Modified Zero Overloading Policy Impact to Pavement's Service Life

Reni Karno Kinasih[1], Mukhlisya Dewi Ratna Putri[2], Nabila[3]

[1,2,3]Civil Engineering Department, Faculty of Engineering, Mercu Buana University,
Jakarta, Indonesia 11480
reni.karno@mercubuana.ac.id;
mukhlisya.dewi@mercubuana.ac.id;
nabila@mercubuana.ac.id

Abstract – Indonesia have not finished yet with the overloading truck problem which makes early failure in Indonesia pavements, mainly in national highways such as Pantura national highway. This is the first research which the aim is to compare the Cumulative Equivalent Single Axle Load (CESA) between 4 policy conditions; (1) zero overloading policy enforced; (2) modified 1 zero overloading policy enforced with 40% legal overloading tolerance for the nine-daily needs (rice, sugar, cooking oil, soy beans, salt, meat, chicken, eggs, onion), portland cement and fertilizer trucks; (3) modified 2 zero overloading policy enforced with 50% legal overloading tolerance for the same transporter as point (3); (4) no policy. This modification of the policy considered to avoid the price increment of those goods caused by the rising expedition cost. The Liddle's formula used with k–factor = 1 for single axles, 0.086 and 0.031 for tandem and tridem axles. The finding of the study shows decreasing CESA between the alternatives compare to no policy applied. Application of policy 2 and 3 reduce the CESA number as much 44% and 34% respectively, there is 10% displaced cargo difference between policy 2 and 3 which must be loaded to other vehicles.

Keywords: Overloading truck; pavement service life; vdf; ESAL

I. INTRODUCTION

Coyle states "transportation users actually buy a package of services at a certain price that must be paid" (Kinasih, 2014), from the statement author assure that customers who buy a package of services, are expecting a package of good and reliable facilities or services. In transportation, the package includes good vehicle, with reliable speed, frequency, interconnection, safety and relatively affordable costs. Those factors must be seriously considered because transportation is not only about moving the people, goods and or animals through space. A good transportation connecting regions effectively and affecting economic raising significantly.

Indonesia consist of 17,504 islands with 5 big main islands; Papua, Kalimantan, Sumatera, Sulawesi, and Java island, is one of East Asia nations facing overloading and over dimension trucks problem. Java island, where Jakarta the capital city located has an important nation highway named Java North Beach Highway (Pantura), Route 1, which plays a strategic role to Indonesian economy. The Pantura highway well known as a quickly damage pavement and lead bad perceptions among people. One of the reason of early damaging in Pantura highway's pavement is because of overloading truck cases, moreover Indonesia has two season; wet and dry season. In the wet season, flooding will worsen the pavement which experience overloading phenomenon (Hatmoko et al, 2017).

Widyaningsih (2018) mention that rapid traffic growth gives impact to the structure of the pavement and to the use of its material. Especially for the pavement structure condition in Indonesia, where the burden of traffic flow often exceeds the limit, so special consideration is needed in planning the asphalt mixture, including improving the quality of the asphalt.

The Minister of Republic Indonesia Transportation Ministry, Budi Karya Sumadi stated that this overloading and over dimension phenomenon incurring costs as much IDR 43 trillion (USD 3,051,268,390 with IDR 14,092.50 per USD) a year, whereas only IDR 26 trillion (USD 1,844,952,989.18) budget to build roads in the same fiscal year (Sicca, tirto.id, 2018). Sumadi stated 63 percents of the various road accidents in consequence of overloading trucks (bus-truck.id, 2018). This is a great waste to left, this linger problem must be solved promptly. Another negative effect of overloading phenomenon is that it increases carbon dioxide (CO_2) emission significantly, ranging from 71.12% to 80.5% depends on the vehicle type (Wahyudi

et al, 2014). As mentioned by Rakhmani (2015) based on Article 28 of Republic Indonesia Constitution No. 22 of year 2009 concerning Traffic and Public Transportation, it is government's responsibility to provide safe transportation facilities. Republic Indonesia Ministry of Transportation soon will enforce zero overloading policy in Pantura highway, but it surely will stimulate goods price rising and inflation will be difficult to avoid.

