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Evaluation and Planning of Strong and Durable Roads Due to Overloaded Vehicle (Case Study : The National Road Bts. Kab. Konawe Utara/Kab. Konawe – Pohara)

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ABSTRACT

In 2020, more than half of the national road length of Bts. Kab. Konawe Utara/Kab. Konawe – Pohara is in a heavily damaged condition. This is due to the heavy vehicles used for the development of the Konawe Industrial Estate passing through this road. This research was carried out by collecting primary data from vehicle tire pressure surveys and secondary data in the form of the results of the 2021 vehicle weight test. Axle loads in the field can be predicted using vehicle tire pressure. Vehicle Damage Factor (VDF) calculation is carried out and compared with the VDF given by the 2017 Revision Pavement Design Manual (MDP). From the various VDF data, a Cumulative Equivalent Single Axle Load (CESAL) calculation is also carried out and also compared. The results obtained from this study are that the actual VDF at the study site for vehicle classes 6b and 7a are respectively greater up to 1.58 and 7.37 times than the actual VDF for the Sulawesi region given by MDP 2017. In direct proportion to that, CESAL due to field loads is greater is up to 3.03 times greater than CESAL due to the actual load for the Sulawesi region provided by the 2017 MDP. The CESAL value due to field loads is up to 7.25 times greater than the CESAL due to the normal load provided by the 2017 MDP.

Keyword : CESAL, MDP 2017, overload vehicle, tire pressure, VDF

INTRODUCTION

An overloaded vehicle is a condition where a vehicle carries a load that exceeds the specified load limit. Based on Law (UU) Number 2 of 2022 concerning the Second Amendment to Law (UU) Number 38 of 2004 regarding roads the load limit in question is the heaviest axle load, namely 10 tons on class I roads and 8 tons on class II and class III roads. The presence of overloaded vehicles is still a threat to road administrators and road users. The impact is that the damage to the bridge road becomes faster and bigger and the chance of traffic accidents is also getting bigger.

Figure 1. Research Sites

This road section is part of the inter-provincial Trans Sulawesi road and one of the main access links to facilitate modes of transportation in developing the economy between districts and provinces. As shown in Figure 1, the location of this research study is the only route connecting Southeast Sulawesi and Central Sulawesi. So, the vehicles passing are not only heavy vehicles that load minerals, but also heavy vehicles operating from Kendari Harbor to Morowali and/or Poso, Central Sulawesi.

Figure 2. Heavy Vehicles operating at the research location

This road is a traffic lane for two nickel industrial factories. In addition, on this section there are a number of commercial vehicles with excess loads that contain excavated C as shown in Figure 2 which will be used at the factory site so that it has the potential to reduce the level of road conditions on that section.

Table 1. Road Conditions Based on IRI Value

Condition	Km	%
Good	0.00	0.00
Moderate	5.10	23.83
Light Damage	5.30	24.77
Heavy Damage	11.00	51.40
Total	21.40	100.00

Source : BPJN for Southeast Sulawesi, 2020

Based on the IRI survey in Semester I of 2020 as shown in Table 1, it was found that 11 km or 51.40% of these sections were in a state of severe damage or with an IRI value of greater than 12 m/km. One of the factors that can create this condition is overloaded vehicles passing through the section in question. It can also be seen that the road conditions on these sections are very diverse, ranging from moderate to dominant conditions, namely severely damaged conditions. However, with almost the same traffic volume and load along the road segment, it should have the same road conditions along the segment, so it is necessary to discuss the causes of the different road conditions, whether it is only due to overload or other factors.

According to Mochtar (2021) rainfall is relatively too high, it rains heavily every morning and evening with a fairly high volume and intensity, so that the air voids under the pavement during the rainy season are always filled with rainwater. It can also force rainwater to start seeping into the underlying subgrade soil layer and create instability in the subgrade soil layer and with excessive traffic loads is a combination that causes fatal damage to pavement. Relatively drier subgrade soil conditions will result in higher pavement stiffness. Conversely, wetter subgrade conditions make the pavement layer softer. From this it can be seen why most road damage occurs during the rainy season and road pavements are rarely damaged during the dry season. So, to make the road more durable and long-lived, it is best if the subgrade soil under the road pavement should always be made as dry as possible. Rainwater is not allowed to stay for a long time under road pavement and on road subgrade soil. Rainwater that has seeped under the pavement layer must be able to flow out as soon as possible from the pavement. So the road subbase layer has to be a granular layer that is highly permeable to water.

