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An Analysis of Loss Cost Due To Road Clock on the Road Construction (Rigid Pavement) Reviewed by the Use of Oil Fuel

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Abstract: This research was conducted against the background of road improvements on the road section in Ambeng-Ambeng Watangrejo village, Duduksampeyan, Gresik Regency along ± 1.5 km which caused traffic jams due to narrowing of road capacity. Vehicle travel time is very influential on the level of fuel consumption, because the longer the travel time experienced by a vehicle, the more fuel consumption will be. The length of congestion will affect the temperature of the vehicle engine which will get hotter which will eventually affect fuel consumption which will be more wasteful and this will result in a considerable material loss value. This study used quantitative research methods and direct surveys. The primary data used in this study included vehicle travel time and vehicle volume. The types of vehicles analyzed are several types of cars fueled by Pertalite. Then the data is processed using references from the Indonesian Road Capacity Guidelines (PKJI 2014) and LAPI-ITB. The results showed that the loss of private cars (KR) fueled by the Pertalite type was quite large, namely on Monday, the total loss during the 6 hours of research amounted to Rp.13.575.702 with an average hourly loss of Rp.2.262.617. As for Tuesday, the total loss during the 6 hours of research amounted to Rp.15.942.725 with an average hourly loss of Rp.2.657.121. And for Wednesday, the total loss during the 6 hours of research amounted to Rp.12.182.256 with an average hourly loss of Rp.2.030.376.

Keywords: congestion, financial loss, fuel consumption

INTRODUCTION

Research Background

The continuous population growth every year has led to an increasing demand for transportation facilities in Indonesia. The transportation sector plays a vital role in human activities. In the current context, with the development of civilization and the increase in individual income, the financial ability to own a personal vehicle according to one's needs has also increased. However, as the number of transportation facilities increases, it is necessary to be supported by adequate infrastructure facilities to facilitate movement from one place to another. Therefore, periodic maintenance and construction of roads are needed to support the smooth flow of transportation across the region.

However, when performing road maintenance or construction, it is inevitable that consequences such as increased traffic density will occur, resulting in traffic congestion. The most noticeable impact on the Indonesian population at present is the increase in the use of gasoline. During traffic congestion, vehicle engines work longer, resulting in drivers having to spend additional costs for fuel. Moreover, in 2022, the Indonesian government officially increased the prices of all types of fuel in Indonesia. A road located in Duduksampeyan District, Gresik Regency, which is currently undergoing road construction, has caused traffic congestion during normal hours and complete paralysis during peak hours, forcing another section of the road to be converted into a two-way lane.

With these reasons, this research aims to determine the amount of losses in Pertalite gasoline due to congestion on the Duduksampeyan road section, Gresik Regency, along approximately 1.5 km on Monday, Tuesday, and Wednesday. This information can be used as a basis for determining policies to address congestion during road construction.

Research Problem Boundaries

To refine the research outcomes, the following problem limitations need to be established:

1. The value of losses due to congestion will only focus on the consumption of Pertalite gasoline.
2. The examination will not consider the cylinder capacity and year of manufacture of vehicles.
3. This study will not investigate motorcycles as their travel time or congestion level is lower compared to cars.

LITERATURE REVIEW

Road Capacity

According to Indonesian Road Capacity Guidelines (PKJI 2014), road capacity is defined as the maximum flow of vehicles that can pass through a road segment under specific conditions at a given time (hourly). Road capacity can be calculated using the following equation:

$$C = C_O \times FC_{LJ} \times FC_{PA} \times FC_{HS} \quad (1)$$

Where:
C_O = Base capacity (skr/hour).
FC_{LJ} = Adjustment factor for road width.
FC_{PA} = Adjustment factor for median barrier.
FC_{HS} = Adjustment factors for lateral resistance and road shoulder.

Traffic Volume

Volume is the number of vehicles that pass through a road section within a unit of time (hour). Traffic volume consists of the movement of individual drivers and vehicles that interact within and around the road section. (Tamin, 2008).

Light Vehicle Unit

According to PKJI (2014), the definition of Light Vehicle Unit (Skr) is a unit of traffic flow where different vehicle flows have been converted into equivalent light vehicle flows using Light Vehicle Equivalents (Ekr). Ekr is defined as a factor that indicates the difference in vehicle types compared to light vehicles in terms of their impact on the speed of light vehicles in traffic flow (for passenger cars and similar light vehicles, emp = 1.0).