A strategy as a win-win solution to reduce early damage on pavement and to avoid inflation urge to devised. Zero overloading policy must be modified, the modification could be to give legal overloading to transporter of nine-daily needs (rice, sugar, cooking oil, soy beans, salt, meat, chicken beef, eggs, onion), portland cement and fertilizer. The legal overloading to them as much 40% - 50%. This research aims to figure out the impact of those modified zero overloading policy scenario to Pantura highway pavement service life using Liddle's Formula.

In addition to Pantura roads, in East Sumatera National Road, Indonesia pavement service life finished in 3 years and 8 months from 10 years designed service life (Jihanny et al, 2018), while in Pringsurat Road connecting Ambarawa – Magelang in Central Java, Indonesia, the pavement structure can only withstand overload for 5.6 years from the designed age of 10 years (Simanjuntak et al, 2014). Not only in Indonesia, other countries facing the same problem, in Narayanghat-Muglingin, Nepal, the pavement service life reduced as much 6 years due to overloading vehicle (Ojha, 2018). Overloading truck in Wisconsin, United States of America as much 1.8% from total AADT predicted generates 18.5% cracks (Titi et al, 2018). In Ahmedabad Ring Road, India, trucks with 10% overloading generates damaging impact to the pavement more than 40% compared to the same trucks carries a normal load (Jayswal et al, 2017). While in Nigeria, the damaging factor number is 11.12 and 9.39 in North and South area (Ede, 2014). Overloading in Malaysia is quite worrying ranging from 25% - 101% of it's legal weight limit (Karim et al, 2013). Some researchers suggest 5-10 cm more pavement thickness to overcome effect of overloading trucks (Raheel, et al., 2018) (PK. Shahul and Prathap, 2018). All those facts show that previous researchers focused on how much the reduction of pavement or bridge service life due to some percentages overloading. Regard to previous researches, the novelty of this research is that the author focused on figure out the better solutions in the form of policy to overcome the overloading problem without affecting excessive the price of goods negatively and without burdening more costs in road construction. Cumulative equivalent standard axle load (CESA) calculated to evaluate the differences between the policies.

II. METHODS

Variables of the study are truck axle configurations and the loads as independent variables that influence the magnitude of Equivalency Single Axle Load (ESAL) and Cumulative equivalent standard axle load (CESA) numbers.

The instrument used for this research is annual average daily traffic (AADT) of Pantura highway, ESAL and CESA formulas. In addition, researcher used distribution of loading on the vehicle's axle based on circular letter of Republic Indonesia Directorate General of Land Transportation No. SE.02/AJ.108/DRJD/2008 concerning the Maximum Limitation Guide Maximum Permitted Load and Permitted Combination Load and Road Pavement Manual with Benkelman Beam No. 01/MN/BM/83which is distributed by Republic Indonesia Public Work Ministry.

2.1 Equivalency Single Axle Load (ESAL)

In this study, not the tire load as the main concern but the damage that will be experienced by the pavement due to the load is the main concern. As mentioned in Pavement Interactive, the common approach is to convert loads of various magnitudes and repetitions (mixed traffic) to "standard" or "equivalent" loads based on the amount of damage caused to pavement. The standard commonly used is 18,000 lb. Equivalent single axle load. Using this ESAL method, all loads (including dual or tandem and triple or tridem axis loads) are converted to an equivalent number of 18,000 lb or 8.16 tons. Single axle load. This figure of 18,000 lb was obtained from the AASHO Road Test in the early 1960's because it is easier to use a single number to represent all traffic loads in the complicated empirical formula used to predict pavement age (Pavement Interactive). For ESAL calculation, author used the formula derived by Liddle, which is calculated based on an empirical approach.

