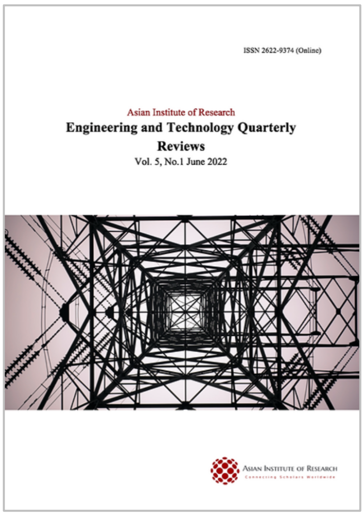

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An Evaluating of the Broader Economic Benefit of the Medan-Binjai Toll road on National Highway Performance

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Abstract
The development of toll roads provides a number of improved services to the road users, connectivity, and their existence can promote the equitable development of a region. The use of toll roads has a variety of impacts on economic issues. The quality of pavement gradually declines along with the increase in pavement service ages and heavy traffic load. After toll operated, over the years the number and characteristics of traffic on national highway have changed. The impact of diverting traffic from the national highway route, will reduce the traffic congestion and improve pavement performance. This paper presents a case study of the wider impact of the toll road investment based on national highway pavement performance and remaining service of life. A scenario is provided to distinguish the traffic diversion from national highway. The imposing toll road would increase the remaining service life of the national highway performance for approximately 6 years from the initial design. Medan-Binjai toll road investment provided high-quality of transport system and on other hand gained a wider benefit for saving the national highway preservation's budget.

Keywords: Economic Benefit, Traffic Diversion, Road Performance, Remaining Service of Life

1. Introduction

Accessibility and mobility are the objective of almost all the transport investments and will contribute significantly to the economic sector (Mohmand 2016). Indonesia's freight transportation mostly covers up of inland transportation which contributes more than 70% of the total freight movement (Lubis 2005; World Bank 2013). The development of toll roads, intended to boost transport across the nation, to improve connectivity, and their existence can promote the equitable development of a country. New toll road links will increase the road capacity, reduce the travel times and facilitate inland freight transportation, as the traffic volume continues to increase.

The quality of pavement will gradually decline along with the increase in pavement service ages and the heavy traffic load, and it is quite essential to investigate the causes that deteriorate the quality of pavement to select the proper maintenance technique (Hamdi et al. 2015; Yang 2016). Pavement failures in most developing countries have been traced to or combination of traffic load, construction, and climate (Syafriana 2015). Construction of new toll road can have a positive direct impact by reducing the vehicle operating cost and will significantly reduce vehicle traffic and congestion problems on national highways.

After toll operated, over the years the number and characteristics of traffic as a national highway have changed. However, the impact of diverting traffic from the national road route, will reduce the traffic congestion and improve pavement performance (Lozano 2014). Studies in pavement engineering have shown that traffic load is a major factor in design of pavement and has become an important factor causing damage to pavement structure (Yang 2016; Singh 2019).

This paper presents a case study of the wider impact of the toll road investment on a region based on national highway pavement performance and remaining service of life. The information on traffic load required for the pavement design equation. The damaging effect of the traffic loads can be defined by a number of 18-kip equivalent single axle loads (ESALs). The estimation of the remaining service life of the national highway based on AASHTO 1993, by using two scenarios. The first scenario presented the traffic without toll road, and the second scenario presented with toll road operated.

2. Literature Review

2.1. Road Performance

The performance of road pavement can be interpreted as the ability of road structural to carry out traffic load and climatic effects over a period of time. Lack of performance service ages becomes the concern primarily because it indicates how far the pavement serviceability could function before rehabilitation work is required to return its function.

Keeping the road pavement in an acceptable level of service is one of the most important aspects, and it can be achieved by having better routine pavement maintenance. A number of factors cause damages to the road pavement such as traffic load, material properties, the environment, and construction practices (Kaare 2012; Jihanny 2018). It is generally used AASHTO to determine a pavement performance as a function of the Pavement Serviceability Index (PSI) and 80 kN ESAL. PSI is stated as a function of pavement condition index and the loss of serviceability (ΔPSI) is the difference between the initial serviceability and the terminal serviceability of the pavement. PSI is expressed as a function of pavement condition index (PCI) and structure condition index (SCI) as shown in equation (Hatmoko 2019).

$$\text{PSI} = f\ (PCI, SCI) < PSIT \quad (1)$$

Where:

PSIT = terminal present serviceability index for design

ΔPSI becomes the main concern, rather than PSI, because it explains how long the pavement could serve the traffic loads and environmental effects before a maintenance is required to extend its service life. The equation of ΔPSI is given by (AASHTO 1993):

$$\Delta PSI = \Delta\ PSI_{traffic} - \Delta\ PSI_{SW\ FH}$$

(2)

In Which:

$\Delta PSI_{traffic}$ = serviceability loss due to traffic load

$\Delta PSI_{SW\ FH}$ = serviceability loss due to swelling (effect of moisture and frost)

2.2. Remaining Service Life of Flexible Pavements

Remaining service life (RSL) is defined as the estimation of pavement service ages remain or the predicted time of pavement serviceability before rehabilitation (Gedafa 2008). The design of pavement service life is recommended for 20 years may be applied to a national highway. Rehabilitation work is needed to restore the pavement performance back to its original condition, wherein the decrease in pavement serviceability index (ΔPSI) will be affected by traffic loads as illustrated in Figure 1.

