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Analysis Of The Influence Of Vehicle Overloading On The Remaining Life Of The Road Plan

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Sidoarjo East Ring; Overload; Road Design Age.

Abstract

The Sidoarjo East Ring Road is one of the roads in Sidoarjo. Along it are industrial warehouses, which are the main route for heavy vehicles such as trucks carrying large commercial goods. The presence of trucks carrying large commercial goods passing through the Sidoarjo East Ring Road affects the condition of the planned road pavement. Therefore, this research needs to be carried out to find out how much influence overloading has on reducing the design life of the road. This research uses AASHTO 1993 guidelines. There are two types of data: secondary data in the form of average daily traffic and vehicle load data crossing the Sidoarjo East Ring Road and primary data in the form of average daily traffic. From the data obtained, the ESAL value, W18 value, truck factor value, and remaining life of the road plan can be calculated. Based on the data analysis that has been carried out, the standard ΣW18 values are 471678.71 to 3467360.95, and the ΣW18 overload in 2021 is 626066.63 to 4625156.45. If the truck factor value is >1, the Sidoarjo East Ring Road section is experiencing overload due to heavy vehicles. The percentage value of remaining life due to LHR and overload is 7.392%, and in overload conditions, there is a reduction in the planned life of the road by 0.8 years from the planned life of 5 years, where the planned life of the road will end in 2025, the second month since the road opened in 2021.

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1. Introduction

Background

Roads are transportation infrastructure essential in facilitating economic, social, cultural, and various other activities (Fatikasari et al., 2021). With the increase in the population and vehicles in Indonesia, the need for adequate roads is increasing. In this regard, optimal road construction planning following technical standards is critical regarding function, volume, and traffic characteristics. Based on what happens in the field, roads will experience a decline in their structural function as they age, mainly when used by heavy vehicles with excessive loads. On today's highways, premature damage often occurs to roads that have just been repaired and roads that have just been built. Based on several studies, the primary reasons for road damage are less than optimal construction quality, inadequate drainage problems, and vehicle loads that exceed the specified quantity (overloading) (Safitra et al,. 2019).

The road section will be studied on the Sidoarjo East Ring Road, which is located in Sidoarjo Regency. This road is 11 km long and has a 2/2 UD road type with a road width per lane ranging from 3.5 meters to 5 meters. This road section is categorized as a class I road, namely Primary Collector Road, with flexible pavement. The existence of this road is essential in the development of the Sidoarjo area, which is proven by the existence of industrial warehouse areas along this road, such as SIRIE Warehouse, DC Kawan Lama Warehouse, Safe n Lock Warehouse, and many other industrial warehouses in the Sidoarjo East Ring Road area (Salsabilla, 2023). With industrial warehousing activities in this area, various types of light to heavy vehicles pass through every day, which could be one reason why several roads in Sidoarjo's East Ring Road are damaged due to overloading.

The reason for this research is that Sidoarjo East Ring Road is located in an industrial warehouse area, which is the main route for heavy vehicles, such as trucks carrying oversized loads of goods. This condition affects the planned road pavement. This is proven by research conducted by (Wicaksana, 2023), showing that sections of the eastern ring road experienced severe damage. It can be seen from potholes and bumpy roads that disturb traffic users. Research conducted by (Muzakki et al., 2021) showed that the East Ring Road experienced road damage, which affected the service life of the road plan that had been determined.

Based on the events described above, this research needs to be carried out to determine the impact of vehicle overloading on the remaining planned life of the Sidoarjo East Ring Road using the AASHTO 1993 method, while the data search method uses a qualitative method by searching for primary data and secondary data in the form of past data. average daily traffic and data on vehicle loads crossing the Sidoarjo East Ring Road. With this, analysis of the planned age of the road will be an important thing to know the actual condition of the road. This will help design road pavement or road improvements to become more optimal.

Average daily traffic (LHR)

Average daily traffic (LHR) and average annual traffic (LHRT) are two types of traffic data important in transportation planning. LHR is the number of vehicles that pass an observation point during 24 hours, while LHRT is the number of vehicles that pass an observation point during 24 hours and is calculated throughout the year (Wibisono et al., 2019). There are two types of LHR data in this research. The first was obtained from authorized agencies or bodies in linear terms with the subject of this research, while the second was obtained from the results of surveys conducted by the researchers themselves.

