Analysis of Pavement Condition Index (PCI) and Solution Alternative Of Pavement Damage Handling Due to Freight Transportation Overloading
(Case Study: National Road Section West Sumatra Border-Jambi City)

Wahid WAHYUDI [a], Putra Abu SANDRA [b], Agus Taufik MULYONO [c]

[a]) *Student of Doctoral Programme at Brawijaya University, Malang, Indonesia*
Email :wahiiidwah@yahoo.com
[b]) *Student of M Master* of *Transport Systems* & *Engineering, University of Gadjah Mada, Yogyakarta*
Email :asputra.ugm@gmail.com
c) Professor at Civil Engineering, University of Gadjah Mada, Yogyakarta, Indonesia
Email :atm8002@yahoo.com

Abstract: Pavement damage faster than design life becomes an important issue that remains unsettled until now. One of the main causes of damage to pavement is freight vehicles overload. This aims of this research is to identify the effect of overloading in reducing pavement index. The method used in this research are the calculation of pavement damage factor and pavement condition index, along with finding a correlations between pavement condition index and an average load of each types of freight vehicles. This result of the research indicate that pavement condition index on the national road West Sumatra Border to Jambi City has reached the terminal pavement condition index (IPt) in the 4th year whereas it designed for 10 years. It means the deficit design life is about 60%. The best alternative for pavement repair adjusted to the current conditions are subgrade improvement and replacement of pavement type become rigid pavement.

Keywords: Alternative Solution, Damage Factor, Overloading, Pavement Damage, Pavement Condition Index.

1. INTRODUCTION

Road infrastructure is one of transport infrastructure that plays an important role in improving the accessibility of area and population mobility, also has the advantage of other transportation infrastructure that can reach the "door to door service". Some research shows that road infrastructure plays a vital role in economic growth, so the precision of infrastructure investment's supply is very important. Evidence suggests that the greater the investment funds for building roads is not directly proportional to the increase in its steadiness, as a matter of fact there's a decrease in the level of service. Pavement damage faster than the design life remains unsettled until now. This phenomenon suggests that there are external factors beyond the authority of the organizers that can directly stimulate the rate of structural damage.

Factors causing structural damage to the road pavement can be clasified in two dimensions, namely: (i) internal causes, especially those related to the implementation of pavement quality during construction, and (ii) external causes, especially related to road surface water drainage system and freight vehicles overload (Mulyono, 2007). dominant causes'identification of these aspects can be done by observing the condition of the field, ranging from traffic conditions, economic potential, basic soil types, drainage conditions and the condition of the existing road damage . Pavement conditions on national roads West Sumatra Border to Jambi City in good category is 50.8%, 21.2% in moderate condition; 16.8% in light damage condition and 11.1% severely damaged (Directorate General of Highways, 2012).

The dominant type of pavement damage in National road West Sumatra Border to Jambi City is rutting which based on thickness theory of Brown and Brunton (1987) stated that the cause of rutting are deformation stimulated by load in long time. This study aimed to explore the correlation of freight vehicles overloadand decreasing of servicing index pavement and then find the alternative solution.

2. METHODOLOGY

Figure 1 presents the concept of thinking in analyzing the effect of freight vehicles overloadagainst pavement index reduction and alternative solution to handle the road pavement damage. Steps in conducting this study begins with identifying the condition of the road pavement and conduct pavement damage literature related study. Then performed the primary data collection and secondary data, such as: (a) type of freight transportation; (b) traffic counting survey, (c) the data overloading; and (d) history of road pavement. Several step analysis are: (a) damage factor analysis; (b) cumulative ESAL analysis, (c) servicing index analysis; and (d) find an alternative solution to handle the road pavement damage. Indicator of pavement damage due to overloading expressed in rutting area (former groove wheel vehicle overload) exceeds 60% of the total area of damage is measured in waterlogged conditions (Gedafa, 2006).

2.1. Survey Location

The research location is on national road Batas Provinsi Suamtera Barat-Jambi City which can be seen in **Figure 2**. In more detail the location of the survey consisted of several roads based on Public Works Ministerial Decree 14/2009 as listed in **Table 1.**

Table 1. List of road study sites

No	Link	Link Name	Road Long (km)
1	018	JLN. ARAH KE MUARA TEBO / PATTIMURA (MU	2,91
2	019	BTS. KAB. TEBO/KAB. BUNGO - MUARA TEBO	18,96
3	020	MUARA TEBO - SEI BENGKAL	50,78
4	021	SEI BENGKAL - BTS. KAB. BATANGHARI/KAB.	15,07
5	022	BTS. KAB. BATANGHARI/KAB. TEBO - MUARA T	52,47
6	023	MUARA TEMBESI - BTS. KOTA MUARA BULIAN	10,65
7	023	JLN. MUARA TEMBESI (MUARA BULIAN)	4,53
8	024	JLN. GAJAH MADA (MUARA BULIAN)	5,14
9	026	SP. MANDALO DARAT - BTS. KOTA JAMBI / SP	3,26
		Total Road Length (Km)	163,75

2.2. Conducting Survey

Survey conducted in this research consisted of primary data and secondary data survey. Primary survey consists of a traffic counting survey, pavement damage condition surveys and load of freight vehicles surveys. Survey of secondary data consist of collecting pavement history and load freight vehicles each year which pass this road.