Traffic Speed

Journey Speed is the effective speed of a vehicle moving between two locations, calculated by dividing the distance between the two locations by the time taken by the vehicle to travel between them, including all periods of traffic delay. (Atiya, A. E, 2019).

$$\text{Journey Speed} = \frac{Long\ Journey}{Travel\ Time} \text{ (km/hour)} \quad (2)$$

Degree of Saturation

The degree of saturation is used as the main factor in determining the performance level of intersections and road segments. The value of the degree of saturation (D_S) indicates whether the road segment has a capacity problem or not (Muchlisin & Lubis, 2016). According to PKJI (2014), the equation to determine the degree of saturation is as follows:

$$D_S = \frac{Q}{C} \quad (3)$$

Where:
Q = Vehicle volume (skr/hour)
C = Road capacity (skr/hour)

Fuel Oil Consumption

(Muhamad Isnaeni in Khafidz, 2015) In conducting research related to fuel consumption calculations, the fuel consumption formula proposed by LAPI-ITB, which has been converted into passenger car units, is used, resulting in the following equation:

$$F1 = A + BV + CV2 \quad (4)$$
$$F2 = EV2 \quad (5)$$
$$F3 = D \quad (6)$$

Where:
F1 = Fuel consumption at constant speed (liter/100 smp-km)
F2 = Fuel consumption during acceleration (liter/smp)
F3 = Fuel consumption during idle (liter/smp-hour)
V = Vehicle speed (km/hour)
$A = 170.10^{-1}$ $C = 490.10^{-5}$ $E = 770.10^{-8}$
$B = -455.10^{-3}$ $D = 140.10^{-2}$

And to calculate the fuel loss caused by traffic congestion, it can be calculated using the following formula:

Fuel loss = vehicle volume x fuel consumption rate (Liters/km) x fuel price (7)

METHODOLOGY

The research design used in this study is quantitative research and direct survey. Quantitative research is a method in which the results are presented in the form of descriptions using numbers and statistics, while the direct survey method aims to enable the researcher to accurately and precisely depict the situation at the location.

Research Time and Location

The research and data collection were conducted on the Duduksampeyan road segment in Gresik Regency, specifically in Ambeng Ambeng Watangrejo village, spanning approximately 1.5 km. The survey was conducted for 3 days, specifically on Monday, Tuesday, and Wednesday during peak hours, which are in the morning from 07:00 AM to 09:00 AM (WIB), in the afternoon from 12:00 PM to 02:00 PM (WIB), and in the evening from 04:00 PM to 06:00 PM (WIB).

Data Collection Techniques

The primary data collection was conducted through direct surveys at the research location. This survey activity required 8 surveyors, each assigned with specific tasks to collect the necessary primary data.

The primary data sought included vehicle volume and travel time of vehicles passing through the Duduksampeyan road segment.

1. Finding Vehicle Volume
   To determine the vehicle volume, 4 individuals were involved. Two individuals were assigned to calculate the volume of three types of vehicles traveling from Lamongan to Surabaya, while the other two individuals calculated the volume of three types of vehicles traveling from Surabaya to

Lamongan. The vehicles to be counted included private vehicles, passenger vehicles, and trucks. The vehicle volume was counted using mini tally counters when the vehicles crossed predetermined boundaries.

2. Finding Travel Time of Vehicles
   To determine the travel time of vehicles, 4 individuals were involved. Two individuals were responsible for calculating the travel time of vehicles traveling from Lamongan to Surabaya, while the other two individuals calculated the travel time of vehicles traveling from Surabaya to Lamongan. The survey technique used to determine the travel time of vehicles was License Plate Observation, where two individuals were positioned on the western side at the beginning of the road construction, and the other two individuals were positioned on the eastern side at the end of the road construction. They recorded the time when the vehicles crossed the designated start and finish lines.