$$ESAL = k \left[\frac{P}{8,16}\right]^4 \quad \text{.........................(1)}$$

Where 'P' represent load on each group of axle, and k-factor is a correction factor for tandem and triple axles which the value is varied based on the method selected i.e. Asphalt Institute, AASHTO, Bina Marga, etc. Asphalt Institute assign the k-factor value 0.0773 for tandem axle and 0.017 for triple, AASHTO assign 0.133 and 0.044 for tandem and triple, respectively, while Directorate General of Highways, Ministry of Public Work Republic Indonesia define 0.086 for the tandem axle but not listed the value for triple axle, however some researcher proposed, based on their study, 0.053 and 0.031 for triple axle (Hadiwardoyo et al, 2012). For this research, author set 0.086 for tandem axle and 0.031 for triple axle.

ESAL of each group of axle in a vehicle calculated, afterwards total ESAL of the vehicle obtained. This calculation shows the level of damage (vehicle damaging factor) caused by the vehicle, moreover it shows which axle group or axle configuration generates biggest damaging to pavement (Kinasih, 2014)

2.2 Cumulative Equivalent Standard Axle Load (CESA)

CESA represents the accumulation ESAL estimation throughout the pavement's service life. CESA calculation needed as one of the parameters to determine the thickness of a pavement (Hadiwardoyo et al, 2012). When overloading phenomenon is allowed to happen, the CESA value determined in the initial design will be reached before

the end of the design pavement life, as if the traffic growth exceed the designed prediction.

$$CESA = \frac{n}{20}\{(\sum_{j=1}^{n} AADT_J \times C_J \times E_J) + (\sum_{j=1}^{n} AADT_J \times (1+i)^n \times C_J \times E_J)\} \quad \text{……..(2)}$$

Where: n = the designed pavement service life, AADT = annual average daily traffic at the opening and at the end of pavement service life, C = lane distribution factor, E = ESAL, i = rate of traffic growth.

The author set some slightly different terms used in this study, but the differences do not change the main principle. The terms are; CESA, the author means it as the ESAL accumulation of the traffic in a lane of the road, so the formula is:

$$CESA = AADT \text{ X } C_J \text{ X } E_J \text{……...…… (3)}$$

$CESA_n$ means the CESA accumulation of the traffic along the designed pavement service life, formula 2 used to find the $CESA_n$.

2.3 The Policy Applied

To facilitate reader understanding, here is the explanation about the policy and it's modification used in this study to find out it's implication to CESA number: (1) zero overloading policy enforced, stated as ideal condition; (2) modified 1 zero overloading policy (modified 1 policy) means the other vehicles enforced to conform zero overloading, but to the nine-daily needs (rice, sugar, cooking oil, soy beans, salt, meat, chicken, eggs, onion), portland cement and fertilizer trucks transporter permitted 40% legal overloading; (3) modified 2 zero overloading policy (modified 2 policy) means the other vehicles enforced to conform zero overloading, but to the nine-daily needs (rice, sugar, cooking oil, soy beans, salt, meat, chicken, eggs, onion), portland cement and fertilizer trucks transporter permitted 50% legal overloading; and (4) no policy applied.

III. RESULTS AND DISCUSSION

This research was conducted in seven interconnected Pantura line sections in West Java area, from Tangerang to Losari as long 274,8 kilometers, the traffic was examined in two directions separately. ESAL calculation of each vehicle can be seen in table 1 for Heavy Commercial Vehicles, while ESAL calculation of light vehicles (including passenger cars) shown in table 2. The observation shows that the existence of Trans Java Toll Road, which the early section was officially opened in June 13th, 2015 changes the characteristics of the Pantura Road. In year 2009, author conducted research in the same sections, light vehicles still dominated the AADT with percentage 55% and heavy vehicles by 45%, but now the percentage of light vehicles is only 38%, and commercial vehicles is 62%.