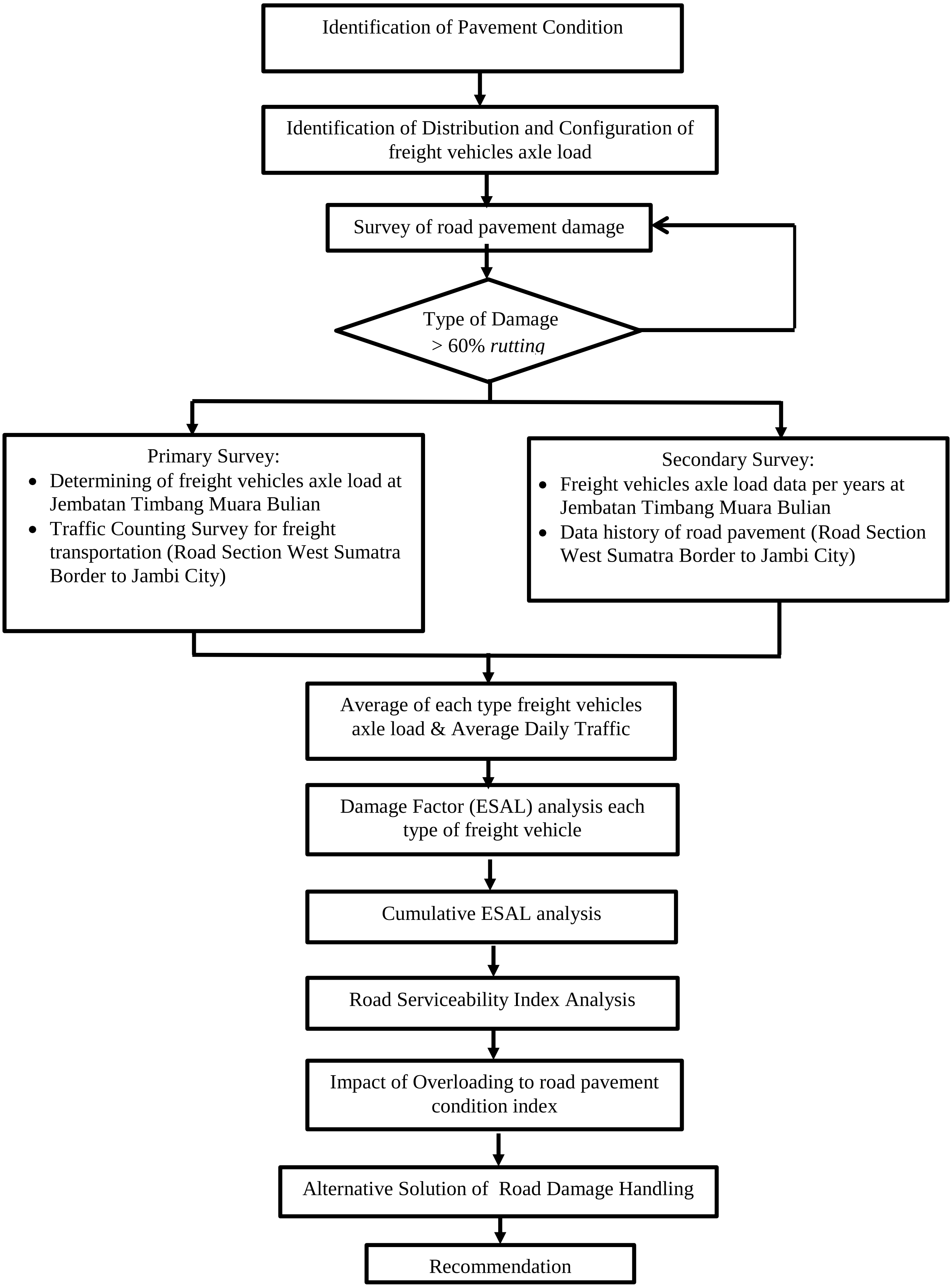


Figure 1. The research concept of analysis pavement condition index and alternative solution of road pavement distress handling due to overloading freight transportation.

3. LITERATUR REVIEW

3.1. Konfigurasi Beban Sumbu Kendaraan Berat Angkutan Barang

According on Technical Guidance from Public Works Ministry of Indonesia No. 19 Year 2004, comodities freight vehicle are classified into some type based on the number of axis and vehicle's wheel as shown in **Figure 2.**

1. **Type 6A** (Truck 1,2 L)
   Single Axis Double Wheel; Load distribution: sb-1(3Ton), sb-2(5Ton)
2. **Type 6B** (Truck 1,2 H)
   Single Axis Double Wheel; Load distribustion: sb-1(3Ton), sb-2(5Ton)
3. **Type 7A** (Truck 1,2,2)
   Tandem Axis Double Wheel; Load distribution: sb-1(5Ton), sb-2(9Ton), sb-3(9Ton)
4. **Type 7B-1** (Truck 1,2+2,2)
   Tandem Axis Double Wheel; Load distribution: sb-1(5Ton), sb-2(10Ton), sb-3(10Ton), sb-4(10Ton)
5. **Type 7B-2** (Truck 1,2,2+2,2)
   Tandem Axis Double Wheel; Load distribution: sb-1(5Ton), sb-2(9Ton), sb-3(9Ton), sb-4(10Ton), sb-5(10Ton)

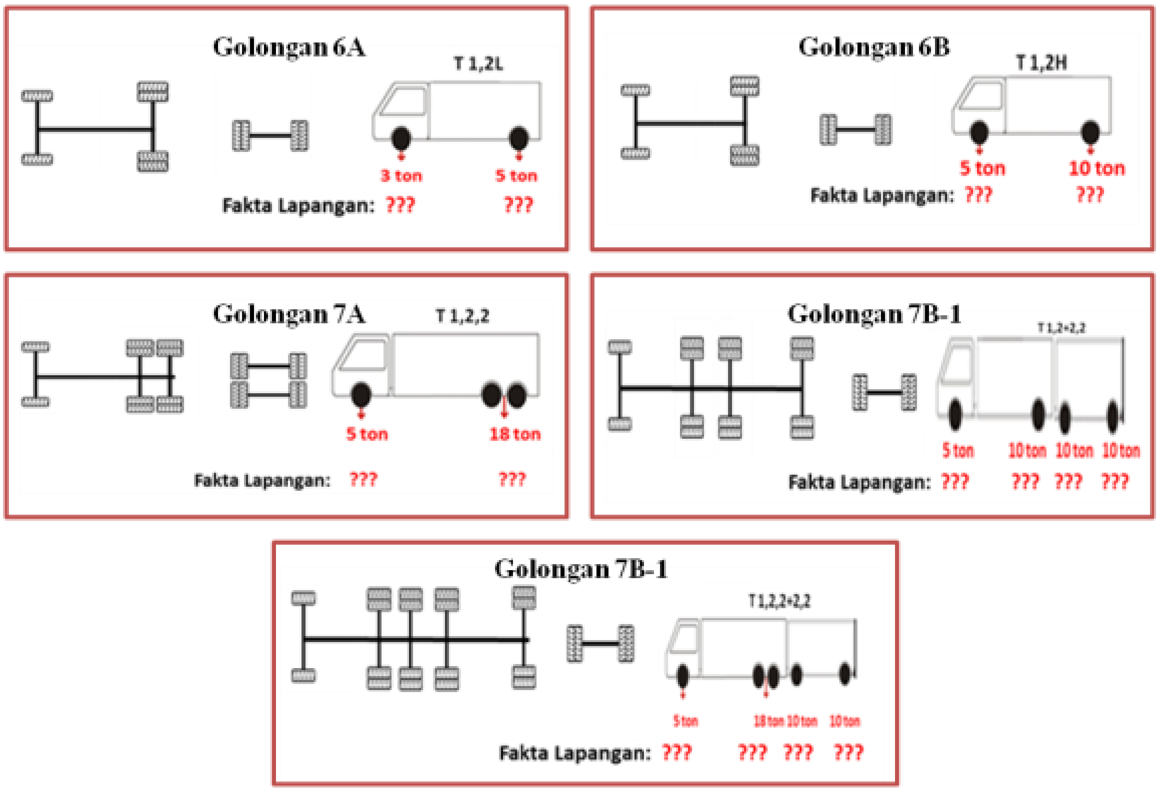


Figure 2. Clasification of freight vehicle based on the number of acis and vehicle's wheel

3.2. Damage Factor of Road Pavement

Vehicle Damage Factor analysis are classified **according to** type of axle vehicle, **ie single and dual axis** (Directorate General of Highways, PTT-01-2002-B), as shown in Equation (1), Equation (2) and Equation (3).