Traffic growth

Traffic growth is the change in the number of vehicles passing on a road section from year to year during the life of the road plan (Sukirman, 2010). To determine the percentage of traffic growth (i) during the service life of a road plan using the AASHTO (1993) method, it can be obtained using equations 1 – 2 below.

$$\text{i} = \left(\frac{LHR_n}{LHR_0}\right)^{\frac{1}{n}} - 1 \quad (1)$$

$$\text{LHR}_\text{n} = LHR_n(1+i)^n \quad (2)$$

Overload Percentage

Overload occurs when a vehicle's axle load exceeds the maximum permitted limit, whether for passenger vehicles, goods cars, or unique vehicles that carry loads that exceed the maximum permitted limit, both in total weight (JBI) and maximum axle load (MSM). An overloaded vehicle can also be called an overloaded vehicle. This maximum limit is determined based on the carrying capacity of the road, type of vehicle, and type of load (Nuridha, 2020). The percentage of excess load during the service life of the road plan can be determined using the AASHTO (1993) method using equation 3 below.

$$\text{Overload Percentage} = \frac{Weighing\ Result - JBI}{JBI} \times 100\% \quad (3)$$

Vehicle Axle Load Equivalent Figure

Road damage, also known as Vehicle Damage Factor (VDF), is an essential factor determining pavement thickness. The heavier the vehicle, especially a truck-type vehicle, the greater the VDF value. This is caused by the more significant pressure exerted by heavy vehicles on the road surface (Nurkholis, 2018). To find out the equivalent figure for each vehicle axle during the service life of the road plan using the AASHTO (1993) method, it can be obtained using equations 4 – 7 below.

$$\text{Single Wheel Axle VDF} = \left[\frac{L}{5{,}40}\right]^4 \quad (4)$$

$$\text{Double Wheel Axle VDF} = \left[\frac{L}{8{,}16}\right]^4 \quad (5)$$

$$\text{Double Two Wheel Axle VDF} = \left[\frac{L}{13{,}76}\right]^4 \quad (6)$$

$$\text{Double Three Wheel Axle VDF} = \left[\frac{L}{18{,}45}\right]^4 \quad (7)$$

Load Repetitions During Plan Life (W_{18})

In AASHTO 1993, the traffic axle load was measured using standard axle path repetitions over the design life (**W_{18}**). Standard axle track repetition during the design life (**W_{18}**) is the cumulative amount of traffic axle load estimated to occur on the design lane during the design life. This estimate considers the direction distribution factor (DD) and the commercial vehicle lane distribution factor (DL). The lane distribution factor adjusts the cumulative load (ESAL) on roads with two or more lanes in one direction. Thus, the lane distribution factor considers the distribution of vehicle axle loads between different lanes to obtain a more accurate estimate of the cumulative load on the road pavement. To determine the cumulative standard axle load or standard axle trajectory repetitions during the design life (W18) during the service life of the road plan using the AASHTO method (1993) can be obtained using equations 8 – 9 below.

$$\text{ESAL} = \Sigma LHR \times VDF \quad (8)$$

$$W_{18} = \Sigma ESAL \times D_D \times D_L \times i \times 365 \quad (9)$$

Truck Factor (TF)

Overload can be measured by the truck factor (TF) value. The truck factor (TF) is the total value of ΣESAL, which determines whether a road is experiencing excessive load. If the truck factor (TF) value is greater than 1, then the road is damaged due to excessive load (Purwahono et al,. 2023). The truck factor (TF) value using the AASHTO (1993) method can be obtained using equation 10 below.

$$\text{Truck Factor (TF)} = \frac{\Sigma\ ESAL}{\Sigma\ LHR} \quad (10)$$

Decrease in Remaining Plan Life

Road pavement is designed to withstand traffic loads throughout its lifetime. Its design life value is proportional to or equal to the expected number of traffic load passes. When the number of load passes during the road's service life increases, the pavement's performance declines, which is indicated by a decrease in the design life. Equation 11 below can be used to determine the reduction in the remaining life of the plan (Remaining Life) using the AASHTO (1993) method.

$$\text{Remaining Life} = 100\left(1 - \left(\frac{N_p}{N_{1,5}}\right)\right) \quad (11)$$

2. Research Method

The location reviewed in this research is the Sidoarjo East Ring Road section (STA 2+200 – STA 7+600). The data analysis method used in this research uses the AASHTO (1993) Design of Pavement Structures guidelines published by the American Association of State Highway and Transportation Officials. The Microsoft Excel program assisted this data analysis.

