WIM-BRIDGE SYSTEM EVALUATION ON ROAD PAVEMENT
(STUDY CASE : ABC SECTION SEMARANG TOLL ROAD)

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ABSTRACT

ABC Section Semarang Toll Road is one of many toll roads that are traversed by transport vehicles with a load exceeding the permit limit, especially for vehicles originating from the Port of Tanjung Mas. These overloaded vehicles cause a decrease in pavement condition due to pavement damage on Semarang Section ABC Toll Road Section. This study aims to determine the magnitude of the impact of overload vehicles on the remaining life of the road by using overload vehicle detection from the Weight in Motion Bridge system. The method used in this study refers to Bina Marga Pd T-05-2005-B and AASHTO 1993. Based on the results of the analysis that has been done, it can be concluded that there is a decrease in residual life due to overloading vehicles for the year 2022 in Section A, Line A reaches conditions of 26.93% and 37,46%; Section B Line A achieves pavement failure; Section C of Line A reaches 44.65% and 38.33% conditions; Section A Lane B reaches 32.02%; Section B Lane B achieves failure pavement; and Section C of Line B reaching 54.42% and 40.70%.

Keywords : Overload; Residual age; Vehicle Damage Factor; weight in motion bride

INTRODUCTION

ABC Section Semarang Toll Road is one of the toll roads that is traversed by overloaded vehicles coming from Tanjung Mas Port. The overloaded vehicles will increase the Vehicle Damage Factor (VDF) on the road pavement. According to the data of overloaded vehicles control operation conducted by PT. Jasa Marga (Persero) Tbk, in the years of 2016-2018, particularly in Semarang Branch, the overloaded vehicles reached 66,89% in 2016; 53,03% in 2017; and 58,54% in 2018. The problem discussed this research is the Vehicle Damage Factor (VDF) value of the overloaded vehicles on Semarang Toll Road ABC Section based on vehicle weight measurement from WIM Bridge technology and the impact of the overloaded vehicles to remaining life degrading of the pavement of Semarang Toll Road Section ABC. Overloading is defined as the amount of the load weight of passenger vehicles, carriage cars, long trucks, and trailer trucks exceed the allowed weight (Simanjuntak et al, 2014, p.541). Furthermore, one of factors the road damage is the overloaded traffic that results in remaining life to be shorter than has been planned. The factor of age degrading acceleration is dominated by vehicles in category 7B and 7C (Atiya et al, 2014, p.671). Therefore, purpose this paper is determine the magnitude of the impact of overload vehicles on the remaining life of the road by using overload vehicle detection from the Weight in Motion Bridge system.

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Flexible Pavement

Flexible Pavement is a pavement using asphalt as the binder. The layer structure of the flexible pavement is presented on Figure 1.

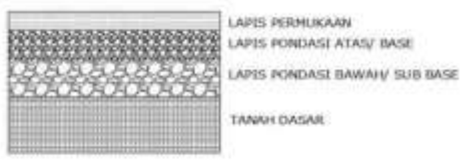

Figure 1 : Flexible Pavement Layer Structure
Source: Bina Marga No.03/M/N/B/1983

Weight In Motion Bridge

Weight in Motion Bridge (WIM Bridge) is a measurement system of the actual traversed vehicles weight by using the structure of the bridge and without stopping the vehicles (PUPR, 2019, p.iii).

Vehicle Damage Factor (VDF)

Vehicle Damage Factor (VDF) is a comparison of damage level effected by the weight track of single vehicle axle in one lap of the vehicle which is 18,000 lbs. According to (Apriyadi, 2018, p.34), an overload weight can increase VDF cummulative value. VDF value can be calculated through a collation of vehicle weight axle (P) with category of vehicle axle (k) as the formulation below:

$$VDF = (\frac{P}{k})^4 \ldots\ldots\ldots\ldots\ldots (1)$$

with :
VDF = Vehicle Damage Fa (1)
P = vehicle weight axle (in ton)
K = 5.4 for single axle of single wheel
8.16 for single axle of double wheels
13.76 for tandem axle of double wheels
18.45 for triple axle of double wheels

Equivalent Single Axle Load

In accordance with AASHTO (1993), ESAL Traffic can be measured with the equation:

$$W_{18} = LHR_j \ x \ VDF_j x D_D x \ D_L x 365 \ \ldots(2)$$

with :
W18 : Traffic design on traffic lane, Equivalent Single Axle Load.
LHRj : Total of traffic vehicles daily vehicle type j.
VDF_j : *Vehicle Damage Factor* for vehicle type j.
D_D : Direction Distribution Factor
D_L : Lane Distribution Factor