Single axle (maximum axle load of 8 ton or 10 ton):

$$\text{ESAL} = \left[\frac{\text{axle load (kg)}}{\text{8160 kg}}\right]^4 \quad (1)$$

Tandem axle (maximum axle load of 15 ton or 18 ton):

$$\text{ESAL} = 0.086\left[\frac{\text{axle load (kg)}}{\text{8160 kg}}\right]^4 \quad (2)$$

Tridem axle (maximum axle load of 20 ton or 25 ton):

$$\text{ESAL} = 0.026\left[\frac{\text{axle load (kg)}}{\text{8160 kg}}\right]^4 \quad (3)$$

3.3. Cumulative Damage Factor of Road Pavement (Cumulative ESAL)

After analysis of damage factor, nest is calculating cumulative ESAL all types of freight vehicles using Equation (4):

$$W18 = \sum_{N1}^{Nn} LHRxVDFx365 \quad \text{.......... (4)}$$

Where:

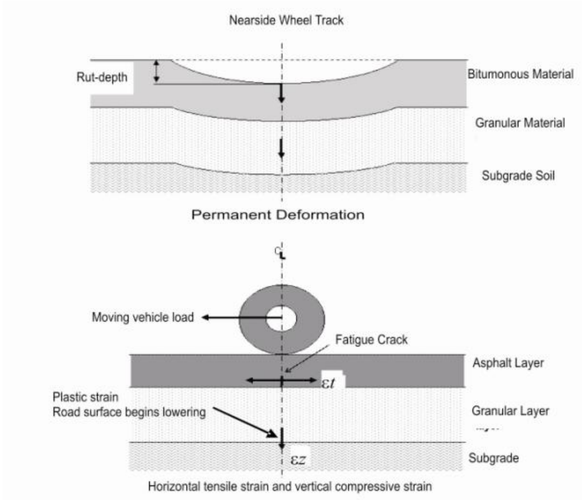
W18 = Value Cumulative Damage Factor

LHR = Average daily Traffic

VDF = Vehicle damage factor

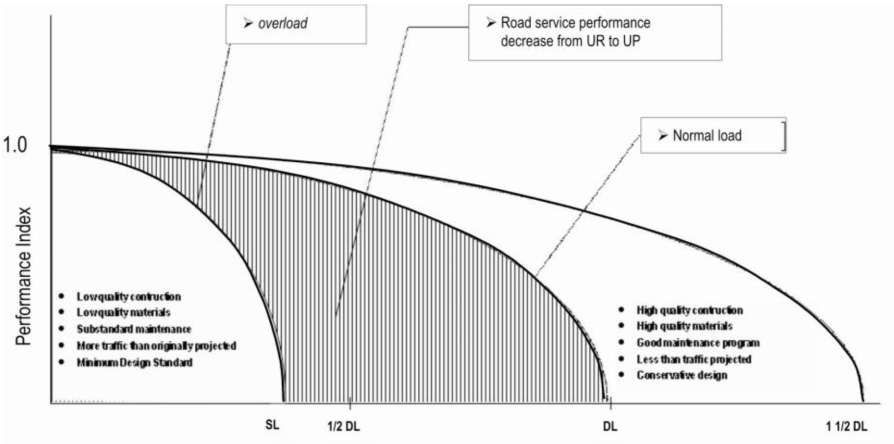
3.4. Pavement Servicing Index

Brown & Brunton’s pavement thickness theory (1987) concluded that vehicle load supported by road pavement would result in two critical strains, i.e. (1) horizontal tensile strain (εt) occurred on the lower side of road surface; and (2) vertical compressive strain (εz) occurred on the upper side of subgrade. **Figure 3** illustrates the two kinds of strains. If the existing tensile strain is larger than the inner horizontal tensile strain, pavement cracking will occur. Furthermore, if the vertical compressive strain is larger than the permissible ground vertical strain, plastic strain will occur that subsequently will initiate rutting and rut-depth. The plastic strain subsequently will cause permanent deformation on the pavement. The plastic strain is accelerated by long loading time due to slow speed of overloading freight vehicles. Based on the theory, Mulyono (2007) had stated that the greater the load repetition of overloading vehicles during the design lifetime and indicator used is Serviceability index (see **Figure 4**).



Source: Brown & Brunton (1987)

Figure 3. Illustration of horizontal tensile strain and vertical compressive strain as well as road surface deformation on flexible pavement due to vehicle load repetition



Source: Directorate General of Regional Infrastructure, Ministry of Settlement and Regional Infrastructure (2001) in Mulyono (2007)

Figure 4. Illustration of road pavement service quality decrease rate resulted from overloading vehicle

Analysis of the current value of the pavement condition index using equations derived from the equation of flexible pavement thickness calculation can be seen in Equation (5) to Equation (9).

$$LogW18 = 9{,}36\log(SN+1) - 0{,}20 + \left(\frac{Gt}{(0{,}40 + (1094/(SN+1)^{5{,}19}}\right) + \log\left(\frac{1}{R}\right) + 0{,}372(Si - 3{,}0) \quad (5)$$

$$Gt = Log\left(\frac{IPo - IPt}{IPo - 1{,}5}\right) \quad (6)$$

$$Log\left(\frac{IPo-IPt}{IPo-1,5}\right)=\left(\log W18-9,36\log(SN+1)+0,20-\log\left(\frac{1}{R}\right)-0,372(Si-3,0)\right)\left(0,40+(1094/(SN+1)^{5,19}\right)$$

.... (7)

$$Z=\left(\log W18-9,36\log(SN+1)+0,20-\log\left(\frac{1}{R}\right)-0,372(Si-3,0)\right)\left(0,40+(1094/(SN+1)^{5,19}\right)$$

..............(8)

IPt (tahun ke-n) = IPo- {(IPo-1,5)(10^Z)……………………….……………………..….............(9)

4. RESULT

4.1. Result of Damage Factor Analysis

Damage factor analysis is largely determined by the value of the load (P) transport weight and value of the cumulative equivalent standard axle load which is determined by average daily traffic (LHR) obtained by traffic counting. The compilation of survey result consisting of LHR values, load average, and load freight vehicles can be seen in **Table 2.**