Flow Chart

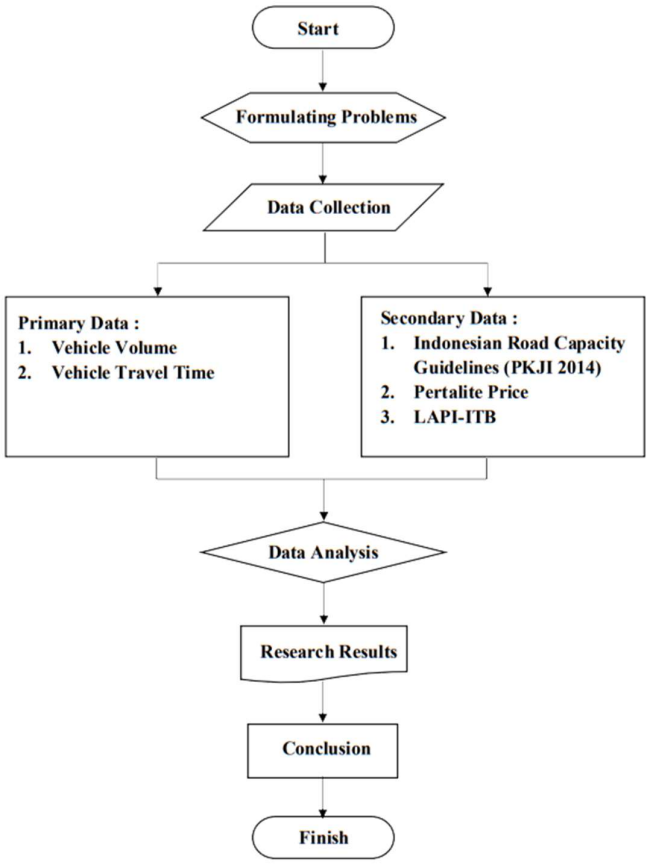

Image 1. Flow Chart

RESULTS AND DISCUSSION

Road Capacity Analysis

From the data obtained in the field, the values were collected and inserted into equation (1) as follows:

C = 1700 x 1,00 x 1,00 x 0,88 = 1496

The road capacity at the survey location is 1496 skr/lane. Therefore, the road capacity at the survey location for 2 lanes is 2992.

Analysis of Vehicle Travel Time

Vehicle travel time data (table 1) was obtained by recording the vehicle license plate number and the time when the vehicle crossed the designated start and finish lines. The travel time is calculated using the following formula:

Travel time = time of crossing finish line - time of crossing start line (8)

Table 1. Vehicle Travel Time

Time	Monday		Tuesday		Wednesday	
	License Plate	Travel Time	License Plate	Travel Time	License Plate	Travel Time
07:00-08:00	S1253BN	00:27:08	S1454LR	00:08:59	S1905LA	00:18:22
	S1160HD	00:13:08	B2807XIM	00:25:37	N9451BJ	00:23:28
08:00-09:00	S1795LO	00:12:11	AG1983WU	00:12:11	W1487BD	00:04:48
	L1959DE	00:07:06	N991RJ	00:16:22	L1281KB	00:13:03
12:00-13:00	K9828RD	00:05:42	S1989XY	00:10:40	W1322TV	00:10:07
	W1227XY	00:05:53	W1392AE	00:13:29	W1992TT	00:10:37
13:00-14:00	L1593RB	00:06:40	B1785WZA	00:04:25	L1674QF	00:08:20
	S1079GG	00:05:39	S1563LM	00:09:57	L73CK	00:08:36
16:00-17:00	N1057NC	00:04:16	W1542BT	00:04:34	L1959QR	00:13:36
	K9250FN	00:06:26	S1078BK	00:18:21	W1866AR	00:08:55
17:00-18:00	L1794FK	00:05:56	S1536JN	00:12:51	L1868GP	00:09:12
	S1893LC	00:05:33	W1436H	00:19:55	B18HFI	00:10:17

Source: Survey Results, 2023

Vehicle Speed Analysis

The vehicle speed (table 2) is obtained from equation (2), where the length of the road traveled is 1.5 km.