Remaining Life

Pavement remaining life is a condition of the road pavement that is degrading due to weighing of the vehicles that has characteristic of damaging the pavement. According to Sentosa (2012), overloaded vehicles can cause a degrading of pavement's life as much as 8 years. Therefore, an analysis is needed to measure the remaining life degrading on Semarang Toll Road Section ABC. Remaining life can be measured with an equation sourced from AASHTO 1993, as below:

$$RL = 100 \left[1 - \left(\frac{N_p}{N_{1,5}}\right)\right] \ldots\ldots (3)$$

with :

RL = Remaining Life (%)
N_p = *Total traffic* that has accrossed the pavement (*ESAL*)
$N_{1,5}$ = *Total traffic* at the end

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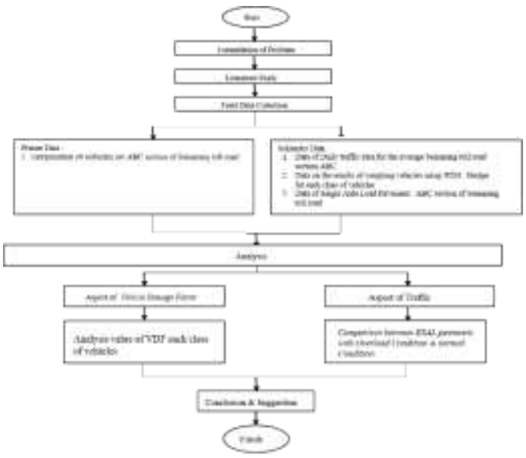
METHODS

The whole research is designed according to the flow chart on Picture 2.



Gambar 2. Research Flowchart

Data Collection

The data of this research is taken from primary and secondary data. The primary data is a survey data of vehicle composition to identify the percentage of vehicle type that crossed on Semarang Toll Road Section ABC with the point is on Toll Gate Krapyak 1, Srondol, and Muktiharjo. In addition, the secondary data is the average of Daily Traffic in 2015-2017, observation data on WIM Bridge in 24 hours, and Equivalent Single Axle Load Pavement data on Semarang Toll Road Section ABC.

Data Analysis

After the primary and secondary data are collected, the next step is:

1. Forecast analysis LHR and overload percentage for 2018-2022.
2. Vehicle Damage Factor (VDF) analysis for the allowed load weight and overload condition.
3. Equivalent Single Axle Load (ESAL) analysis for the vehicle condition with allowed load weight and overload.
4. Remaining lifetime analysis on Semarang Toll Road Section ABC.

RESULT AND DISCUSSION

Vehicle Composition Percentage

The percentage data of vehicle composition on Semarang Toll Road Section ABC was obtained from vehicle composition survey conducted on Toll Gate Krapyak 1, Srondol, and Muktiharjo as presented on Table 1.

LHR Forecast Analysis

LHR Value forecasting on Line A and B on Semarang Toll Road Section ABC uses linear regression method, hence the LHR value on Semarang Toll Road Section ABC in 2015 - 2022 is identified. The LHR forecast analysis on Line A and B can be seen on Table 2 and Table 3.

Forecast Analysis on Overload Percentage

Forecasting on overload percentage on Semarang Toll Road Section ABC in 2018 – 2022 have been conducted. The forecast analysis result of overload percentage can be seen on Table 4.

Based on Table 4, the overload percentage was decreasing in 2015 with value 0% because there was no overloaded vehicles control operation yet.

Vehicle Damage Factor Value Analysis

Conducting an analysis on vehicle damage factor value using WIM Bridge data measurement for the overloaded

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vehicles that would be compared with the value of allowed weight vehicle condition. Observation Data on Overloaded Vehicles from WIM Bridge can be seen on Table 5.

Based on the measurement data at WIM Bridge as presented on Table 5, there are 3,113 overloaded vehicles. The next is calculating VDF value for the vehicles categories detected on vehicles composition survey refer to VDF equation of Bina Marga Pd T-05-2005-B. The VDF value analysis for the allowed condition and overload can be seen on Table 6.

