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Research Article

Vehicle Influence Simulation Over Dimension Overload on Road Conditions

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Abstract

Heavy vehicle traffic with loads exceeding predetermined standards significantly affects road damage that often occurs. The study's purpose is to see the effect of over-dimension overload vehicle (ODOL) on the IRI value, design age, and costs in road maintenance on national roads, the Palembang - Jambi section, Indonesia. The analysis is carried out using the vehicle damage factor (VDF) assessment to obtain the effect of the vehicle axle. The results of the evaluation are then used to get the residual value of the design life. The sensitivity analysis of road conditions to heavy vehicles' configuration shows the main factors influencing road damage. The research carried out resulted in comparing the IRI value with three simulation conditions and handling costs. The results show that the effect of ODOL on the remaining design life resulted in a residual of 5.78 years for the overload load and 5.85 with a loading simulation on the overload load. Regression analysis produces equation models and parameters that affect road damage due to ODOL vehicles, namely load, number of axles, and trucks. ODOL's arrangement simulation can improve the IRI value and save road maintenance costs using simulations on the HDM-4.

Keywords

Vehicle, over-dimension overload, road damage, HDM - 4

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INTRODUCTION

Roads play an essential role in realizing the development of national life. The condition of road stability remains good if it has the right service level. The condition of road stability will decrease, and the quality decreases with increasing road life. Vehicles whose dimensions and capacities exceed the specified limit are among the causes of the decline of road stability and quality. As a result, the planned life of the Road is not fulfilled. Also, the presence of ODOL causes damage to the road several times greater than those within the specified load limit.

One of the actions that can be taken to prevent the overload problem is to carry out law enforcement activities to verify trucks' compliance with legal weight limits. It can be done by identifying overloaded truck weight and travel patterns (Nasradeen & Zulkiple, 201). The quality of roads in South Sumatera, especially the Trans Sumatera Road, is currently a concern for supervision. There is still much ODOL passing.

Sensitivity analysis analyzes the factors for the number of trucks, loads, and load sharing on ODOL's axle on road pavement conditions on national roads in the South Sumatera region. It is done to obtain the most influencing factors on road damage, based on volume, traffic, and IRI values.

The purpose of the research is to compare the value of IRI on roads and obtain the number of maintenance costs based on the simulation of the effect of ODOL using the HDM-4 program.

LITERATURE REVIEW

Road Damage

Damage to road pavement, exceptionally flexible pavement, generally consists of four categories, namely, surface deformation, surface defects, cracks, and fillings, as well as potholes (Hapsari et al., 2018). One of the road damage factors is an overloading vehicle track where a vehicle has an axle load condition that exceeds the standard allowable load. ODOL has a significant impact on road damage.

Road damage caused by vehicles is stated in the equivalent number or Equivalent Single Axle Load (ESAL). It can also be called the Vehicle Damage Factor VDF, which can determine the road's planned life (Abuhamoud et al., 2011; Matthews et al., 1996; Simon et al., 2017).

Financing

The pavement structure is not functioning optimally in line with the increasing traffic load, especially with ODOL. There will be a severe problem in road pavement maintenance if the number and load are not controlled. Maintenance of roads with excellent and effective results requires efficient allocation of funds from available funding sources (Sayers, 1986).

Road maintenance is implemented in Indonesia by considering two indicators: the roughness value (IRI) and distress (SDI). Proper maintenance is carried out based on the conditions. IRI values are divided into three types: values < 8 can be carried out routine maintenance; IRI scores 8-12 are subject to rehabilitation, and IRI values > 12 are reconstructed (Batioja-Alvarez et al., 2018; Matthews, 2002). To see the road maintenance cost due to heavy vehicles, look at traffic volume data and actual costs of periodic maintenance and rehabilitation and reconstruction of a road section obtained from local government units. Traffic data, including traffic volume (AADT), individual shaft loads, and traffic growth factors, are obtained from annual maintenance plans (Wang et al., 2016).

Logistic Regression

Multiple linear regression analysis is a linear relationship between two or more independent variables (X1, X2,… .Xn) and the dependent variable (Y). The analysis is done to determine the direction of the relationship between the independent and the dependent variable, whether each independent variable has a positive or negative relationship, and to predict the dependent variable's value if the independent variable's value has increased or decreased (Han et al., 2015; Matthews & Desmond, 1995; Matthews et al., 1999).

Over Dimension Over Load vehicle

Over Dimension Overloading vehicles are vehicles with dimensions and carrying loads that exceed predetermined standards. By definition, overloading is a condition that the axle load of a vehicle exceeds the standard load used in the pavement design assumptions or the number of operational passes before the plan life is reached. Over dimension is the vehicle's condition having a length/width/height that exceeds the predetermined standard. It can cause the load to be not evenly distributed on the vehicle axles (Assogba et al., 2019; Matthews et al., 1998).