Table 2. Vehicle Speed

Time	Monday		Tuesday		Wednesday	
	Travel Time	Speed (km/hour)	Travel Time	Speed (km/hour)	Travel Time	Speed (km/hour)
07:00-08:00	00:27:08	3,32	00:08:59	10,58	00:18:22	4,96
	00:13:08	6,85	00:25:37	3,52	00:23:28	4,62
08:00-09:00	00:12:11	7,39	00:12:11	12,41	00:04:48	18,75
	00:07:06	12,68	00:16:22	5,85	00:13:03	6,91
12:00-13:00	00:05:42	17,40	00:10:40	12,13	00:10:07	10,33
	00:05:53	15,33	00:13:29	6,68	00:10:37	8,47
13:00-14:00	00:06:40	13,81	00:04:25	20,38	00:08:20	10,88
	00:05:39	15,96	00:09:57	9,80	00:08:36	10,52
16:00-17:00	00:04:16	21,32	00:04:34	21,43	00:13:36	6,62
	00:06:26	14,65	00:18:21	4,91	00:08:55	10,27

17:00-18:00	00:05:56	15,20	00:12:51	7,23	00:09:12	9,84
	00:05:33	16,64	00:19:55	4,67	00:10:17	9,20

Source: The Calculation Results (*Microsoft Excel*), 2023

Time Delay Analysis

The delay time as seen in table3, can be calculated using the formula:

Delay time (minutes) = travel time in congestion - travel time without congestion (9)

Where the travel time for a 1.5 km road segment for light vehicles without congestion is 1.54 minutes. To convert the delay time to seconds/pcu, it can be calculated using the formula:

Delay time (Seconds/smp) = delay time (Minutes) x 60 (60 seconds) x ekr (10)

Where ekr for Light Vehicles according to PKJI 2014 is 1,00.

Table 3: Time Delay

Time	Monday		Tuesday		Wednesday	
	Time Delay (minute)	Time Delay (sec./smp)	Time Delay (minute)	Time Delay (sec./smp)	Time Delay (minute)	Time Delay (sec./smp)
07:00-08:00	26,26	1576	7,05	423	16,68	1001
	11,54	692	23,83	1430	21,74	1304
08:00-09:00	10,57	634	10,57	634	2,94	176
	5,52	331	14,68	881	11,49	689
12:00-13:00	3,88	233	8,86	532	8,53	512
	3,99	239	11,75	705	8,83	530
13:00-14:00	4,86	292	2,71	163	6,66	400
	3,85	231	8,03	482	6,82	409
16:00-17:00	2,62	157	2,8	168	11,82	709
	4,72	283	16,67	1000	7,01	421
17:00-18:00	4,02	241	10,97	658	7,58	455
	3,79	227	18,01	1081	8,63	518

Source: The Calculation Results (*Microsoft Excel*), 2023

Fuel Oil Consumption

Fuel consumption data (table 4) is obtained using equation (6), which represents fuel consumption during idle. Here is an example calculation to obtain fuel consumption.

Delay = 1576 second/smp

Fuel Oil Consumption (F) = 140.10^{-2} (liter/smp-hour)

= 140.10^{-2} / 3600 (liter/smp-second)

= $3,889.10^{-4}$ (liter/smp-second) x 1576 second

= 0,00039 (liter/smp-second) x 1576 second

= 0,6146 (liter/smp)

Table 4: Fuel Oil Consumption

Time	Monday		Tuesday		Wednesday	
	Delay (sec./ smp)	Fuel Oil Consumption (liter/ smp)	Delay (sec./ smp)	Fuel Oil Consumption (liter/ smp)	Delay (sec./ smp)	Fuel Oil Consumption (liter/ smp)
07:00-08:00	1576	0,6146	423	0,1650	1001	0,3903
	692	0,2700	1430	0,5576	1304	0,5087
08:00-09:00	634	0,2473	634	0,2473	176	0,0688
	331	0,1292	881	0,3435	689	0,2689
12:00-13:00	233	0,0908	532	0,2073	512	0,1996
	239	0,0934	705	0,2750	530	0,2066
13:00-14:00	292	0,1137	163	0,0634	400	0,1558
	231	0,0901	482	0,1879	409	0,1596
16:00-17:00	157	0,0613	168	0,0655	709	0,2766
	283	0,1104	1000	0,3901	421	0,1640
17:00-18:00	241	0,0941	658	0,2567	455	0,1774
	227	0,0887	1081	0,4214	518	0,2019

Source: The Calculation Results (*Microsoft Excel*), 2023

Traffic Volume Analysis

The number of vehicles is converted into SKR/SMP using the method of multiplying the vehicle volume by Ekr/Emp for each vehicle type. With an average vehicle volume per hour of 405.2, the Ekr/Emp for a 4/2TT road according to PKJI 2014 is 1,0 for Light Vehicles (LV), 1.2 for Medium Vehicles (MV), and 1.6 for Heavy Vehicles (HV). Table 5, table 6 and table 7 are the traffic volume analysis for Monday, Tuesday and Wednesday, respectively.