VDF calculation example:

$$VDF = (\frac{P}{k})^4 = (\frac{6}{5.4})^4 + (\frac{18}{13.76})^4$$
$$= 4.4525$$

VDF calculation for vehicles with classification code 51 the overload condition is below:

$$VDF = (\frac{P}{k})^4 = (\frac{9.1205}{5.4})^4 + (\frac{24.7458}{13.76})^4$$
$$= 18.616$$

The ESAL Value Analysis

It analyzes Equivalent Single Axle Load value using the total of Overloaded Vehicles based on LHR in 2015-2022, the vehicle damage factor value in overload condition from the analysis before in equation of ESAL Traffic value calculation which refers to AASHTO 1993. ESAL Value Analysis result for overload condition for line A and B can be seen on Table 7 and Table 8.

The example of ESAL calculation for vehicles with classification code 51 in overload condition on Section A line A in 2018 is below:

The total of vehicles with classification code 51 on Section A Line A in 2018 is 840 vehicles, in details 348 are allowed condition vehicles and 492 are overload vehicles.

$$W_{18} = LHR_j \; x \; VDF_j x D_D x \; D_L x 365$$
$$= 348x \; 4,4525x0,5x \; 0,8x365$$
$$= 226,519 \text{ SAL}$$

$$W_{18} = LHR_j \; x \; VDF_j x D_D x \; D_L x 365$$
$$= 492x \; 40,8834x0,5x \; 0,8x365$$
$$= 2,936,797 \text{ SAL}$$

As a result, ESAL Traffic sum for vehicles with classification code 51 on Section A Line A in 2018 affected by overload percentage is 3,163,315 SAL.

The Pavement's Remaining Life Analysis

After the ESAL Traffic value is obtained, the next is analyzing the remaining life value percentage of the pavement of Semarang Toll Road Section ABC.

For example:

The Percentage of remaining life of Karpyak-Jatingaleh Section A in 2018 in normal condition.

$$100 \left[1 - \left(\frac{13.305.103}{101.714.155}\right)\right] = 86,92\%$$

The Percentage of remaining life of Krapyak-Jatingaleh Section A in 2018 in overload condition.

$$100 \left[1 - \left(\frac{38.221.959}{101.714.155}\right)\right] = 62,42\%$$

The pavement's remaining life analysis percentage of Semarang Toll Road Section ABC Line A and Line B can be seen on Table 9 -Table 20.

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CONCLUSION

Conclusion

Based on the analysis, it can be concluded that:

1. There is an increase of VDF value caused by overloaded vehicles condition in which truck vehicles with classification code 51 and axle configuration 1, -22 has the highest VDF value of 40.8834
2. There is an acceleration degrading of the remaining life caused by overload weight with average of degrading is 30-40% and at the end of the research year in 2022, Section B consisting of segment SS - *Tembalang* and *Tembalang* - *Akhir* will have pavement failure.

Suggestion

The suggestions given based on the research result are:

1. To maximize the control for overloaded vehicles more than should be allowed, therefore PT Jasa Marga (Persero) Tbk should install Weight In Motion Bridge system on Section A and B Semarang Toll Road Section ABC.
2. PT Jasa Marga (Persero) Tbk should replace the pavement on Semarang Toll Road Section ABC particularly on Section B into rigid pavement to provide better strength against the crossing weight.
3. Sanction should be applied By PT Jasa Marga (Persero) Tbk to the vehicles which have overloaded weight by increasing the toll road fare.

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Appendix

Tabel 1. The Percentage of Vehicle Composition on Semarang Toll Road Section ABC

Time	Vehicle configuration										
	Private Car 1-1	Mini Bus 1-1	Bus 1-2	Two axle truck 1-2	Truk 3 sumbu 11-2	3 axis truck 1-22	Semi Trailer 1-2-22	Semi Trailer 1-2-222	Semi Trailer 1-22-22	Semi Trailer 1-22-222	Truk Trailer 1-2-2-2
Seksi A	91.76%	8.24%	100.00%	100.00%	0.00%	100.00%	100.00%	100.00%	0.00%	0.00%	0.00%
Seksi B	94.15%	3.76%	2.09%	100.00%	0.00%	100.00%	100.00%	71.43%	0.00%	28.57%	0.00%
Seksi C	88.82%	9.33%	1.84%	100.00%	0.00%	100.00%	95.00%	75.00%	0.00%	25.00%	5.00%

Table 2. LHR Forecast Analysis on Line A

Year	A Section	B Section	C Section
2015	24,983	35,442	40,600
2016	26,384	35,446	41,386
2017	27,813	35,987	40,992
2018	29,223	36,170	41,385
2019	30,638	36,443	41,581
2020	32,053	36,715	41,778
2021	33,468	36,988	41,974
2022	34,883	37,260	42,170