Table 2. Data of average daily traffic, load of freight vehicles

No	Freight Vehicles Type	AADT		JBI	Load in the field
		(Vehicle/ day)	(%)	(Ton)	(Ton)
1	Truck 2 As sedang (Type6A)	192	31,41%	8,3	13,92
2	Truck 2 As Berat (Type6B)	252	41,23%	18,2	24,86
3	Truck 3 As (Type7A)	161	26,37%	25	29,73
4	Truck 4 As (Type7B)	3	0,49%	26,2	37,5
5	Truck 5 As (Type7C1)	2	0,32%	31,4	38,5
6	Truck 6 As (Type7C2)	1	0,16%	42	45
	Total	611	100%		

Variable needed in camage factor analysis are data of load of freght vehicles. The result of damage factor analysis can be seen in **Table 3.** The example of calculation to find damae factor are:

(1) Truck 2 as (Type6A)

EA = $\left(\frac{4,73}{8,16}\right)^4+\left(\frac{9,19}{8,16}\right)^4=01,7200\_ESAL$

(2) Truck 2 as Heavy Vehicle (Type 6B)

$$EA = \left(\frac{8,45}{8,16}\right)^4 + \left(\frac{16,4}{8,16}\right)^4 = 17,4975\_ESAL$$

(3) Truck 3 as (Type 7A)

$$EA = \left(\frac{7,43}{8,16}\right)^4 + 0,086\left(\frac{22,3}{8,16}\right)^4 = 56,4408\_ESAL$$

(4) Truck 4 as (Type 7B)

$$EA = \left(\frac{5,68}{8,16}\right)^4 + 0,086\left(\frac{11,4}{8,16}\right)^4 + 0,026\left(\frac{20,5}{8,16}\right)^4 = 3,4319\_ESAL$$

(5) Truck 4 as (Type 7C1)

$$EA = \left(\frac{5,35}{8,16}\right)^4 + 0,086\left(\frac{10,7}{8,16}\right)^4 + 0,026\left(\frac{22,5}{8,16}\right)^4 = 9,8973\_ESAL$$

(6) Truck 4 as (Type 7C2)

$$EA = \left(\frac{5,63}{8,16}\right)^4 + 0,086\left(\frac{17,1}{8,16}\right)^4 + 0,026\left(\frac{30,9}{8,16}\right)^4 = 12,8354\_ESAL$$

Tabel 3. Result of Damage Factor analysis

Jenis Kendaraan	Berat Rata-rata Total (ton)	AS 1		AS 2		AS 3		Total Esal
		P	Esal	P	Esal	P	Esal	
Truck 2 as MV (Type 6A)	13,92	4,73	0,1132	9,19	1,607			1,7200
Truck 2 as HV (Type 6 B)	24,86	8,45	1,1512	16,4	16,35			17,4975
Truck 3 as (Type 7 A)	29,73	7,43	0,6883	22,3	55,75			56,4408
Truck 4 as (Type 7 B)	37,5	5,68	0,2351	11,4	0,323	20,5	2,0925	2,6511
Truck 5 as (Type 7 C1)	38,5	5,35	0,1844	10,7	0,254	22,5	3,0411	3,4792
Trailer (Type 7 C2)	45	5,63	0,2258	17,1	1,659	30,9	10,951	12,8354

Results of damage factor analysis for each class of freight vehicles indicate that vehicle class 7A (3 axle trucks) with a value of damage factor of 56.4408 most contribute to pavement damage and then followed by 6 class B truck (2 axle, heavy truck) while the vehicle types that has the smallest destructive force is vehicle class 6A (2 axle, medium trucks).

The value of vehicle damage factor is counted in to calculate the cumulative damage factor (cumulative ESAL). Cumulative ESAL calculation results can be seen in **Table 4.** Cumulative ESAL were also calculated for the years 2013, 2014, 2019 and 2025 which depend on traffic growth. Traffic growth values were obtained from the comparison between number of freight vehicles in 2012 with number of freight vehicles in 2011. Cumulative ESAL calculation results in 2013, 2014, 2019 and 2025 is shown in **Table 5**. Based on the formula used that Cumulative ESAL value is directly proportional to the traffic volume. Therefore, the greatest cumulative ESAL is in 2025 amounted to 19,241,831.69 _ESAL.

Tabel 4. Vehicle Damage Factor of freight vehicles on national roadruas West Sumatra Border to Jambi City (years 2012)

Jenis Kendaraan	LHR (1)	Esal (total) per jenis kendaraan (2)	Total Esal (1) X (2)
Truck 2 as sedang(6A)	192	1,72	60268,80
Truck 2 as besar (6 B)	252	17,4975	4023550,13
Truck 3 as (7 A)	161	56,4408	8291859,03
Truck 4 as (7 B)	3	2,6511	1451,48
Truck 5 as (7 C1)	2	3,4792	1269,91
Trailer (7 C2)	1	12,8354	2342,46
Total			12.380.741,80

Tabel 5. Vehicle Damage Factor of freight vehicles on national roadruas West Sumatra Border to Jambi City (years 2013, 2014 2019,2025)

Jenis Kendaraan	VDF 2013 (ESAL)	VDF 2014 (ESAL)	VDF 2019 (ESAL)	VDF 2025 (ESAL)
Truck 2 as sedang(6A)	62.197,40	66.241,73	77.540	93.671,68
Truck 2 as besar (6 B)	4.152.303,73	4.422.303,13	5.176.628	6.253.529,14
Truck 3 as (7 A)	8.557.198,52	9.113.621,80	10.668.159	12.887.470,14
Truck 4 as (7 B)	1.451,48	1.451,48	1.699	2.052,52
Truck 5 as (7 C1)	1.269,91	1.269,91	1.486	1.795,76
Trailer (7 C2)	2.342,46	2.342,46	2.742	3.312,45
Total Kumulatif ESAL	12.776.763,50	13.607.230,49	15.928.256,03	19.241.831,69