Figure 1. Beginning IRI value

RESEARCH METHOD

Research Location

The research location is a national road carried out on the Palembang Jambi road with 224.05 km. The road section at the research location crosses three districts/cities and is divided into 18 segments. Each section and segment length can be seen in Table 1 and

Figure 1.

Data Collection

The data used in this study are vehicle volume and cargo data classified in variables, namely the number of vehicle axles. The data is then classified under several scenarios based on the vehicle load distribution on the vehicle axis. After the vehicle is classified under several load sharing scenarios on the vehicle axis, the vehicle damage factor (VDF) is calculated to obtain the effect of the load on the vehicle axle. Thus, the damage that affects the pavement due to overloaded vehicles can be calculated.

Road segment section of Palembang – Jambi

Segment no	Section Name	Section Length (km)
1	Jambi Peninggalan 1	22,72
2	Jambi Peninggalan 2	22,72
3	Jambi Peninggalan 3	22,72
4	Jambi Peninggalan 4	9,625
5	Jambi Peninggalan 5	9,625
6	Jambi Peninggalan 6	2,74
7	Peninggalan – Betung 1	20,03
8	Peninggalan – Betung 2	20,03
9	Peninggalan – Betung 3	20,03
10	Peninggalan – Betung 4	7,86
11	Peninggalan – Betung 5	7,86
12	Peninggalan – Betung 6	1,93
13	Betung Palembang 1	14,74
14	Betung Palembang 2	14,74
15	Betung Palembang 3	14,74
16	Betung Palembang 4	0,83
17	Betung Palembang 5	5,5
18	Betung Palembang 6	5,5

The research is conducted on National Roads in the South Sumatera Region. The data used in this study are the volume of ODOL vehicles and the average load of vehicles crossing national roads in the South Sumatera Region.

Traffic Data

The percentage of heavy vehicles on national roads in the South Sumatera region is still high. It allows the number of vehicles with a load capacity exceeding the maximum allowable load, reducing road stability.

The calculation of the volume of vehicle traffic per year by class can be seen in Table 2.

Table 2.

Yearly vehicle traffic volume Volume

No	Type of Vehicles	Traffic Volume (vehicle/year)
1.	Type 1	19.135
2.	Type 2	101.538
3.	Type 3	4.628
4.	Type 4	463.174
5.	Type 5	199.263
6.	Type 5B	2.305
7.	Type 6B	165.366
8.	Type 7A	158.066
9.	Type 7B	60.018
10.	Type 7C	32.920

The IRI Value (International roughness index)

The IRI (international roughness index) value is a number that states the level of unevenness or roughness of a road surface. The IRI value is determined from the number of results of the automatic measuring vehicle road surface response by combining the reference elevation, height relative to the reference, and longitudinal distance (Boyle & Mannering, 2004; Desmond & Matthews, 1997). The IRI value on the Jambi - Palembang national road can be seen in Figure 2.

Figure 2. Research flow

Road infrastructure financing

Road infrastructure financing is carried out based on the road conditions' value at the research location. Then, the type of handling is analyzed according to the IRI value obtained. On the Palembang-Jambi study Palembang road section, the value of the financing is shown in Table 3.

Table 3.

Average Maintenance Costs Based On Conditions

No	Type of maintenance	Value (Rp. Million/km)
1.	Routine	167,43
2	Rehabilitation	4078,85
3	Reconstruction	15813,78

Methodology

Vehicle volume and cargo data are classified into variables, namely, the number of vehicle axles. Then, a scenario is created in the distribution of vehicle loads on the vehicle axis. After the vehicle is classified under several load sharing scenarios on the vehicle axle, the vehicle damage factor (VDF) is calculated to obtain the effect of the load on the vehicle axle. Thus, the damage that affects the pavement due to overloaded vehicles can be calculated to obtain the remaining value of the planned life of the Road.

The sensitivity analysis of road conditions to heavy vehicles' configuration shows the main factors influencing road damage. The analysis carried out resulted in comparing the IRI value with three simulation conditions and the handling costs of road damage. Figure 3 shows the research flow diagram.