The following are the calculation steps in this research:

1. Analyze Average Daily Traffic (LHR) data obtained from certain agencies or bodies and surveys that researchers have conducted.
2. Calculate the Traffic Growth percentage.
3. Calculate the percentage of Overload Load.
4. Recalculate the Vehicle Damage Factor (VDF) figures for each vehicle due to overload loads.
5. Calculate the standard W_{18} and overload W_{18} values using the equivalent numbers for each type of vehicle.
6. Calculate the percentage of remaining life due to vehicle load

3. Hasil dan Pembahasan

Traffic Growth

To calculate the magnitude of traffic growth that occurs on the Sidoarjo East Ring Road (STA 2+200 – STA 7+600) using secondary data in the form of average daily traffic (LHR) obtained from the Public Works Department of Highways and Water Resources Sidoarjo Regency in table 1 and traffic growth will be calculated using equation 1.1.

Table 1 Secondary LHR Data for Sidoarjo East Ring Road Vehicles

Vehicle Classification	Vehicle Class	Vehicle Axle	Average Daily Traffic (LHR)		
			2021	2022	2023
Sedan, Jeep, and Station Wagon	2	1.1	18123	20954	21856
Opelet, Pick Up, and Mini Bus	3	1.1	689	819	954
Micro Truck	4	1.2 L	705	974	976
Bus	5a	1.2	134	227	219
Big Bus	5b	1.2	167	303	287
2 Axle, 4 Wheel Truck	6a	1.2 H	1248	1187	2590
2 Axle, 6 Wheel Truck	6b	1.2 H	1032	1026	3571
3 Axle Truck	7a	1.22	1863	2647	2965
Towed Truck	7b	1.2 + 22	1569	1654	2648
Trailer Truck	7c	1.22 + 22	948	1461	1820
TOTAL			**26478**	**31252**	**37886**

Source: Sidoarjo Regency Public Works Department of Highways and Water Resources

The calculation step is to calculate the traffic growth from 2021 – 2022 and 2022 – 2023 on the total vehicles for each year. Then, the two values are averaged to obtain the traffic growth value (i) for 2021 – 2023. After calculating the actual traffic growth rate using equation 1.1, the results show that traffic growth (i) from 2021 to 2023 is 19.63%. Then, for the average daily traffic value (LHR), primary data is used by calculating the LHR directly in the field for 24 hours for 3 days in 1 week, then the results are averaged. The LHR produced by this survey is different from the LHR obtained from the Public Works Department of Highways and Water Resources of Sidoarjo Regency. What is different is that the axle configurations for heavy vehicles are more varied. The specifications for heavy vehicles are also differentiated between vehicles with a load and those without a load. The following is the average daily traffic value (LHR) of vehicles passing on the Sidoarjo East Ring Road (STA 2+200 – STA 7+600).

Table 2 Primary Data on LHR of Sidoarjo East Ring Road Vehicles in 2024

Vehicle Classification	Vehicle Class	Vehicle Axle	Average Daily Traffic (LHR)	
			Fill / Empty	2024
Sedan, Jeep, and Station Wagon	2	1.1	Standardy	5350
Opelet, Pick Up, and Mini Bus	3	1.1	Standard	1341
Micro Truck, Truck/Box and Tank Truck	4	1.1	Standard	1018
Bus	5a	1.2	Standard	7
Big Bus	5b	1.2	Standard	13
Truck/Box, 2 Axle Tank Truck	6a	1.2 L	Fill	1890
			Empty	528
Truck/Box, Dump Truck, Tank Truck/Trailer/Flat Deck Truck 2 Axles	6b	1.2 H	Fill	849
			Empty	262
	7a	1.22	Fill	805

Vehicle Classification	Vehicle Class	Vehicle Axle	Average Daily Traffic (LHR)	
			Fill / Empty	2024
Truck/Box, Tank Truck, Trailer, 3 Axis Dump Truck			Empty	282
Towed Truck	7b	1.2 + 22	Fill	71
			Empty	28
4 axle Truck Flat Deck Trailer	7c	1.2 – 22	Fill	471
			Empty	65
5 axle Truck Flat Deck Trailer	7c	1.2 – 222	Fill	123
			Empty	22
Semi-Trailer Trucks and 6 axle Trailer Trucks	7c	1.22 - 222	Fill	20
			Empty	7

Source: Field Survey Calculations

After obtaining the average daily traffic (LHR) from primary data by carrying out direct calculations in the field for 24 hours, to obtain the average daily traffic (LHR) in the years during the plan life, calculations are carried out using the traffic growth value (i), which has been calculated using LHR secondary data obtained from the Public Works Department of Highways and Water Resources of Sidoarjo Regency. To calculate LHR, use equation 1.2. The recapitulation results of vehicle volume growth for each group are shown in Table 3 below.