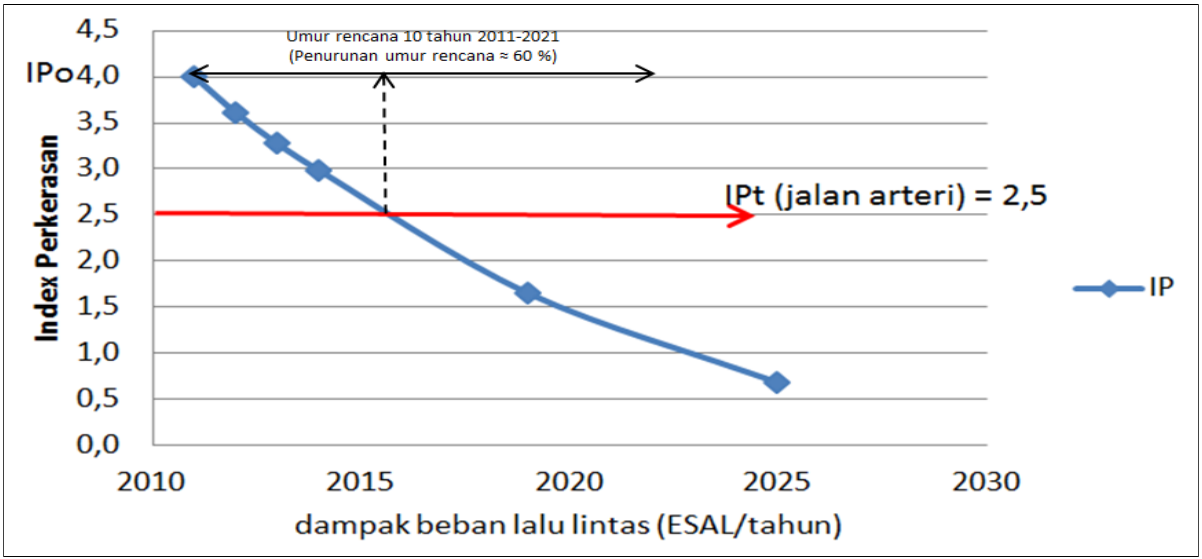
4.2. Evaluation of Pavement condition index (Present Serveciability Rating)

Evaluation of the existing pavement condition index can be conducted by using Equation (9). Data input to evaluate existing pavement condition index are: initial pavement index (IPo) , CBR value, traffic volume, pavement thickness and vehicles damage factor (VDF). The result of analysis can be seen in **Table 6.** Based on the analysis of pavement condition index in 2012, 2013, 2014, 2019, and 2025 it is indicate theat the decline in value of index on value of pavement index varies each year. At the end of 2012 the value of IPT by 3.6066; at hte end of 2013 amounted to 3.2705; at the en of 2014 amounted to 2.9800; at the end of 2019 amounted to 1.6504 and by the end of 2025 amounted to 0.6793.

Decreasing pavement condition index from 4,0 (Ipo) to 2.5 (Standard IPt for national roads) only takes as long as 4 (four) years, while the pavement condition index is designed at 10 years to achieve 2,5. If no action is taken such as pavement overlay or freihgt route management, the pavement condition index value will be 1,5 at the age of 7 (seven) years. It means that the pavement can be used anymore. Pavement condition index values from 2011 to 2025 can be seen as in **Figure 5.**

Tabel 6. The result of pavement condition index analysis

Component		Result	Unit	Component		Result	Unit
W18	=	2.380.742	ESAL	SN	=	6,16	Structural Number
IPo (2011)	=	4,0	-	Log W18	=	7,092746667	ESAL
D1	=	2,5	inci	Z	=	-0,80309832	-
D2	=	7,0	inci	IP (2012)	=	3,6066	-
D3	=	22,0	inci	Delta IP	=	0,3934	-
a1	=	0,42	-	IP (2013)	=	3,2705	-
a2	=	0,29	-	IP (2014)	=	2,9800	-
a3	=	0,14	-	IP (2019)	=	1,6504	-
Si (CBR)	=	6,0	%	IP (2025)	=	0,6793	-
R	=	1,0	-				



Gambar 5. Reducing the value of pavement condition index because overloading by freight vehicle

The evaluation of analysis result is in accordance with the field conditions. Therefore, this can be stated that the axle load of freight vehicles on national road in section West Sumatra Border to Jambi City significantly contribute because the indicate type with the dominant type of problem is rutting, a trace flow vehicles which carrying loads which the weight occurs repeatedly. Theoretically, pavement index in 2012 due to the influence of axle load freight weight is equal to 0.3934 if the index pavement at the end of 2011 is assumed at 4.0. In year 2013, there is a decrease in the value of this index to the number of 0.3361 and also in year 2014 for about 0.2964 value. This is only requires time for 4 (four) years to decreasing the pavement harden index value from 4.0 to 2.5. Based on the thickness of flexibility pavement design guidelines (Pt T-01-2002-B), the clusters of an index value of pavement is: Surface index value at the end of life design (IPt) for arterial roads based on planning guidelines thickness flexibility pavement (Pt T-01-2002- B) is at the rate of 2.5. The results of the final surface value analysis design life index (IPT) for national roads from Padang to the state line of Jambi province, which planned to be reached to the time of 10 years with a value of 2.5 IPT decreased by 60% due to pavement index value of 2.5 has been achieved at the fourth year as a result for the imposition of freight vehicles traffic.

The reduction in pavement life design for about 60% is theoretically very influenced by the ESAL value which is a combination between the contribution of heavy loads or axle loads and freight vehicles traffic volume, while the field conditions there are other factors such as the condition of the sub grade differences for each location, pavement thickness is carried out in the field do not fit with the plan, road drainage conditions and the other factors. Although there are other factors, the theoretical analysis shows that the surface and road pavement has suffered a significant simply damage caused by the contribution of heavy loads and traffic volumes in excess of the maximum limit, or usually called by overload. The conditions that occur on national roads West Sumatra Province state line requires a solution for both aspects of the planning, and operational aspects. The planning aspect solution is to determine the type of harden and the harden thickness that can accommodate the loads that occur in the field instead of the expense incurred ideally without any calculation against overload, while the solution from the operational aspects can be implemented by the application of discipline to set the freight vehicles that crosses the road. Evaluation of pavement condition at the national road from West Sumatra Border to Jambi City shows that the dominant damage type occurs is rutting, deformation and Potholes, as can be seen clearly in Figure 6.

4.3. Alternative Solutions of Pavement Improvement

Type of damage that occurs in the field and the amount of ESAL values obtained from the analysis can be in determining the initial stimulation of alternative solutions to treating damaged pavement sections West Sumatra Province state line to Jambi city. Based on the field conditions, there are 3 (three) alternative solutions for the improvement of these roads with overlay, sub grade improvement and improving the quality of material, and sub grade repairs and replacement of pavement types pavement flexibility to rigid pavement.