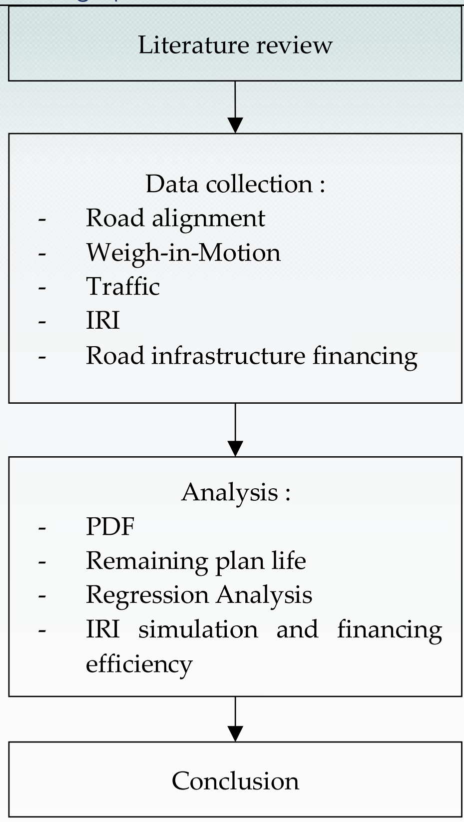

Figure 1. Research Flow

Vehicle Damage Factor (VDF)

Road damage factors due to vehicle axle loads using the Liddle equation model in equation (1).

$$\% \text{ VDF} = k\left[\frac{P}{8{,}16}\right]^4 \qquad (1)$$

Where:

VDF = axis load equivalent figure,

P = axle load (Ton),

k = axle coefficient (1 for single, 0.086 for tandem, 0.053 for triple).

Calculations are made for each type of vehicle according to traffic data. It is simulated with a vehicle that carries loads more than 20% of the standard, 50%, 70%, and 100%. Thus, the destructive force of heavy vehicles that will be calculated is in Group 6, Group 7A, Group 7B, and Group 7C.

Decreasing analysis of road planning life

Analysis of the reduction in the planned life of the Road is carried out by equation (2) and the calculation for the remaining design life using equation (5).

$$\text{VDF cumulative vehicle} = \Sigma \text{ vehicle} \times \text{Total Esal} \qquad (2)$$

$$\text{Remaining plan life} = \frac{(\text{Total Esal Normal}) \times \text{U.R.}}{\text{Total Real Overload}} \qquad (3)$$

Sensitivity analysis of parameters to vehicle damage

A probabilistic method can be developed to evaluate pavement damage due to overloaded vehicles under different road conditions and environments (Green et al., 2011).

Result and Discussion

Damage to Vehicles

The vehicle's destructive force analysis carried out on each vehicle type can be seen in Table 4. The relationship between the percentage of vehicle overload and the percentage increase in the vehicle's damage factor in Figure 4.

Figure 4 shows an increase in the percentage that occurs between VDF and vehicle overload. In other words, it can be seen that the greater the overload in a class of vehicles, the more significant the percentage increase in VDF that occurs.

Table 4

Vehicle Damage Result Analysis

No	Overloaded (%)	Total Overload ESAL	Total Normal ESAL	Escalation of VDF (ESAL)	Escalation Percentage of VDF (%)
Type 6B					
1	20	8,08	2,4	5,68	237
2	50	19,73	2,4	17,33	722
3	70	32,56	2,4	30,16	1257
4	100	62,37	2,4	59,97	2499
Type 7A					
1	20	17,94	3,24	14,70	454
2	50	43,80	3,24	40,56	1252
3	70	72,26	3,24	69,02	2130
4	100	138,42	3,24	135,18	4172
Type 7B					
1	20	20,95	6,91	14,04	203
2	50	51,16	6,91	44,25	640
3	70	84,40	6,91	77,49	1121
4	100	161,68	6,91	154,77	2240
Type 7C					
1	20	28,16	13,6	14,56	107
2	50	68,75	13,6	55,15	406
3	70	113,43	13,6	99,83	734
4	100	217,29	13,6	203,69	1498