Table 3 Primary Data on LHR of Sidoarjo East Ring Road Vehicles

Vehicle Classification	Vehicle Class	Vehicle Axle	Average Daily Traffic (LHR)					
			Fill / Empty	2021	2022	2023	2024	2025
Sedan, Jeep, and Station Wagon	2	1.1	Standard	3125	3739	4472	5350	6401
Opelet, Pick Up, and Mini Bus	3	1.1	Standard	783	937	1121	1341	1605
Micro Truck, Truck/Box and Tank Truck	4	1.1	Standard	595	712	851	1018	1218
Bus	5a	1.2	Standard	4	5	6	7	8
Big Bus	5b	1.2	Standard	7	9	11	13	15
Truck/Box, 2 Axle Tank Truck	6a	1.2 L	Fill	1104	1321	1580	1890	2261
			Empty	309	369	442	528	632
Truck/Box, Dump Truck, Tank Truck/Trailer/Flat Deck Truck 2 Axles	6b	1.2 H	Fill	496	593	709	849	1015
			Empty	153	183	219	262	314
Truck/Box, Tank Truck, Trailer, 3 Axis Dump Truck	7a	1.22	Fill	470	562	673	805	963
			Empty	165	197	236	282	337
Towed Truck	7b	1.2 + 22	Fill	41	49	59	71	85
			Empty	16	19	23	28	33
4 axle Truck Flat Deck Trailer	7c	1.2 – 22	Fill	275	329	394	471	563
			Empty	38	45	54	65	77
5 axle Truck Flat Deck Trailer	7c	1.2 – 222	Fill	72	86	103	123	148
			Empty	13	15	18	22	26
Semi-Trailer Trucks and 6 axle Trailer Trucks	7c	1.22 - 222	Fill	12	14	17	20	24
			Empty	4	5	6	7	8

Source: Data Analysis

Overload Percentage

The overload percentage can be calculated using equation 1.3 with data from the East Java Class II Land Transportation Management Agency, listed in Table 5. The percentage distribution of overload is determined according to vehicle class based on the JBI, which Provincial Regulations have regulated East Java Number 4 Concerning Control of Overloading of Goods Transport, 2012.

Table 4 Vehicle Load Data In 2021 - 2023

Year	Group I				Group II			
	JBI 1500 Kg – 8000 Kg				JBI 8000 Kg – 14000 Kg			
	Σ Vehicles	Overloaded Vehicle	Load Average	JBI Average	Σ Vehicles	Overloaded Vehicle	Load Average	JBI Average
2021	45080	3915	73391,05	56427,41	3766	996	148334,6	117830,7
2022	36625	2500	69694,73	57256,62	4245	633	147089,6	118182,5
2023	44053	5046	68437,1	57802,51	5331	999	146234,7	119703,8
Year	**Group I**				**Group I**			
	JBI 14000 Kg – 21000 Kg				**JBI 1121000 Kg**			
	Σ Vehicles	**Overloaded Vehicle**	**Load Average**	**JBI Average**	**Σ Vehicles**	**Overloaded Vehicle**	**Load Average**	**JBI Average**
2021	1568	787	281732,6	235922	830	472	373322,3	283297,8
2022	1598	512	284353,5	234376,6	1043	344	348210	284473
2023	1963	651	295578,3	234121,8	1211	494	354497,5	282329,2

Source: East Java Class II Land Transportation Management Agency

Table 5 below shows each group's recapitulation results of excess loads, calculated using equation 1.3.