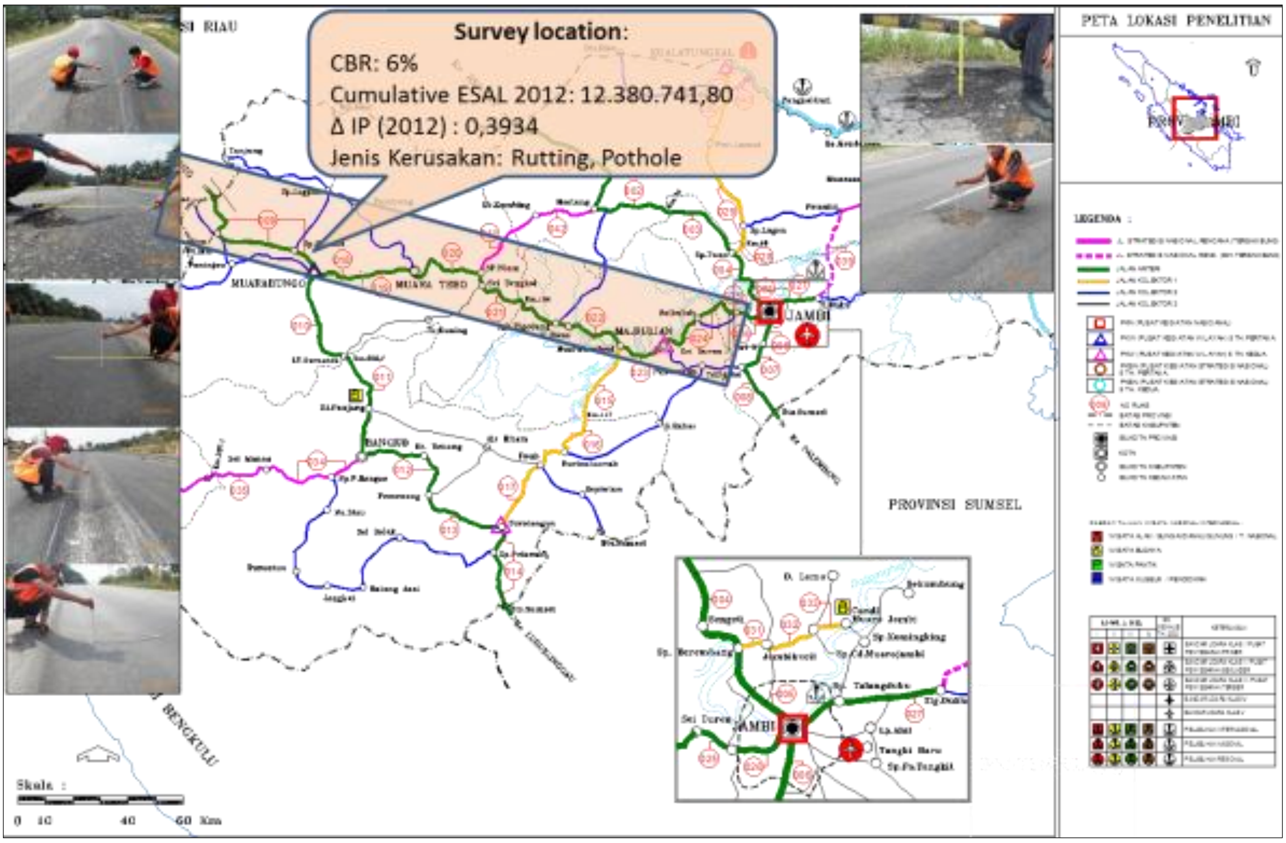


Figure 6. Map of survey sites and types of pavement damage

4.3.1. Roads Overlay

Solutions to the damage of pavement road structure which often applied to the field is performing a routine maintenance every year is overlay the pavement. The analysis conducted on improved roads with overlay on road section West Sumatra Border to Jambi City with the assumption of that road to be overlaid when the IPt value reaches or less than 2.5. The analysis and assessment on road repair with overlay solutions can be observed in Table 7 and Figure 7. Based on Figure 7, can be observed that the value of index of national road pavement West Sumatra state line limit province of Jambi city which is assumed to have initial pavement index value (IPo) of 4.0 in 2011 fell to 2.9800 by the end of the year 2014, and amounted to 2.4993 at the end of 2015. The border of IPT's value for arterial roads to the number of 2.5 has been exceeded before the end of 2015 so as shown in Figure 6:15 pavement index value increased to 4.0 in 2015. The pavement thickness simulated to be improving by 2.5-inch overlay with pavement thickness shrinks assumptions for 4 years to the number of 0.5 inches. Therefore, the pavement thickness increased about 2.0 inches in 2016.

Decreasing value of pavement index from year to year during the period of the first overlay is almost equal to the decrease in value of pavement index in the period of 2011 through 2015. The decreasing of pavement index value in 2016 is equal to 0.4295; amounted to 0.3328 in 2017; amounted to 0.2875 in 2018 and 0.4759 for the year 2019. The overlay result of the first phase also decreased from the pavement index of 4.0 to 2.5 in about the same time with a decrease in the time period 2011-2015 is about 4 years (see Figure 7). The same thing happened to a decrease in the index value for the pavement overlay of the second phase, as in Figure 7 can be seen that an increase in the value of the pavement index of 2.5 to be at 4.0 because of the overlay. Besides an increase in value of the index in the overlay condition at year 2019, there is also an addition of pavement thickness with simulation overlay thickness is the same as in 2015 at 2.5 inches but assuming depreciation pavement thickness of 1.0 inches. Pavement thickness depreciation in the period 2016-2019 compared to 2012-2015 with greater consideration ESAL value greater load and higher traffic volumes.

Table 7. The result analysis for pavement index of national road section West Sumatera Border to Jambi city with overlay

Year	IP	Delta IP	Year	IP	Delta IP
2011	4,0	-	2018	2,9502	0,2875
2012	3,6066	0,3934	2019	2,4743	0,4759
2013	3,2705	0,3361	2019	4,0000	-
2014	2,9800	0,2904	2020	3,5312	0,4687
2015	2,4993	0,4807	2021	3,2021	0,3291
2015	4,0000	-	2022	2,9177	0,2844
2016	3,5705	0,4295	2023	2,4470	0,4707
2017	3,2378	0,3328			