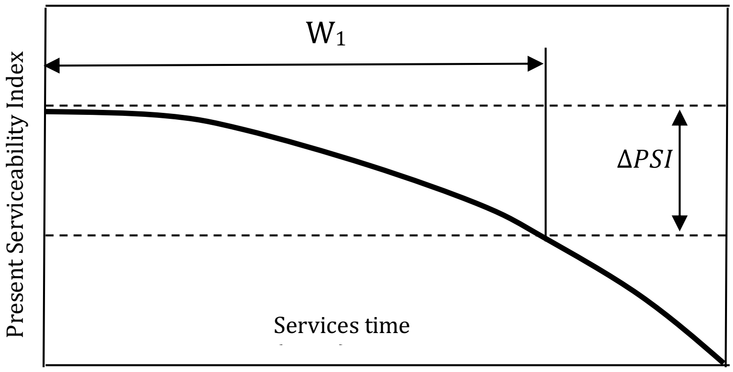

Figure 1: Pavement performance curve (Abaza, 2004)

The assessment of the design period is essential to be applied as a determination of the structural capacity of existing pavements and assists the decision-making process of road maintenance programs for optimizing funds allocation.

3. Method

After toll road is operated, the composition and characteristics of traffic using national highway will also change. The idea is to determine and compare the traffic data to evaluate the Equivalent Single Axle Load (ESAL) and then further analyzed for pavement remaining life.
The wider benefit quantified in this study is estimating the impact of diverted traffic on the remaining service life of national highway pavement. The remaining pavement ages period estimation is performed for two scenarios, specifically with and without the toll road operated.

3.1. Traffic Estimation

For estimating the cumulative traffic estimated to use the pavement over the design period, it is necessary to estimate the traffic on national highways and toll roads. The impact of the traffic load for each scenario is obtained by summing the multiplication of three parameters, i.e., average daily traffic, axle load equivalency factor or vehicle damage factor, and annual traffic growth rate for each type of axle load. The formulation of cumulative traffic load is illustrated as mentioned below (AASHTO 1993):

$$\overline{W_{18}} = \sum_{i} (ADT_i \; x \; E_i x \; G_{Ri}) x \; 365 \qquad (3)$$

$$G_{Ri} = \frac{(1 + g_i)^n - 1}{g_i} \qquad (4)$$

Where:
W_{18} = cumulative standard single axle loads for two ways (ESALs)
ADT_i = average daily traffic for axle load i
E_i = axle load equivalent factor (or vehicle damage factor) for axle load i
g_i = traffic growth for vehicle I (%)
n = service life (year)
Traffic growth rates can be estimated by identifying the past trends of traffic growth, and the traffic estimation in the future or at the end of design period (W_{18}) is illustrated as mentioned below:

$$W_{18} = D_D \, x \, D_L \, x \, \overline{W}_{18}$$

(5)

Where:
W_{18} = cumulative standard single axle load on design lane (ESAL)
D_D = direction distribution factor
D_L = lane distribution factor
The direction distribution factor (D_D) was determined to be 0.5 as the national road are two-way roads and the lane distribution factor (D_L) was assumed to be 0.75 as the section considered as undivided roads with two-lane carriage.

3.2. Pavement Remaining Life

A second method for calculating the remaining service life in this paper is applying a model to estimate the impact of traffic loads on pavement structure by calculating the service life of pavement. AASTHO 1993 recommended equation to count remaining service life obtained from fatigue equation (N_P) and rutting ($N_{1.5}$), therefore could be estimated using the following equation:

$$RL = \left[1 - (\frac{N_P}{N_{1.5}})\right] \, x \, 100\%$$

(6)

With:
RL = Remaining Life (%)
N_P = Total traffic to date
$N_{1.5}$ = Total traffic to pavement failure

4. Results and Analysis

4.1. Medan-Binjai Toll road

Medan-Binjai Toll Road is a toll road that connects two cities in North Sumatra, mainly Medan and Binjai. The toll road is part of the Trans Sumatra Toll Road with a total length of 16.8 kilometers. Construction of new toll roads can have a positive direct impact by reducing the vehicle operating cost and will significantly reduce vehicle traffic and congestion problems on national road.