Table 5 Percentage of Overload for Each Vehicle Class

Year	Group 6a Vehicles	Group 6b Vehicles	Group 7a Vehicles	Group 7b Vehicles	Group 7c Vehicles
2021	30,06%	25,89%	19,42%	15,89%	15,89%
2022	21,72%	24,46%	21,32%	11,20%	11,20%
2023	18,40%	22,16%	26,25%	12,78%	12,78%
Average	23,39	24,17%	22,33%	13,29%	13,29%

Source: Data Analysis

In Table 4, apart from knowing the percentage of overload, you can also find the percentage of average daily traffic (LHR) overload that occurs on the road sections studied. The primary data in Table 3 is a survey of average daily traffic (LHR). For vehicles passing on the road section under study, there is a possibility of overloading of vehicles passing by; therefore, the percentage of average daily traffic (LHR) overload is obtained from secondary data in Table 4. To find the percentage of LHR overload, add all the LHR overloads recorded in Table 4 each year, divide by the number of LHR that occurred in one year, and then average the percentage results for the 3 years. The following Table 6 contains a recapitulation of the percentage of average daily traffic (LHR) that experiences overload.

Table 6 Average Daily Traffic Percentage (LHR) of Overloaded Vehicles

Year	LHR Overload					Total LHR Overlod/Year	Total LHR/Year	Total LHR/Year
	Vehicle Class							
	Group 6a Vehicles	Group 6b Vehicles	Group 7a Vehicles	Group 7b Vehicles	Group 7c Vehicles			
2021	3915	996	787	236	236	6170	51244	12,04%
2022	2500	633	512	172	172	3989	43511	9,17%
2023	5046	999	651	249	249	7193	52558	13,69%
TOTAL PERCENTAGE OF LHR OVERLOAD THAT OCCURRED								11,63%

Source: Data Analysis

After obtaining the percentage of average daily traffic (LHR) overload from Table 6 of 11.63%, the next step is to project the percentage of LHR overload on the survey LHR shown in Table 3. This percentage of LHR overload is only used to separate LHR standard and LHR overload in vehicle classes 6a, 6b, 7a, 7b, and 7c. For overloaded vehicles, LHR can be used to calculate W18 overload. The following is an example of calculating primary data LHR if divided by standard LHR and overload LHR based on the percentage obtained from Table 6.

LHR_{2021} Standar Group.6a (Standard) = LHR_{2021} Total Group.6a (Fill) – (LHR_{2021} Total Group.6a (Fill) × 11,63%)
= 1104 - (1104 × 11,63%)
= 976

LHR_{2021} Standar Group.6a (Overload) = LHR_{2021} Total Group.6a (Fill) – LHR_{2021} Standar Group.6a (Fill)
= 1104 – 976
= 128

To recapitulate standard LHR and overload LHR, the percentage of LHR overload obtained is divided based on the percentage shown in Table 7 below.

Table 7 Standard Vehicle LHR and Overloads That Occur in 2021 - 2025

Vehicle Class	Vehicle Axle	Fill / Empty	Average Daily Traffic (LHR)									
			2021		2022		2023		2024		2025	
			Standard	Overload	Standard	Overload	Standard	Overload	Standard	Overload	Standard	Overload
2	1.1	Standard	3125	0	3739	0	4472	0	5350	0	6401	0
3	1.1	Standard	783	0	937	0	1121	0	1341	0	1605	0
4	1.1	Standard	595	0	712	0	851	0	1018	0	1218	0
5a	1.2	Standard	4	0	5	0	6	0	7	0	8	0
5b	1.2	Standard	7	0	9	0	11	0	13	0	15	0
6a	1.2 L	Fill	976	58	1167	154	1396	184	1670	220	1998	263
		Empty	309	0	369	0	442	0	528	0	632	0
6b	1.2 H	Fill	438	55	524	69	627	83	750	99	897	118
		Empty	153	0	183	0	219	0	262	0	314	0
7a	1.22	Fill	416	55	497	65	595	78	711	94	851	112
		Empty	165	0	197	0	236	0	282	0	337	0
7b	1.2 + 22	Fill	36	5	44	6	52	7	62	8	75	10
		Empty	16	0	19	0	23	0	28	0	33	0
7c	1.2 – 22	Fill	243	32	291	38	348	46	416	55	498	66
		Empty	38	0	45	0	54	0	65	0	77	0
7c	1.2 – 222	Fill	64	8	76	10	91	12	109	14	130	17
		Empty	13	0	15	0	18	0	22	0	26	0
7c	1.22 - 222	Fill	10	1	13	2	15	2	18	2	21	3
		Empty	4	0	5	0	6	0	7	0	8	0