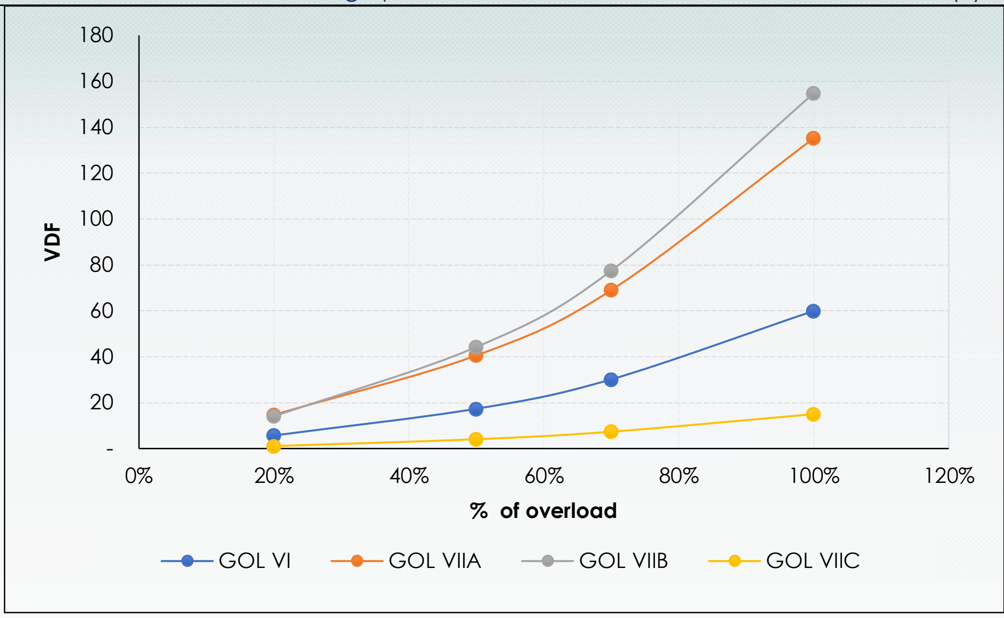

Figure 2. Graph of the relationship between the VDF value and the percentage of overload

Planned Life Analysis

The calculation of the planned life of the Road is obtained from the division between the normal cumulative VDF of all vehicles with the cumulative VDF of all overload vehicles.

$$\text{Remaining planned life} = \frac{(1.834.330) \times 10}{3.171.587}$$

The results are 5.78 years for excessive loads and 7.89 for excessive loads that are distributed evenly. The loading simulation is carried out on 7A vehicles with large volume and considerable damage power. Loading simulation is done by moving 30% of type 7A loads into type 7C vehicles (Semi-Trailer Truck / 1.22-222). Graph of road service life can be seen in Figure 5.

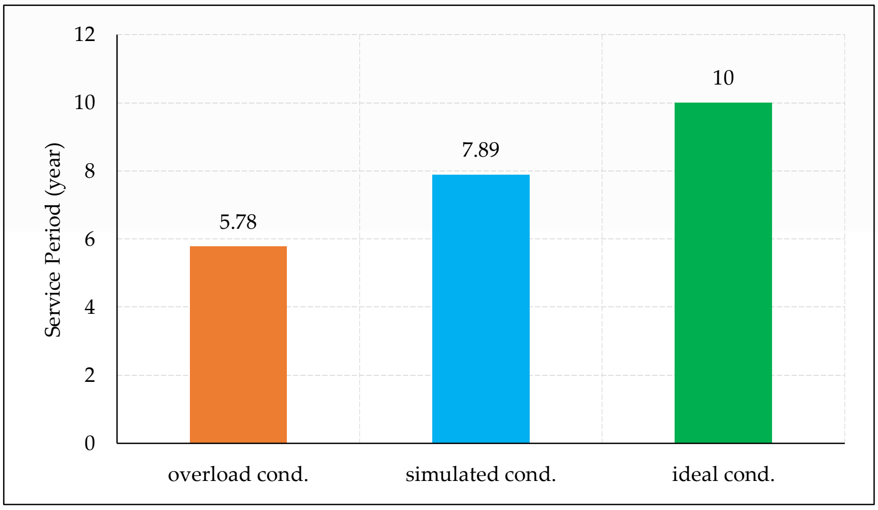

Figure 3. Road service life

2.1 Sensitivity parameter to damage caused by ODOL vehicles

The study shows four factors that influence ODOL's trajectory on-road damage: the amount of load carried, IRI, speed, and the number of vehicles. Vehicles and traffic data are analyzed in a statistical table to see the effect of these four factors, which produce the following equation:

$Y = 6{,}04 - 1{,}59 X_1 - 0{,}00774 X_2 - 0{,}53 X_3 + 1{,}88 X_4$

where, Y = Structural Number (SN), X_1 = load , X_2 = AADT, X_3 = IRI, X_4 = Speed.

From the function above, it can be seen that the parameter X1 is positive. It means that the greater the load passing through the Road, the lesser the SNvalue. The results also indicate that the worse the road conditions are followed by the negative values of X2 and X3 if it shows that the larger and more axles and trucks will distribute the load more evenly according to the serviceability of the Road, which makes the service life of the road segment better.

Table 5 shows that the model made is adequate, with an adjusted R square value of 0.83, and each simulated factor is a significant or influential parameter.

