel Consumption for i-type vehicle	Litre/km
$HBBM_j$	Fuel prices for j-types fuel	IDR/litre
Vehicle types (i)	Sedan (SD), Utility (UT), Small Bus (BL), Big Bus	Pcs
Fuel types (j)	Solar (SR) or premium (PRM)	Litre
$KBBM_i$	$= (\alpha + \beta_1/V_R + \beta_2 \times V_R^2 + \beta_3 \times R_R + \beta_4 \times F_R + \beta_5 \times F_R^2 + \beta_6 \times DT_R + \beta_7 \times A_R + \beta_8 \times SA + \beta_9 \times BK + \beta_{10} \times BK \times A_R + \beta_{11} \times BK \times SA)/1000$	Litre/km
A	Constant (looking for table 4.)	
$\beta_1 \ldots \beta_{11}$	Parameter coefficients	
V_R	Average Speed	Km/h
R_R	Ramp	%
F_R	Derivative road	
DT_R	Average degree of curve	Km/h
A_R	Average acceleration	Km/h
SA	Standard deviation of acceleration	
BK	Vehicle weight	Kg
Oil Consumption (BO_i)	$= KO_i \times HO_j$	IDR/km
KO_i	Oil consumption for vehicle i-types	litre/km
HO_j	Price of oil for oil j-type	IDR
e-katalog lkpp	The unit price set by the Indonesian government for the procurement	IDR
BP_i	Spare Parts Consumption for i-type vehicle	IDR/km
BU_i	Vehicle i-type maintenance cost	IDR/km
BB_i	New vehicle i-type prices	IDR

5. Result and discussion

5.1. Evolution of speed and flow

The results of the survey data are then grouped into three pavement conditions namely good, fair and poor versus speed in each condition.

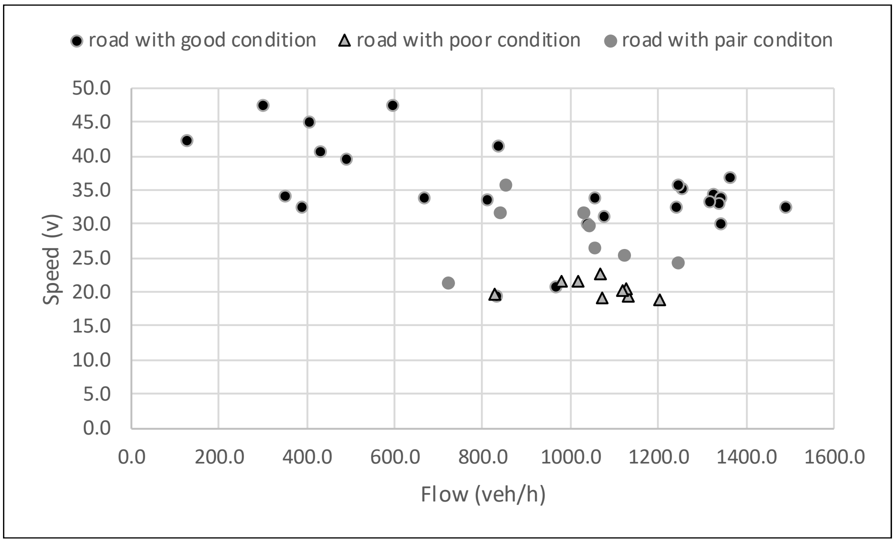

Fig 4. The relationship between speed and flow

Figure 4 shows that on roads with good conditions, users can drive their vehicles on average speed at 36.5 km / hr. Whereas for road conditions with fair distres, users can only reach an average speed of 32.5 km / h, and for road with poor distress conditions the average speed only reaches 20.1 km / hr. (Kim, 2015) used the greenshields model to simulate traffic flow. In this study greenshields models were used as a reference in seeing the evolution of speed changes caused by distress of road surface.

5.2. Vehicle operating cost

Furthermore, based on the formulas described in table 3, the author calculates the vehicle operating costs for each road surface condition. The VOC calculation results are explained in Figure 5, which shows that speed reduction has an impact on increasing vehicle operating costs. This speed reduction was caused by damage to the road surface which was left unrepaired while road users were forced to bear more operational costs than they should.