Source: Data Analysis

Standard W_{18} Calculation

The first condition to be compared in calculating W18 is W18 with the standard condition. For the standard W_{18}, the vehicle damage factor (VDF) and average daily traffic (LHR) values are used in conditions adjusted to field conditions, namely in standard conditions. The vehicle damage factor (VDF) value refers to the 2024 road pavement design manual. The W_{18} value will be calculated for 5 years according to the planned age of the road, namely 2021 to 2025. The equivalent single axle load (ESAL) calculation is carried out first, and it will be calculated for each vehicle axle configuration using equation 1.8. After obtaining the total ESAL value per year, the standard ESAL calculation is then carried out according to the planned age of the road using equation 1.9.

Table 8 below shows the standard ESAL and W18 values calculation for 2021.

Table 8 Recapitulation of the 2021 standard W_{18} Value Calculation

Vehicle Classification	Vehicle Class	Vehicle Axle	Fill / Empty	LHR 2021		VDF	ESAL 2021
				Standard	Overload		
Sedan, Jeep, and Station Wagon	2	1.1	Standard	3125	0	0,0005	1,56
Opelet, Pick Up, and Mini Bus	3	1.1	Standard	783	0	0,0007	0,55
Micro Truck, Truck/Box and Tank Truck	4	1.1	Standard	595	0	0,0286	17,01
Bus	5a	1.2	Standard	4	0	2,6	10,63
Big Bus	5b	1.2	Standard	7	0	2,6	19,24
Truck/Box, 2 Axle Tank Truck	6a	1.2 L	Fill	976	58	0,3	292,66
			Empty	309	0	0,1	30,86
Truck/Box, Dump Truck, Tank Truck/Trailer/Flat Deck Truck 2 Axles	6b	1.2 H	Fill	438	55	1	438,04
			Empty	153	0	0,7	107,26
Truck/Box, Tank Truck, Trailer, 3 Axis Dump Truck	7a	1.22	Fill	416	55	10,1	4196,58
			Empty	165	0	2,7	444,73
Towed Truck	7b	1.2 + 22	Fill	36	5	2,2	80,24
			Empty	16	0	1,4	22,62
4 axle Truck Flat Deck Trailer	7c	1.2 – 22	Fill	243	32	8,5	2066,42
			Empty	38	0	5,2	196,41
5 axle Truck Flat Deck Trailer	7c	1.2 – 222	Fill	64	8	3,3	210,07
			Empty	13	0	2,5	31,64
Semi-Trailer Trucks and 6-axle Trailer Trucks	7c	1.22 - 222	Fill	10	1	4,7	49,33
			Empty	4	0	3,2	13,08
TOTAL ESAL Standard							8228,93
W_{18} Standard 2021							471678,71

Source: Data Analysis

Standard W18 calculations during the plan life are carried out in the same way as in subsequent years, so a recapitulation of calculations is obtained as follows.

Table 9 Recapitulation of ESAL Values and Standard W_{18} Values During the Plan Life

Year	Σ ESAL Standard	W_{18} Standard	Σ W_{18} Standard
2021	8228,93	471678,71	471678,71
2022	9844,26	564269,25	1035947,96
2023	11476,05	657802,51	1693750,47
2024	14088,46	807544,73	2501295,20
2025	16854,02	966065,76	3467360,95

Source: Data Analysis

W_{18} Overload Calculation

The second condition to be compared in calculating W_{18} is W_{18} with an overload condition. The initial stage to determine the W_{18} overload value is to calculate the VDF overload value first. The data used for VDF overload calculations is vehicle load data obtained from the East Java Class II Land Transportation Management Agency, which is listed in Table 4 using equations 1.4 – 1.7. To calculate VDF overload, each vehicle axle configuration is calculated, and the percentage of overload for each vehicle is still used per vehicle class. For adjustments to vehicle classes and axle configurations, refer to the 2024 pavement design manual. The equivalent single axle load (ESAL) calculation is carried out first, and it will be calculated for each vehicle axle configuration using equation 1.8. After obtaining the total ESAL value per year, the standard ESAL calculation is then carried out according to the planned age of the road using equation 1.9.

Table 8 below shows the overload ESAL and W18 values calculation for 2021.