Table 3. LHR Forecast Analysis on Line B

Year	A Section	B Section	C Section
2015	21,532	38,990	32,643
2016	22,942	38,985	33,363
2017	24,414	39,578	33,216
2018	25,844	39,772	33,648
2019	27,285	40,066	33,934
2020	28,726	40,360	34,221
2021	30,167	40,654	34,507
2022	31,608	40,948	34,794

Table 4 Analysis Result of Overload Percentage

No.	Year	Percentage of Overload
1	2015	0.00%
2	2016	66.89%
3	2017	53.03%
4	2018	58.54%
5	2019	33.00%
6	2020	33.23%
7	2021	29.66%
8	2022	26.95%

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Table 5. Total of Overloaded Vehicles

Transportation type	Classification Code	Amount
Private Car	20	485
Minibus	30	1636
Two axle truck	40	62
Bus	41	266
3 Axle Truck	50	4
3 Axle Truck	51	368
Bus	56	2
4 Axle Truck	57	11
4 Axle Truck	58	2
Truck Trailer	60	2
Truck Trailer	61	18
Truck Trailer	62	129
Truck Trailer	63	6
Truck Trailer	70	4
Semi Trailer	100	5
Semi Trailer	101	3
Semi Trailer	102	88
Semi Trailer	111	5
Semi Trailer	120	17
Amount		3113

Table 6. Vehicle Damage Factor Value Analysis for Allowed condition and overload

VDF Condition	Vehicle Configuration								
	Private Car 1-1	Mini Bus 1-1	Bus 1-2	Two axle truck 1-2	3 axle truck 1-22	Semi Trailer 1-2-22	Semi Trailer 1-2-222	Semi Trailer 1-22-222	Truck Trailer 1-2-2-2
Overload	0.0024	0.0071	3.7796	3.7796	4.4525	6.7079	10.7700	12.9777	8.2906
Permission	0.0812	4.1366	18.5164	15.3483	40.8834	15.0534	29.0333	22.1388	38.0351

Table 7. ESAL Value Analysis of Line A

Year	A Section	B Section	C Section
2015	3,067,555	5,138,150	6,581,313
2016	12,178,197	18,209,738	23,302,641
2017	10,802,259	15,848,412	19,712,132
2018	12,173,948	17,109,124	21,300,080
2019	8,822,887	12,121,957	15,031,183
2020	9,259,096	12,320,132	15,180,202
2021	9,060,842	11,727,567	14,365,634
2022	8,961,485	11,297,259	13,757,098

Table 8. ESAL Value Analysis of Line B

Year	A section	B Section	C Section
2015	2,643,770	5,652,540	5,291,541
2016	10,589,610	20,027,749	18,785,231
2017	9,481,931	17,429,936	15,972,956
2018	10,766,201	18,813,174	17,317,358
2019	7,857,430	13,327,464	12,266,288
2020	8,298,398	13,543,537	12,433,427
2021	8,167,855	12,890,449	11,808,855
2022	8,121,221	12,415,892	11,348,960

Table 9. The Remaning Life Percentage of Krapyak - Jatingaleh Line A.

Table 10. The Remaining Life Percentage of Jatingaleh - SS Line A.

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Segment	Year	Remaining Life Percentage	
		Permit Condition	*Overload condition*
Krapyak - Jatingaleh	2015	96.98%	96.98%
	2016	93.78%	85.01%
	2017	90.43%	74.39%
	2018	86.92%	62.42%
	2019	83.17%	53.75%
	2020	79.24%	44.64%
	2021	75.14%	35.74%
	2022	70.97%	26.93%

Segment	Year	Remaining Life Percentage	
		Permit condition	*Overload condition*
Jatingaleh - SS	2015	97.42%	97.42%
	2016	94.68%	87.17%
	2017	91.81%	78.08%
	2018	88.81%	67.84%
	2019	85.60%	60.42%
	2020	82.24%	52.63%
	2021	78.73%	45.00%
	2022	75.16%	37.46%

Table 11. The Remaining Life Percentage of SS - Tembalang Line A.