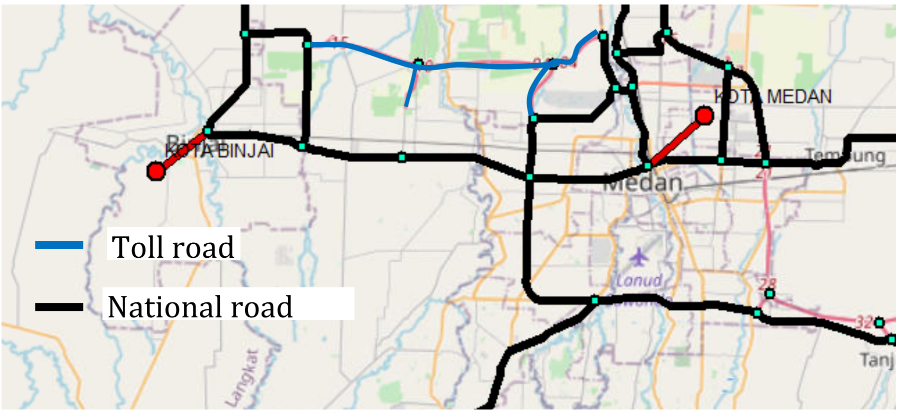

Figure 2: Medan-Binjai Toll Road

Traffic congestion is one of major problems and increases the cost, the delays and more fuel consumed (Lozano, 2014). The evidence indicates that the toll road reduces congestion and increases driving speed on the national road. Traffic diversion is substantially related to toll rate and the elasticity becomes increasingly negative with higher toll fares. Annual Average Daily Traffic (AADT) is a basic measurement that indicates vehicle traffic load on a road segment. The table below illustrates a comparison of empirical AADT data between a national road and a toll road.

4.2. Diverted traffic

The empirical data acquired indicates that by diverting a portion of the traffic volume from the national road to the new built-toll road, it is expected that congestion on the national road will be alleviated. As for the effect of toll road, the traffic volume indicates the past trend of the traffic after/before Medan-Binjai toll road operated in 2017, as illustrated in table 1.

Table 1: Traffic volume on Medan-Binjai section

NO	Vehicle Classification	National Road					Toll Road				
		2016	2017	2018	2019	2020	2016	2017	2018	2019	2020
1	Passenger car	14.980	8.978	8.283	3.944	4.574	-	7.226	9.245	14.889	14.450
5	Bus	696	399	384	217	331	-	335	429	690	670
7	single unit 2-axles truck	4.403	3.670	3.782	3.424	3.480	-	1.109	1.157	1.824	1.998
9	single unit 3-axles truck	2.249	2.091	2.207	1.978	1.981	-	533	526	835	1.049
10	Single trailer 4 or more-axles	508	377	363	266	255	-	137	119	235	263

4.3. The Impact of shifting Traffic on the Performance of National Road Pavements

Direct effects of investments on toll roads, such as the redistribution of traffic and congestion effects are directly related to the toll road which is under operation. This paper has developed a practical approach for estimating the impact of a toll road on national road performance that has evaluated the pavement remaining life, based on traffic data on Medan-Binjai which was obtained during 2016-2020 period.

The cumulative calculation of ESAL (CESAL) from 2016 to 2020 period is required to estimate the remaining pavement performance ages of the national highway. The CESAL value is to make a comparison between the two scenarios, as illustrated in Fig 3.

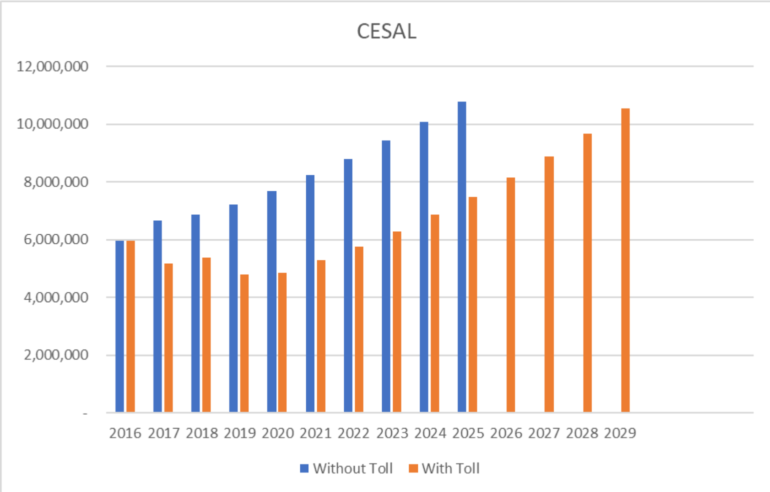

Figure 3: CESAL comparison

The design life of the pavement in this study is 10 years. From the result, we can determine that there is an extension in service life for approximately 6 years from the initial design.

5. Discussion

The study did not examine directly the direct impact but the results suggested that the imposing tolls would increase the remaining service life of the national road performance by pushing truck traffic into toll roads that have been designed to handle heavy truck traffic. The development of toll roads does not actually reduce congestion, when the government imposes a high tariff, people will do everything possible to avoid paying it.

This paper examined the broader impact of toll road investment based on national road pavement performance especially on service life remaining. This diversion may not have an increased cost for truckers but this has significant policy implications. At what tariff do truckers divert from national road to the toll road.

This study has implications for the stakeholders involved in the development of Indonesian road infrastructure by highlighting the broader benefit received by the national highway in which the toll road investment occurs.

On encountering the declining road performance and capacity of rehabilitation budgets, the national road authority needs to optimize the allocation of a limited budget. The routine maintenance costs prediction model is needed to examine in future research, and it is important to evaluate the validity of the remaining service period of the pavement by using the International Roughness Index (IRI) value.

Acknowledgments

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