Table 10 Recapitulation of the 2021 overload W_{18} Value Calculation

Vehicle Class	Vehicle Axle	Fill / Empty	LHR 2021		VDF		ESAL 2021
			Standard	Overload	Standard	Overload	
2	1.1	Standard	3125	0	0,0005	0,0005	1,56
3	1.1	Standard	783	0	0,0007	0,0007	0,55
4	1.1	Standard	595	0	0,0286	0,0286	17,01
5a	1.2	Standard	4	0	2,6	2,6	10,63
5b	1.2	Standard	7	0	2,6	2,6	19,24
6a	1.2 L	Fill	976	58	0,3	0,64	375,32
		Empty	309	0	0,1	0,004	30,86
6b	1.2 H	Fill	438	55	1	15,26	1317,99
		Empty	153	0	0,7	0,04	107,26
7a	1.22	Fill	416	55	10,1	11,74	4838,61
		Empty	165	0	2,7	0,02	444,73
7b	1.2 + 22	Fill	36	5	2,2	8,04	118,83
		Empty	16	0	1,4	0,01	22,62
7c	1.2 – 22	Fill	243	32	8,5	25,59	2885,36
		Empty	38	0	5,2	0,08	196,41
7c	1.2 – 222	Fill	64	8	3,3	22,66	399,95
		Empty	13	0	2,5	0,11	31,64
7c	1.22 - 222	Fill	10	1	4,7	29,97	90,78
		Empty	4	0	3,2	0,18	13,08
TOTAL ESAL Overload							10922,38
W_{18} Overload 2021							626066,63

Source: Data Analysis

Overload W_{18} calculations during the plan life are carried out in the same way as in subsequent years, so a recapitulation of calculations is obtained as follows.

Table 11 Recapitulation of ESAL Values and Overload W_{18} Values During the Plan Life

Year	Σ ESAL Overload	W_{18} Overload	Σ W_{18} Overload
2021	10922,38	626066,63	626066,63
2022	13066,45	748963,50	1375030,13
2023	15631,39	895985,04	2271015,17
2024	18699,83	1071866,90	3342882,08
2025	22370,61	1282274,38	4625156,45

Source: Data Analysis

Standard Truck Factor (TF)

The first condition that will be calculated in the truck factor (TF) calculation is the truck factor (TF) with standard conditions. The standard truck factor (TF) value can be calculated using equation 1.10. The following is a standard truck factor (TF) calculation.

Is known:

Σ ESAL Standard 5 years = 60491,72

Σ LHR 5 years (N) = 56753

Nilai TF Standard $= \frac{\Sigma\ ESAL\ Standard}{N}$

$= \frac{60491,72}{56753}$

$= 1,07$

Overload Truck Factor (TF)

The second situation to calculate the truck factor (TF) is the truck factor (TF) in an overloaded state. The truck factor (TF) overload value can be calculated using equation 1.10. The following is the calculation of truck factor (TF) overload.

Is known:

Σ ESAL Overload 5 years = 80690,66
Σ LHR 5 years (N) = 56753

Nilai TF Overload $= \frac{\Sigma\ ESAL\ Overload}{N}$

$= \frac{80690,66}{56753}$

$= 1,42$

The standard truck factor (TF) value is 1.07, and the overload truck factor (TF) is 1.42. From the results obtained from calculating the truck factor (TF) value >1, it can be stated that the Sidoarjo East Ring Road section (STA 2+200 – STA 7+600) with a road design life of 5 years is experiencing overloading due to heavy vehicles.

Standard Remaining Life (RL)

The first condition calculated in the remaining life (RL) calculation is the remaining life (RL) with the standard condition. The standard remaining life (RL) value can be calculated using equation 2.11, with the standard ΣW18 value for each year during the plan life divided by the standard ΣW_{18} value in the last year. Table 12 contains a recapitulation of standard remaining life values.

Table 12 Remaining Life Standard Value

Year	N_P	$N_{1,5}$	RL (%)
2021	471678,71	3467360,95	86,40%
2022	1035947,96	3467360,95	70,12%
2023	1693750,47	3467360,95	51,15%
2024	2501295,20	3467360,95	27,86%
2025	3467360,95	3467360,95	0,00%

Source: Data Analysis

Overload Remaining Life (RL)

The second condition calculated in the remaining life (RL) calculation is the remaining life (RL) with an overload condition. The remaining life (RL) overload value can be calculated using equation 2.10, with the ΣW18 overload value for each year during the plan life divided by the standard ΣW_{18} value in the last year. Table 13 contains a recapitulation of standard remaining life values.