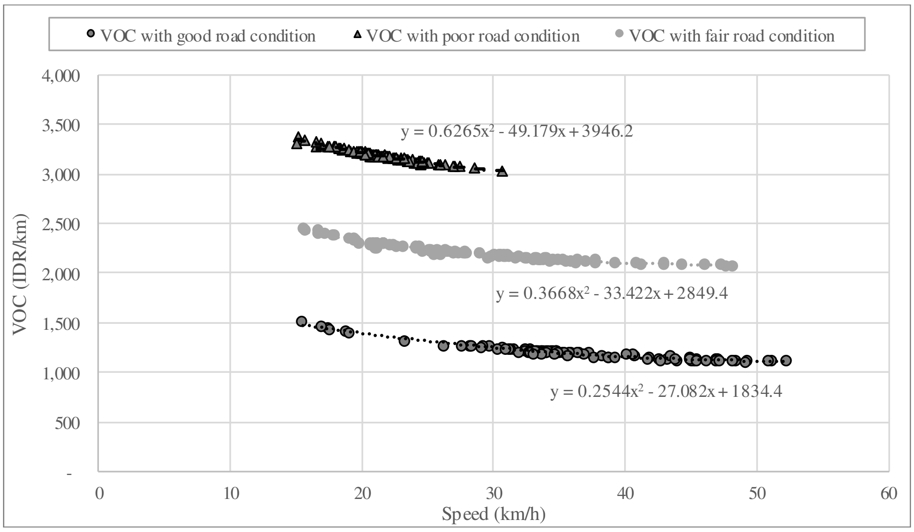

Fig 5. Vehicle operational costs on good road conditions, fair distress and poor

VOC average for good road surface conditions with IRI = 2 are IDR 1,201 per vehicle / km. For road conditions with fair distress with IRI = 5 is IDR 2,214 per vehicle / km and for poor road conditions with IRI = 9 is IDR 3,186. From the results of empirical data obtained equations to obtain VOC values with different road surface conditions. For good road conditions following the equation (1)

$$y = 0.2544v^2 - 27.082v + 1834.4 \quad (1)$$

for fair road conditions following equation (2)

$$y = 0.3668v2 - 33.422v + 2849.4 \quad (2)$$

while for poor roads condition following equation (3)

$$y = 0.6265v^2 - 49.179v + 3946.2 \quad (3)$$

The above equations apply only to the same conditions as the road conditions when studied. When used for different road conditions and traffic flow, further studies must be carried out to obtain accurate results.

5.3. The effect of delaying road maintenanc

The unit price average for the overlay activity obtained from the lkpp e-catalog is IDR 1,031,214 per ton, with overlay material density of 2.3 tons/m3 so that a volume to become 280 m3 with a thickness of 4 cm is needed weighing 644 tons. From the calculation above, an agency fee of IDR 665,299,961 is needed to complete an overlay along of 1 km with a road width of 7 m.

Table 4. Vehicle Operating Cost at different times

	Today (IDR)	Three months later (IDR)	Next Year (IDR)
Agency Cost	665,299,961	665,299,961	705,217,959
BC of Vehicle Operating Cost	48,709,674	1,461,290,220	17,779,031,010
Total Cost	**714,009,635**	**2,126,590,181**	**18,484,248,969**

Road repair if done immediately will only cause agency and VOC costs for some time. The cost of road repairs will increase if the road conditions are left for a long period of time so that it will cause more damage and VOC costs increase. Table 4. presents the cost of repairing road damage carried out immediately, 3 months to come or 1 year later. Calculation of road physical repairs is assumed only by AC-WC overlay treatment with a thickness of 4 cm. Calculations are carried out by calculating the time value of money with the future value principle in accordance with equation (4) and considering the increase in the level of distress and the interest rate of 6%.

$$FV = Po\ (1+i)^n \tag{4}$$

Delaying road repairs for up to 3 months increases the weight of vehicle operating costs to 74.86%, while delaying road repairs for the next 1 year makes the weight of vehicle operating costs to 96.28% of the total cost of repairs. With the delay in repairing road distress, road users suffer significant losses.

6. Conclusion

This research produced several conclusions that could be used as a reference and consideration for the agency in deciding policies related to road maintenance:

- Increased distress of roads affects the decrease in the speed of vehicles passing through, resulting in increased vehicle operating costs;
- Postponement of road repairs does not significantly affect agency costs, but has a very significant effect on vehicle operating costs;
- This study applies only to research sites with the same characteristics, for another locations that are not the same characteristics further research development is needed.

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