From table 1 it can be seen the increase in ESAL of each heavy commercial vehicle if the vehicle carries an overload. When the overloading is as much as 40% of the permitted load, the ESAL number increases 4 times from

the ideal condition. Meanwhile, if a commercial vehicle carries an overload of 50% of the permitted load, ESAL increases as much as 5 times from it should be. This study also confirms that the more axles in a vehicle generates smaller ESAL values, table 3 shown that coded 11 A vehicle which is a 5-axle-trailer with maximum permitted load 37 tons has ESAL value only 3.90677 whereas vehicles with code 8 is a 4-axles-articulated truck with lesser maximum permitted load which is 31.4 tons having ESAL value of 3.90833, this fact indicates that vehicles with more axles have better efficiency. To convinced, comparing those two vehicles with coded C 11 vehicle which is 6-axles-trailers that are permitted to carry loads up to 45 tons have an ESAL value of only 3.68836, lesser than coded 11A vehicle's and coded 8 vehicle's ESAL value.

Table 1. ESAL of Heavy Commercial Vehicles

Vehicle Type (Code) and Axle Configuration	ESAL 0% Overload	ESAL 40% Overload	ESAL 50% Overload
Small Bus 12 ton (5A) 1.1	0,58462	2,24588	2,95964
Bus (5B) 1.2	2,54779	9,78760	12,89820
3-axle-truck (6) 1.22	2,32855	8,94534	11,78826
4-axle-truck (7) 1.1.22	2,62086	10,06828	13,26808
4-axle-truck (8) 1.2 + 2.2	3,90833	15,01423	19,78591
3-axle-truck (9) 1.2-2	6,11791	23,50255	30,97191
4-axle-trailer (10) 1.2-22	4,58403	17,61000	23,20664
5-axle-trailer (11A) 1.2-222	3,90677	15,00827	19,77805
5-axle-trailer (11B) 1.22-22	4,36478	16,76774	22,09670
6-axle-trailer (11C) 1.22-222	3,68836	14,16919	18,67230

Source: Author's survey and calculation

Table 2. AADT and ESAL of Light Vehicles

Vehicle Type (Code)	Axle Configuration	Indonesian Permitted Load	ESAL 0% Overloading
Passenger Cars (2A)	1.1	2	0.0005
Small truck (2B)	1.1	2	0.0005
Passenger Cars (2C)	1.1	1	0.000028
Small bus (3)	1.1	5	0.0176
Bus (4A)	1.1	9	0.3673
Bus (4B)	1.2	16	2.2941

Source: Author's survey and calculation

In addition to show how the number of axles affects the ESAL value which means it affects the vehicle's damaging factor on road pavement, this study also confirms

that the more axles gathered in one group generates a smaller impact on road damage. In table 3. seen that 3 axles converged into 1 group (tridem) on 6-axles-trailer with maximum permitted load to this group of axle is 21 tons generates ESAL value 1.35981, it means only 0.065 ESAL per 1 ton load, while on the same vehicle, 2 axles gathered in 1 group (tandem) with maximum permitted load to this group of axle is 18 tons creates ESAL value 2,03623, which means 0.113 ESALs per 1 ton of load.

With existing AADT, the CESA experienced by Pantura highway pavement for both lanes is 223,047.64 ESAL if the zero overloading policy conditions applied without exception and tolerance for both heavy and light vehicles, it means that all vehicles carry cargo in accordance with the specified Indonesian permitted axle load limit (JBI/JBKI), the author state it as an ideal condition. Discovered by a survey the number of vehicles which have a right of permitted overload tolerance is about 29.63% of heavy vehicles AADT, so consequence of the modified 1 policy applied, the CESA number suffered by the pavement for both lanes is equal to 251,308.72 ESAL, 13% extra ESAL from the ideal condition. Meanwhile, if the modified 2 policy enforced, the CESA number is 325,249.69 ESAL. The alteration of CESA due to policies enforcement shown in figure 1.