Table 13 Remaining Life Overload Value

Year	N_P	$N_{1,5}$	RL (%)
2021	626066,63	3467360,95	81,94%
2022	1375030,13	3467360,95	60,34%
2023	2271015,17	3467360,95	34,50%
2024	3342882,08	3467360,95	3,59%
2025	4625156,45	3467360,95	-33,39%

Source: Data Analysis

Based on Table 11 and Table 12, the comparison of standard remaining life values and remaining life overload values can be presented in graphical form as shown in Figure 1 below:

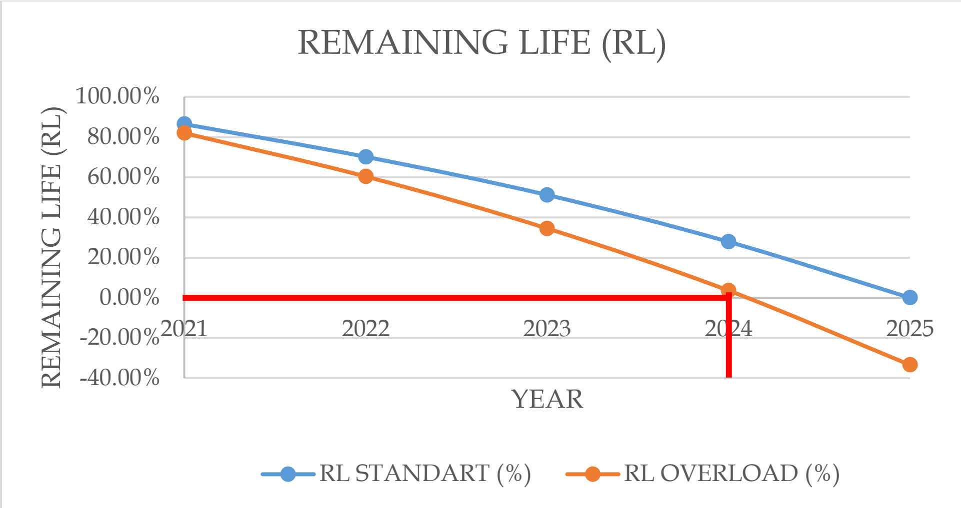

Figure 1. Comparison Chart of Standard and Overload Remaining Life (RL) Values

Source: Data Analysis

From Table 12 for remaining life (RL) overload, it can be seen that the percentage of 0% remaining life (RL) occurs between the fourth and fifth years or between 2024 and 2025. The remaining life of the plan can be calculated using the following interpolation method.

It is known from Table 13:

December 2024	NP_{2024}	= 1	= 3342882,08
	NP_{2025}	= 13	= 4625156,45
	$N_{1,5}$	= X	= 347360,45

$$\frac{x-1}{13-x} = \frac{347360{,}45 - 3342882{,}08}{4625156{,}45 - 347360{,}45}$$

$$\frac{x-1}{13-x} = 0{,}107513701$$

$$X - 1 = 1{,}397678113 - 0{,}107513701\,X$$

$$1{,}107513701\,X = 2{,}397678113$$

$$X = \frac{2{,}397678113}{1{,}107513701}$$

$$= 2{,}165 / 12$$

$$= 0{,}18 \approx 0{,}2 = \text{2nd Month}$$

The plan life value when the plan life percentage value reaches 0% is:

Plan Life Value = 4 year + X month
= 4 year + 0,2 month
= 4,2068 year

Based on the calculations above, it is obtained that there is a decrease in the planned life for overload conditions, namely:

Reducing The Plan Age = 5 – 4,2
= 0,8
= 8%

4. Simpulan

Based on the data analysis carried out in this research, it can be concluded that the truck factor value in overload conditions is 1.42, so it can be stated that the truck factor value is > one on the Sidoarjo East Ring Road section (STA 2+200 – STA 7+600) experiencing overloading due to heavy vehicles. The remaining life percentage value due to LHR and excessive load is 8%, and in overload conditions, interpolation is carried out. The results show that there is a reduction in the design life of the road on the Sidoarjo East Ring Road section (STA 2+200 – STA 7+600) by 0.9 years from the age 5-year plan, where the planned life of the road will end in 2025, the first month since the road opened in 2021.

5. Daftar Pustaka

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