Table 2. VDF Value for Each Vehicle Based on the Bina Marga Method

Vehicle Class	Sulawesi			
	Beban Aktual		Normal	
	VDF 4	VDF 5	VDF 4	VDF 5
5B	1.0	1.0	1.0	1.0
6A	0.55	0.5	0.5	0.55
6B	4.5	7.4	8.5	3.4
7A1	10.1	18.4	18.3	4.1
7A2	10.5	20.0	17.7	4.2
7C1	15.9	29.5	20.4	7.0
7C2A	19.8	39.0	14.7	4.0
7C2B	20.7	42.8	-	-
7C3	24.5	51.7	22.9	9.8

Source : MDP 2017

The 2017 Revised Pavement Design Manual (MDP) also states that if an axle load survey is not possible for the planner and previous axle load survey data is not available, then the value of the Vehicle Damage Factor (VDF) can use the table to calculate the traffic load. There is a table that divides the Load Equivalence Factors by region as shown in Table 2 and is sourced from the 2011 WIM survey in Java Island, which is not necessarily relevant, so it is necessary to look for relevant data to form the basis for designing research site.

Jihanny et al (2021) conducted research related to the impact of overloaded vehicles on the design life of flexible pavement on strategic road sections in Palembang and Lampung. To analyze the impact of overloaded trucks on the design life, VDF values and percentage of overloaded vehicles from the WIM survey analysis were used to estimate the cumulative standard axle load (CESAL) and design traffic volume. Daily traffic data is collected from on-site traffic counting surveys. The results of CESAL with overloaded vehicles will be compared with the CESAL estimates with standard loads to calculate the impact of overloading. Then the service life reduction value of the pavement structure can be measured. The CESAL value from the WIM data analysis is greater than the CESAL Standard value. At the end of the design life (10 years), the total number of standard CESALs is 24.83 million ESAL. Meanwhile, the total amount of excess burden CESAL is around 48.47 million ESAL. The overload CEAL value is almost 1.95 times more than the standard load CEAL.

The impact of overloaded vehicles on the pavement structure is calculated by estimating the remaining service life of the pavement. Remaining Service Life (RSL) is defined as the estimated number of years that a pavement will function under normal conditions only with routine maintenance. After doing the calculation, the pavement RSL is 5.12 years. From these results there is a decrease in service life. This reduction is approximately 4.88 years from the pavement design life or almost half of the pavement design life. Therefore, it can be concluded that the excess load will result in the road segment not being durable.

RESEARCH METHOD

In this study, a data comparison was made between the Vehicle Damage Factor (VDF) provided by the 2017 Revised Pavement Design Manual and the Vehicle Damage Factors that occur in the field. Data collection on vehicle weight was carried out using two methods, namely by using secondary data from the results of picking heavy vehicles in the field and using primary data by direct measurement of vehicle tire pressure. The types of vehicles that were surveyed for measuring tire pressure were only in vehicle groups 6b and 7a. Then, to obtain the vehicle weight from the tire pressure data, an empirical approach is carried out based on Prastyanto and Mochtar (2018) with the following equation.

$$P = 0.099p \quad \text{.....(1)}$$

Where :
P = axle load (tons)
p = tire pressure (psi)

Vehicle weight data obtained through an empirical approach is only for the rear wheel weight of the vehicle. The weight of the front wheels of the vehicle is carried out based on the average proportion of the weight of the vehicle between the front and rear wheels which is sourced from the results of the vehicle sampling test (secondary data).

Then, the calculation of the Vehicle Damage Factor for the weight of the vehicle in the field is carried out, both from primary data and secondary data. The VDF data that is calculated is VDF to the power of 5. Then, a comparison is made between the field VDF and the VDF provided by the 2017 Revised Pavement Design Manual. The VDF data used to represent this research analysis is the 90% percentile value. The VDF calculation formula varies according to the type of axle configuration as shown in the following formula.

For wheel configuration, Single Axle Single Wheel (SASW)

$$VDF5 = \left(\frac{P}{5,40}\right)^5 \quad \text{.....(2)}$$

For wheel configuration, Single Axle Dual Wheel (SADW)

$$VDF5 = \left(\frac{P}{8,16}\right)^5 \quad \text{.....(3)}$$

For wheel configuration, *Tandem Axle Dual Wheel (TADW)*

$$VDF5 = \left(\frac{P}{13,76}\right)^5 \quad \text{.....(4)}$$

Where :
P = axle load (tons)

Next, perform the CESAL calculation based on the 2017 MDP on variations in the previously calculated VDF values. The CESAL is calculated based on the 2017 MDP Normal Load VDF, 2017 MDP Actual Load VDF, and the VDF that has been analyzed in this study.

DATA COLLECTION

The traffic volume data used in this study comes from the Southeast Sulawesi BPJN Traffic Enumeration Survey Data on 7-9 June 2022. The vehicle categories used are only heavy vehicles or vehicles with six or more wheels which in the study location this research is dominated by class 6b and 7a vehicles as shown in Table below.