The observation in the field found the fact that 70% of heavy vehicles carried overloading 30% - 80% from Indonesian permitted axle load limit (JBI/JBKI), so when those 70% of heavy vehicle carried the average overload which is 50% they generate CESA as much 742,981.17 ESAL for both lanes, it is 3.33 times of ideal condition CESA. It means the Pantura highway in fact, compare with the ideal condition, endures more 519,933.55 ESAL.

Mentioned earlier that CESA is one of the parameters used to determine the thickness of the pavement, when CESA increase 3.33 times from the ideal CESA value, the age of the pavement will finish earlier. This statement is supported by the results of the CESAn calculation using AADT 2019 as the base year, 20 years service life plan (n) and 7% per year vehicle growth, then the pavement designed to experience 1,086,178,671 ESAL. Unfortunately with current traffic, the ideal first year CESA prediction is 223,047,621 ESAL. The effect to Pantura national highway pavement service life due to the scenarios policy apllied can be seen in the figure 2.

IV. CONCLUSION

A proper policy need to be applied in Pantura highway to prevent pavement early damaging, the worst scenario in this study which is modified 2 zero overloading policy affect 56% CESA reduction, it will help pavement service life last 2.28 times longer than no policy enforced. Using this modified 2 policy some transporters mostly permitted to add up to 20% of the load they used to carry, and the others need to reduce maximum up to 30%. While the modified 1 zero overloading policy will reduce 66% CESA, some transporters mostly permitted to add up to 10% of the load they used to carry, and the others need to reduce maximum

up to 40% (there is 10% larger than modified 2 policy). The more vehicles needed to be utilized, the more expedition cost increment. It need advanced economic research to find out how the 10% gap load reduction between modified 1 and modified 2 policy affect the inflation. Nevertheless, the application of the policy will need a strategy to assure only the proper vehicle uses its right to carry permitted overloading, otherwise the condition will remain the same.
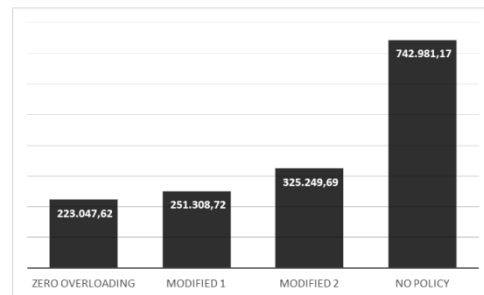

Figure 1. Alteration of CESA due to policy enforcement

Table 3. ESAL Value of each Heavy Commercial Vehicle's Axle

Vehicle Type (Code)	Items	ESAL					
		1st Axle	2nd Axle	3rd Axle	4th Axle	5th Axle	6th Axle
Small Bus 12 ton (5A)	Beban (ton)	6	6				
	ESAL	0,29231	0,29231				
Bus (5B)	Beban (ton)	6	10				
	ESAL	0,29231	2,25548				
3-axle-truck (6)	Beban (ton)	6	18				
	ESAL	0,29231	2,03623				
4-axle-truck (7)	Beban (ton)	6	6	18			
	ESAL	0,29231	0,29231	2,03623			
4-axle-truck (8)	Beban (ton)	5,652	8,792	8,478	8,478		
	ESAL	0,23017	1,34769	1,16523	1,16523		
3-axle-truck (9)	Beban (ton)	4,716	10,742	10,742			
	ESAL	0,11157	3,00317	3,00317			
4-axle-trailer (10)	Beban (ton)	6	10	18			
	ESAL	0,29231	2,25548	2,03623			
5-axle-trailer (11A)	Beban (ton)	5,92	9,99	21,09			
	ESAL	0,27703	2,24647	1,38327			
5-axle-trailer(11B)	Beban (ton)	6	18		18		
	ESAL	0,29231	2,03623		2,03623		
6-axle-trailer (11C)	Beban (ton)	6	18		21		

Source: Author's calculation

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