Table 5

Results Of Sensitivity Analysis

Regression Statistics	
Multiple R	0,916393828
R Square	0,839777648
Adjusted R Square	0,836696449
Standard Error	0,004351332
Observations	160

The effect of ODOL on the IRI value

The effect of ODOL on road pavement conditions (IRI Value) is simulated in three scenarios, namely the condition of vehicle volume without ODOL, the condition of the entire vehicle volume including ODOL (normal), and conditions with load settings on ODOL. A comparison of the IRI value of the Road can be seen in Figure 6.

Road Maintenance Saving Efficiency due to ODOL arrangement.

Regulating excess traffic of goods vehicles (ODOL) when following a scenario where Class 7A vehicles are distributed to class 7C vehicles by 30% will reduce road maintenance costs, as shown in Table 6.

The graph above shows that ODOL vehicles consistently increase the IRI value on each road section, which will worsen the road section's condition. Regulating the excessive loads has consistently improved every road segment's conditions, as shown in sections 7, 8, 9, 13, 14, and 15, where the handling that should be carried out in rehabilitation becomes only routine handling. Meanwhile, in sections 5, 11, and 17, reconstruction can be saved into handling rehabilitation.

Table 4 shows the savings that can be made by controlling the ODOL vehicles that cross the Palembang - Jambi road.

Table 6

Savings Based On Odol Settings

No	Traffic Condition	Cost (million)
1	Normal	303.217
2	Normal + ODOL	1.339.385,94
3	ODOL managed	651.358,32

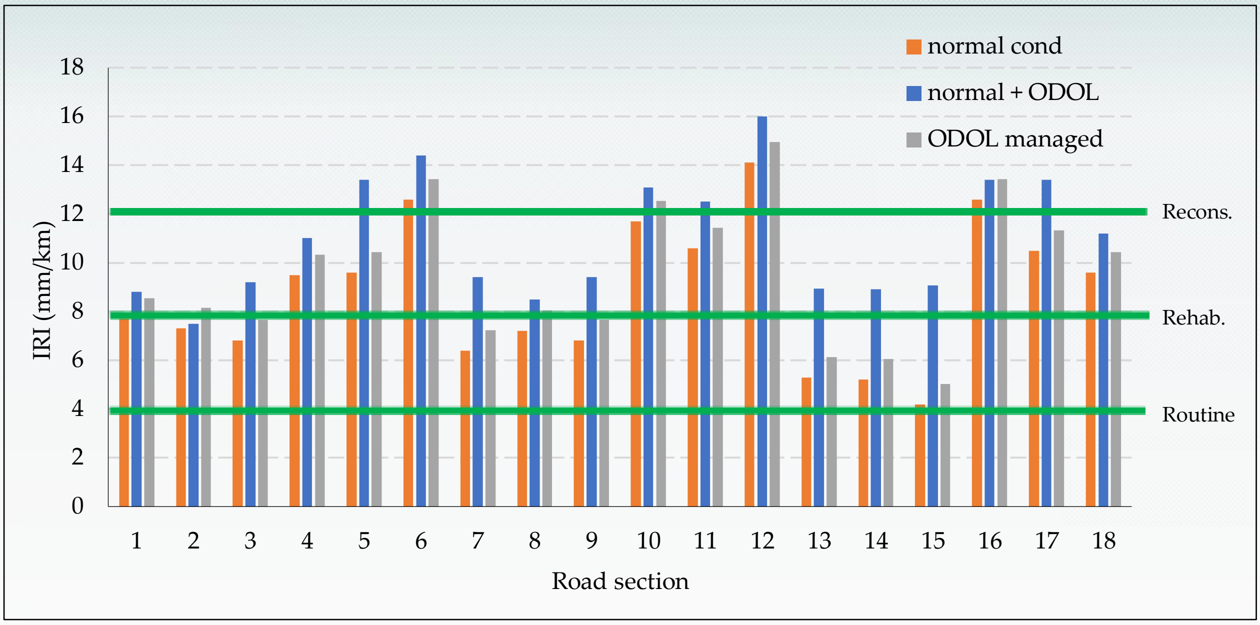

Figure 4. IRI Value

Conclusion

In the study, a simulation of the effect of ODOL on road pavement is simulated. Based on the analysis that has been carried out, the conclusions of the study are as follows;

1. The effect of vehicles with excessive loads on the remaining planned life on national roads in the South Sumatera region is 5.78 years for overload loads and 7.89 for actions on overload loads.

2. Parameters that affect road damage due to ODOL are load, AADT, IRI, and speed, and the model developed is reliable.

3. Regulating ODOL can improve the IRI value in each road segment at the research location.

4. Savings in road maintenance costs on research roads can be carried out with the loading scenario on ODOL vehicles.

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