Table 3. Heavy Vehicle Traffic Volume in 2022

No.	Vehicle Class	Type of Vehicle	Volume (Veh./day)			Average Volume (Veh./day)
			07 June 2022	08 June 2022	09 June 2022	
1.	5b	Large Bus	0	0	1	1
2.	6b	Medium Truck with 2 Axles	388	512	420	440
3.	7a	Heavy Truck with 3 Axles	90	66	69	75
4.	7b	Trailer Truck	0	0	0	0
5.	7c	Semitrailer Truck	0	1	0	1

Source : BPJN for Southeast Sulawesi, 2022

On June 14-15 2021 a Vehicle Weight Pick Test was carried out at the research study location Sta. 7+200 and Sta. 21+500. The vehicle weight sampling test consisted of 56 units of class 6b vehicles and 11 units of class 7a vehicles. The average of the sample is shown in Table 4 below.

Table 4. Average Vehicle Load from the 2021 Vehicle Weight Test

No.	Vehicle Class	Front Wheel Load (Tons)	Rear Wheel Load (Tons)	Total Load (Tons)	Wheel Load Distribution (%)	
					Front Wheel	Rear Wheel
1	6b	3.65	11.06	14.72	24.83	75.17
2	7a	5.76	31.58	37.34	15.43	84.57

Source : BPJN for Southeast Sulawesi, 2021

In August – September 2022, primary data collection was carried out on the tire pressure of heavily loaded vehicles at the case study locations of this research. The heavy vehicles surveyed are class 6b and 7a vehicles. Then, from the tire pressure data, the rear wheel load is obtained based on the empirical approach of Prastyanto and Mochtar (2018) as seen in Formula 1. To predict the front wheel load, it is obtained by using the wheel load distribution as shown in Table 4 based on the vehicle class. The average of these data is in Table 5.

Table 5. Average Vehicle Load from Tire Pressure Approach

No.	Vehicle Class	Tire Pressure (psi)	Wheel Load Distribution (%)		Front Wheel Load (Tons)	Rear Wheel Load (Tons)	Total Load (Tons)
			Front Wheel	Rear Wheel			
1	6b	136.81	24.83	75.17	13.54	4.56	18.10
2	7a	148.64	15.43	84.57	29.43	5.36	34.79

Source : Author, 2022

RESEARCH ANALYSIS

From the Vehicle Weight Pick Test data, VDF is calculated using Formulas 2, 3, and 4. Then the 90% percentile data is taken to carry out the CESAL analysis. The results of the analysis are listed in Table 6.

Table 6. Comparison of VDF-5 Based on the Vehicle Weight Pick Test against VDF-5 MDP 2017

No.	Vehicle Class	VDF-5	VDF-5 MDP 2017	Ratio
1	6b	11.48	9.00	1.28
2	7a	140.72	19.10	7.37

Sumber : Author, 2022

From the vehicle weight data based on the tire pressure approach, VDF is calculated using Formulas 2, 3, and 4. Then the 90% percentile data is taken to carry out the CESAL analysis. The results of the analysis are listed in Table 7.

Table 7. VDF-5 Comparison Based on the Tire Pressure Approach to VDF-5 MDP 2017

No.	Vehicle Class	VDF-5	VDF-5 MDP 2017	Ratio
1	6b	14.26	9.00	1.58
2	7a	51.53	19.10	2.70

Source : Author, 2022

Then, a CESAL analysis was performed based on the previously calculated VDF-5 variation. CESAL is calculated based on the following Formula 5.

$$ESA_{TH-1} = \left(\sum LHR_{JK} \times VDF_{JK}\right) \times 365 \times DD \times DL \times R \qquad \text{…..(5)}$$

Where :

ESA_{TH-1} : cumulative equivalent standard axle in the first year.
LHR_{JK} : average daily traffic for each type of commercial vehicle (vehicle unit per day)
VDF_{JK} : Vehicle Damage Factor for each type of commercial vehicle
DD : Directional distribution factor. Taken 0.5.
DL : Lane distribution factor. Taken 100% because the road in this research case study has 1 lane in each direction.
CESAL : Cumulative equivalent standard axle load over the design life
R : Cumulative traffic growth multiplier factor. Calculated using Formula 6.

$$R = \frac{(1+0{,}01i)^{UR}-1}{0{,}01i} \qquad \text{…..(6)}$$

Dimana :

UR : design age (years). Taken 20 Years.
i : annual traffic growth rate (%). Taken 4.75% because it is according to the 2017 MDP for the average Indonesian arterial and urban roads.