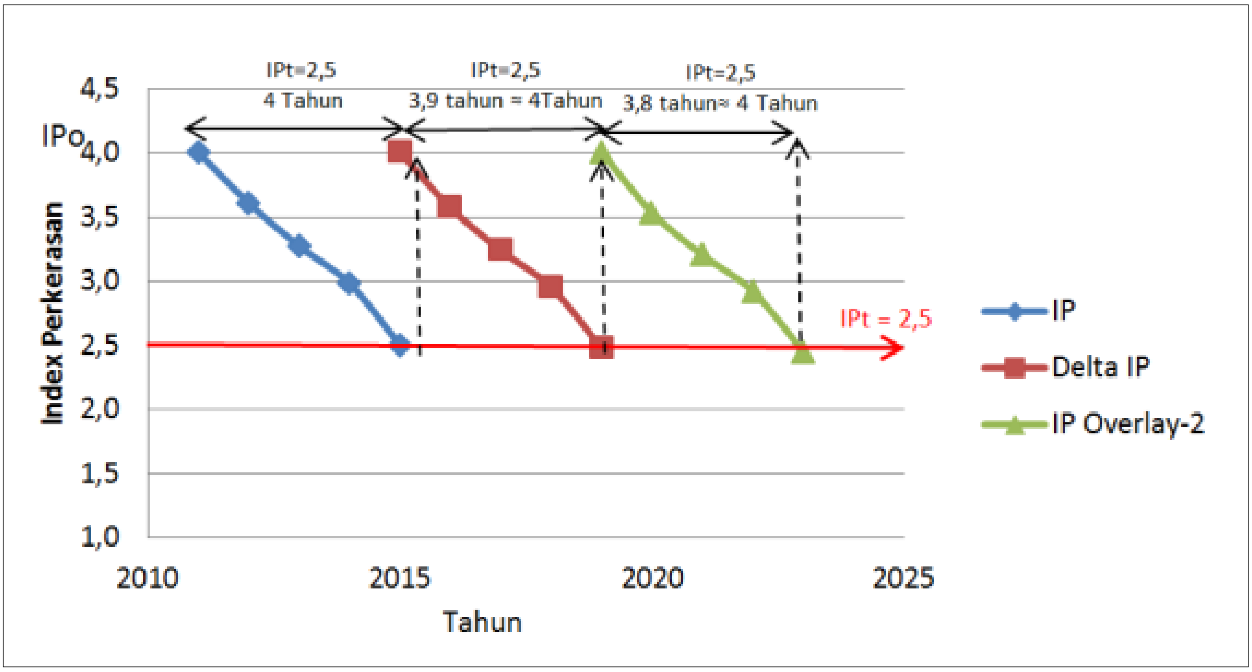


Figure 7. Pavement condition index value of road section West Sumatra Border to Jambi city with overlay

Decreasing of pavement index value in 2020 is amounting to 0.4687; amounting to 0.3291 in 2021; amounted to 0.2844 in 2022; amounted to 0.4707 in 2023. Since at the end of 2022 the pavement index value of national road West Sumatra Border to Jambi City is 2.2844 and 2.4470 for the year 2023, so the overlay should be done in mid-2023. Based on the analysis, time required by national road West Sumatra Border to Jambi City for overlay maximum of 4 years.

4.3.2. Sub grade and Quality Materials Improvement

Analysis of alternative solutions to the sub grade improvement and quality material improvement using the index value as an indicator of the condition of the pavement and flexible pavement design equation Aashtoo (1993) which adopted in pavement design guidelines (Pt T-01-2002-B). Alternative solutions to the sub grade improvement can effects the change in the value of CBR that become larger and increase the value of the coefficient of the relative strength of pavement materials (a1, a2, and a3). Analysis of alternative solutions to the sub grade improvement and quality material improvement used is also performed on each road segment focus of study.

In the year 2011 structure pavement repair planning and overlay analysis assumed CBR value of 6% to obtain the value of the carrying capacity of the land on certain conditions (Si) of 5.0 (five) while the quality of the material is assumed to use the asphalt concrete material (a1 = 0.42), cement treated base (a2), and aggregate base (a3 = 0.14) which is a material with the best quality so that the only difference in the analysis on the basis of soil conditions. Sub grade conditions are improved by compaction to obtain the CBR value of 10% and the soil bearing capacity values obtained in certain circumstances of 10.0.

The analysis and assessment of alternative solutions sub grade improvement and quality material improvement on roads segment from West Sumatra Border to Jambi City can be seen in Table 8 and Figure 8. Based on Figure 8 can be observed that the value of pavement index of West Sumatra Border to Jambi City which is assumed to have initial pavement index value (IPo) of 4.0 in the year 2011 decreased to 2.9800 by the end of the year 2014 and amounted to 2.4993 at the end of 2015. IPt thresholds for arterial roads of 2.5 has been exceeded before the end of 2015 so as shown in Figure 8, an increase in value of the index pavement to 4.0 by the end of 2015 because of improving sub grade dan overlay the pavement. The decreasing in value of the pavement index from year to year after the sub grade repairs to be smaller. A decrease pavement index value in 2016 is equal to 0.2762; amounted to 0.2782 in 2017; amounted to 0.2093 in 2018, amounting to 0.2300 in 2019, 0.2194 for 2020, amounting to 0.2057 in 2021 and amounted to 0.2018 in 2022. Based on analysis, the time which is required to do overlay for national roads on West Sumatera Border to Jambi city is about 6 years (see Figure 8). Alternative solutions to the sub grade improvement in segment West Sumatera province state line limits to Jambi city cost quite expensive, but can save time overlay requirement for 2 years.

Table 8. The result of analysis pavement index section of West Sumatra Province boundaries to Jambi city national road with basic soil improvement (do something)

Year	IP	Delta IP	Year	IP	Delta IP
2011	4	-	2016	3.7238	0.2762
2012	3.6066	0.3934	2017	3.4336	0.2782
2013	3.2705	0.3361	2018	3.2008	0.2093
2014	2.98	0.2905	2019	2.9407	0.2300
2014	2.4993	0.4807	2020	2.7201	0.2194
2015	4.0000	-	2021	2.5132	0.2057
			2022	2.3114	0.2018