Segment	Year	Remaining Life Percentage	
		Permit condition	*overload condition*
SS-Tembalang	2015	92.18%	92.18%
	2016	84.34%	64.49%
	2017	76.31%	40.38%
	2018	68.20%	14.35%
	2019	59.98%	0.00%
	2020	51.65%	0.00%
	2021	43.22%	0.00%
	2022	34.69%	0.00%

Table 12. The Remaining Life Percentage of Tembalang - End of Line A.

Segment	Year	Remaining life percentage	
		Permit condition	*overload condition*
Tembalang-Akhir	2015	93.74%	93.74%
	2016	87.46%	71.58%
	2017	81.04%	52.28%
	2018	74.55%	31.46%
	2019	67.97%	16.70%
	2020	61.31%	1.70%
	2021	54.56%	0.00%
	2022	47.73%	0.00%

Table 13. The Remaining Life Percentage of SS - Gayamsari Line A.

Segment	Year	Remaining life Percentage	
		Permit condition	*overload condition*
SS-Gayamsari	2015	97.18%	97.18%
	2016	94.31%	87.20%
	2017	91.46%	78.76%
	2018	88.58%	69.63%
	2019	85.68%	63.20%
	2020	82.77%	56.69%
	2021	79.84%	50.54%
	2022	76.90%	44.65%

Table 14. The Remaining Life Percentage of Gayamsari - Ps. Johar Line A

Segment	Year	Remaining life percentage	
		Permit condition	*overload condition*
Gayamsari - Ps. Johar	2015	96.86%	96.86%
	2016	93.66%	85.74%
	2017	90.48%	76.33%
	2018	87.27%	66.17%
	2019	84.05%	58.99%
	2020	80.80%	51.75%
	2021	77.54%	44.89%
	2022	74.26%	38.33%

Table 15. The Remaining Life Percentage of Krapyak - Jatingaleh Line B.

Segment	year	Remaining life percentage	
		Permit condition	*Overload condition*
Krapyak - Jatingaleh	2015	97.27%	97.27%
	2016	94.35%	86.35%
	2017	91.27%	76.58%
	2018	88.03%	65.47%
	2019	84.62%	57.37%
	2020	81.02%	48.81%
	2021	77.24%	40.39%
	2022	73.27%	32.02%

Table 16. The Remaining Life Percentage of Jatingaleh - SS Line B.

Segment	Year	Remaining life pecentage	
		Permit condition	*Overload condition*
Jatingaleh - SS	2015	97.27%	97.27%
	2016	94.35%	86.35%
	2017	91.27%	76.58%
	2018	88.03%	65.47%
	2019	84.62%	57.37%
	2020	81.02%	48.81%
	2021	77.24%	40.39%
	2022	73.27%	32.02%

Table 17. The Remaining Life Percentage of SS - *Tembalang* Line B.

Table 18. The Remaining Life Percentage of *Tembalang* - End of Line B.

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Segment	Year	Remaining life Percentage	
		Permit condition	*overload condition*
SS-Tembalang	2015	91.43%	91.43%
	2016	82.82%	61.05%
	2017	74.01%	34.61%
	2018	65.12%	6.07%
	2019	56.11%	0.00%
	2020	46.98%	0.00%
	2021	37.74%	0.00%
	2022	28.38%	0.00%

Segment	Year	Remaining life percentage	
		Permit condition	*overload condition*
Tembalang-Akhir	2015	92.78%	92.78%
	2016	85.53%	67.21%
	2017	78.12%	44.95%
	2018	70.63%	20.92%
	2019	63.05%	3.90%
	2020	55.37%	0.00%
	2021	47.59%	0.00%
	2022	39.71%	0.00%

Table 19. The Remaining Life Percentage of SS - Gayamsari Line B.

Segment	Year	Remaining life percentage	
		Permit condition	*overload condition*
SS-Gayamsari	2015	97.71%	97.71%
	2016	95.37%	89.57%
	2017	93.03%	82.65%
	2018	90.66%	75.15%
	2019	88.27%	69.84%
	2020	85.86%	64.45%
	2021	83.43%	59.34%
	2022	80.97%	54.42%

Table 20. The Remaining Life Percentage of Gayamsari - Ps. Johar Line B

Segment	Year	Remaining life Percentage	
		Permit condition	*overload condition*
Gayamsari - Ps. Johar	2015	97.02%	97.02%
	2016	93.97%	86.43%
	2017	90.93%	77.43%
	2018	87.85%	67.67%
	2019	84.74%	60.76%
	2020	81.61%	53.75%
	2021	78.44%	47.10%
	2022	75.25%	40.70%

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