Table 8. Some of the results of CESAL calculations based on variations in data sources

No.	Data Sources	VDF					DD	DL	R	CESAL ($x10^6$)
		5b	6b	7a	7b	7c				
1	Normal Load MDP 2017	1	4	6.7	0	13.5	0.5	1	32.21	13.38
2	Actual Load MDP 2017	1	9	19.1	0	59.6	0.5	1	32.21	32.05
3	Actual Load MDP 2017 + Vehicle Weight Pick Test	1	11.48	140.72	0	59.6	0.5	1	32.21	92.09
4	Beban Aktual MDP 2017 + Tire Pressure Approach	1	23.47	81.48	0	59.6	0.5	1	32.21	96.98

Source : Author, 2022

From Table 8, it can be seen that the result of the field VDF being larger than the VDF provided by the 2017 MDP resulted in a very large CESAL value. The CESAL ratio between the field version of the VDF (results of picking tests and tire pressure approach) to the normal load of the 2017 MDP is 6.88 and 7.25. Therefore, it would be wrong to designate a normal load road plan because the actual traffic is much heavier than the normal load referred to by MDP 2017. The CESAL ratio between VDF field versions (results of picking tests and tire pressure approaches) to the actual load of MDP 2017 is 2.87 and 3.03. Thus, the actual load given by the 2017 MDP does not yet represent the traffic load on the ground because it results in a larger CESAL.

CONCLUSION

Based on the results of calculations and comparisons it can be concluded as follows :

1. The actual VDF occurring at the case study site for vehicle class 6b is up to 1.58 times greater and for vehicle class 7a is up to 7.37 times greater than the actual VDF for the Sulawesi region given by MDP 2017. Therefore, the design process cannot again to use the VDF given by MDP 2017.
2. For now, normal load design cannot be carried out at the case study location because overloaded vehicles cannot be controlled. This can be seen in the CESAL value due to the field load which is up to 7.25 times greater than the CESAL due to the normal load given by the 2017 MDP.
3. In direct proportion to the field VDF value which is greater than the VDF provided by the 2017 MDP, the CESAL due to field loads is up to 3.03 times greater than the CESAL due to the actual Sulawesi regional load provided by the 2017 MDP. As a result, it is feared that the resulting design will not be able to withstand actual traffic load on site.

Note. This paper has been presented in ICIFAM #1 2022, Surabaya, 21-22 June 2022, organized by Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia. ICIFAM – International Conference on Infrastructure & Facility Asset Management.

REFERENCES

[1] BPJN for Southeast Sulawesi (2020). *Perencanaan Teknis Jalan (DED) Paket Preservasi Jalan Bts. Kab. Konawe Utara/Kab. Konawe - Pohara,* BPJN for Southeast Sulawesi, Kendari.

[2] BPJN for Southeast Sulawesi (2021). *Hasil Uji Petik Berat Kendaraan Ruas Jalan Bts. Kab. Konawe Utara/Bts. Kab. Konawe - Pohara,* BPJN for Southeast Sulawesi, Kendari.

[3] BPJN for Southeast Sulawesi (2022). *Survey Lapangan Pencacahan Lalu Lintas Ruas Jalan Bts. Kab. Konawe Utara/Bts. Kab. Konawe - Pohara,* BPJN for Southeast Sulawesi, Kendari.

[4] Directorate General of Highways (2017). *Manual Desain Perkerasan Jalan Revisi 2017*, Directorate General of Highways, Jakarta.

[5] Jihanny, J., Subagio, B.S., Shih-Hsien, Y., Karsaman, R.H., dan Hariyadi, E.S. (2021). "The Overload Impact On Design Life Of Flexible Pavement", *International Journal of GEOMATE*, Vol. 20, No. 78, hal. 65-72.

[6] Mochtar, I.B. (2021). "Teknologi Perbaikan Tanah Terkini untuk Pembangunan Jalan yang Kokoh dan Awet", *Seminar Webinar HPJI-Jatim.* Video Conference on 30 September 2021.

[7] Mochtar, I.B. (2021). “ Pembangunan Jalan dengan Teknologi Terkini untuk Memperbaiki Kinerja Jalan”, *Seminar Webinar HPJI-Jatim.* Video Conference on 30 September 2021.
[8] Prastyanto, C.A. (2018). Dampak Beban Berlebih (*Overloaded*) Pada Kendaraan Berat Terhadap Persamaan *Equivalent Axle Load* (Eal) Pada Perencanaan Perkerasan Jalan Berdasarkan Teori Deformasi Permanen (*Permanent Deformation*), Dissertation, Institut Teknologi Sepuluh Nopember, Surabaya.
[9] Republic of Indonesia Government (2022). *Undang-Undang Republik Indonesia Nomor 2 Tahun 2022 Tentang Perubahan Kedua Atas Undang-Undang Nomor 38 Tahun 2004 Tentang Jalan*, Republic of Indonesia Government, Jakarta.