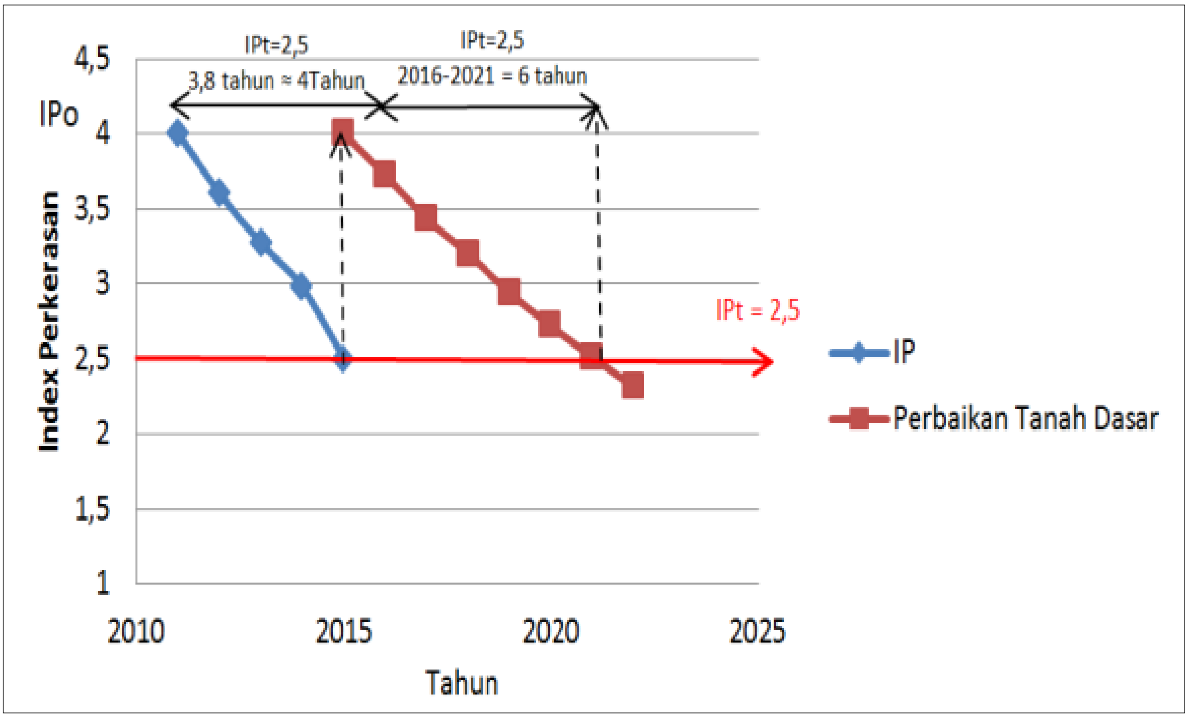


Figure 8. The condition of pavement index value on the section of West Sumatra Province boundaries to Jambi city with sub grade improvement

4.3.3. Sub grade improvement and conversion of flexible pavement types to become a rigid pavement

Analysis of alternative solutions to the sub grade improvement and conversion of flexible pavement types become rigid pavement performed on each road segment focus of study. The results of field surveys conducted showed that there are several roads that have been using this type of rigid pavement but the overall percentage of rigid pavement on roads focus of study is still below 20% of the total length of roads so that the study focused on the type of pavement on the previous calculation of each section road is assumed to use a flexible pavement and the equations used only aashtoo equation for flexible pavements.

The analysis and assessment of alternative solutions sub grade improvement and conversion of flexible pavement types become rigid pavement on roads West Sumatra Province Border to Jambi City can be seen in Table 9 and Figure 9. Based on Figure 9 and Table 9 by converting a flexible pavement and rigid pavement pavement thickness assuming beta 10.0 inches or 25.4 cm, then the national roads West Sumatra Province boundaries to Jambi city require pavement overlay after the age of 7 years. The decrease in value of the index on national road West Sumatra Border to Jambi city is equal to 0.3112 in 2016; 0.2558 in 2017; 0.2071 in 2018; 0.1921 in 2019; 0.1845 in 2020; 0.772 in 2021, and 0.1715 in 2022.

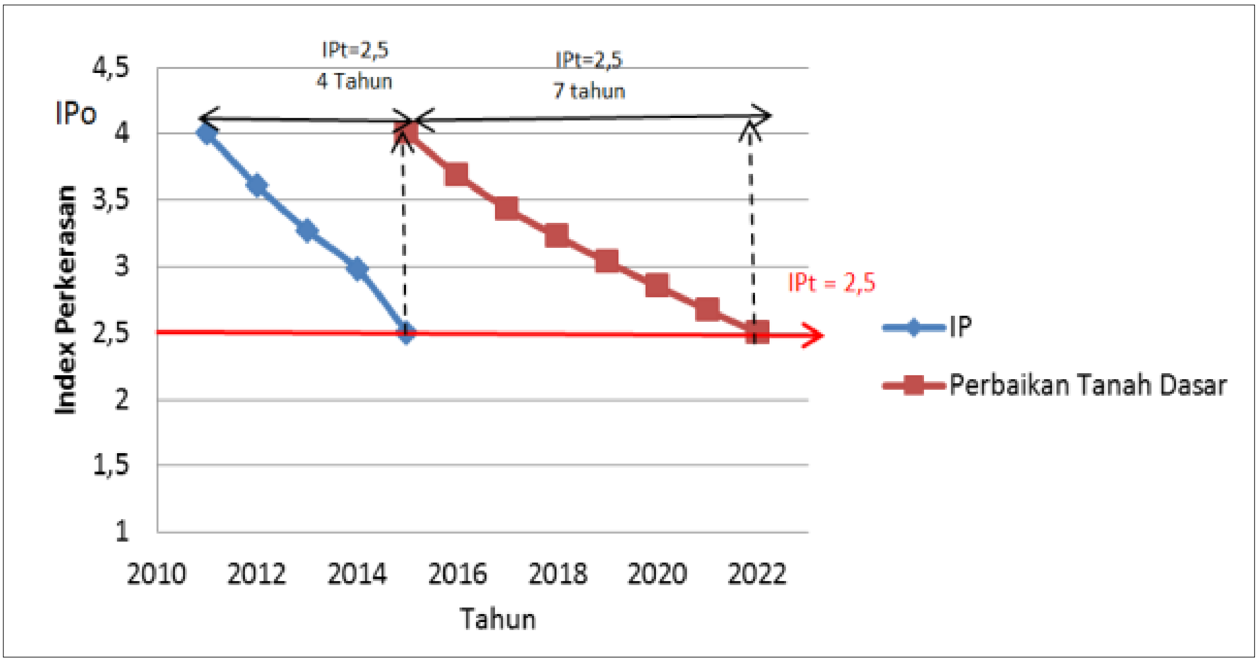


Figure 9. The condition of pavement condition index value segment of West Sumatra Province Border to Jambi City with flexible pavement conversion into rigid pavement

Table 9. The result pavement index analysis section of West Sumatra Province Border to Jambi City with flexible pavement conversion into rigid pavement

Year	IP	Delta IP	Year	IP	Delta IP
2011	4.0	-	2016	3.6888	0.3112
2012	3.6066	0.3934	2017	3.4330	0.2558
2013	3.2705	0.3361	2018	3.2259	0.2071
2014	2.9800	0.2904	2019	3.0338	0.1921
2015	2.4993	0.4807	2020	2.8493	0.1845
2015	4.0000	-	2021	2.6721	0.1772
			2022	2.5006	0.1715

5. CONCLUSION

The analysis showed that the effect of freight vehicles overload to the value of the pavement index national road West Sumatra Border to Jambi city is decreasing in value of the terminal pavement index (IPt) from 4.0 to 2.5 only need 4 years. Whereas, it is designed for 10 years. If there is no improvement from this decline untill 9 years, the road will be severely damage and difficult to be passedbecause the pavement index less than 1,5. Analysis of the three types of alternative pavement damage handling solutions above, it can be concluded that the national road sections Wes Sumatra Border to Jambi City should be done sub grade improvement and replacement of pavement types of flexible pavements become rigid pavement.

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