Table 5: Monday Traffic Volume

Time	Lamongan-Surabaya			Total smp/hour	Surabaya-Lamongan			Total smp/hour
	1	1,2	1,6		1	1,2	1,6	
	LV	MV	HV		LV	MV	HV	
07:00-08:00	321	36	312	669,0	149	31,2	419,2	599,4
08:00-09:00	334	21,6	296	651,6	178	26,4	505,6	710,0
12:00-13:00	213	14,4	438,4	665,8	199	32,4	620,8	852,2
13:00-14:00	222	16,8	376	614,8	227	27,6	651,2	905,8
16:00-17:00	209	9,6	254,4	473,0	238	33,6	670,4	942,0
17:00-18:00	169	3,6	188,8	361,4	241	31,2	556,8	829,0

Source: Survey Results, 2023

Tabel 6: Tuesday Traffic Volume

Time	Lamongan-Surabaya			Total smp/hour	Surabaya-Lamongan			Total smp/hour
	1	1,2	1,6		1	1,2	1,6	
	LV	MV	HV		LV	MV	HV	
07:00-08:00	103	26,4	243,2	372,6	40	16,8	224	280,8
08:00-09:00	117	38,4	273,6	429,0	113	15,6	193,6	322,2
12:00-13:00	201	43,2	468,8	713,0	117	20,4	452,8	590,2
13:00-14:00	114	37,2	248	399,2	147	21,6	403,2	571,8
16:00-17:00	126	15,6	225,6	367,2	61	15,6	329,6	406,2
17:00-18:00	96	9,6	164,8	270,4	174	16,8	284,8	475,6

Source: Survey Results, 2023

Table 7: Wednesday Traffic Volume

Time	Lamongan-Surabaya			Total smp/hour	Surabaya-Lamongan			Total smp/hour
	1	1,2	1,6		1	1,2	1,6	
	LV	MV	HV		LV	MV	HV	
07:00-08:00	40	16,8	224	280,8	64	13,2	241,6	318,8
08:00-09:00	113	15,6	193,6	322,2	105	20,4	259,2	384,6
12:00-13:00	117	20,4	452,8	590,2	133	13,2	497,6	643,8
13:00-14:00	147	21,6	403,2	571,8	122	19,2	516,8	658,0
16:00-17:00	61	15,6	329,6	406,2	173	16,8	275,2	465,0
17:00-18:00	174	16,8	284,8	475,6	82	14,4	412,8	509,2

Source: Survey Results, 2023

Analysis of Degree of Saturation

The degree of saturation (table 8) is calculated with equation (3), where Q represents the total volume in both directions. It can be considered congested if the value of the degree of saturation is greater than 0.75.

Table 8: Degree of Saturation

Time	Monday		Tuesday		Wednesday	
	Q / C	Dj	Q / C	Dj	Q / C	Dj
07:00 – 08:00	1268,4/1496	0,848	817,2/1496	0,546	599,6/1496	0,401
08:00 – 09:00	1361,6/1496	0,91	987,8/1496	0,66	706,8/1496	0,472

12:00 – 13:00	1518/1496	1,015	1356,2/1496	0,907	1234/1496	0,825
13:00 – 14:00	1520,6/1496	1,016	954/1496	0,638	1229,8/1496	0,822
16:00 – 17:00	1415/1496	0,946	967,6/1496	0,647	871,2/1496	0,582
17:00 – 18:00	1190,4/1496	0,796	756/1496	0,505	984,8/1496	0,658

Source: The Calculation Results (*Microsoft Excel*), 2023

Fuel Oil Losses

The data on fuel loss (table 9) is obtained by processing traffic volume data and fuel consumption (Liters/smp). Fuel loss can be calculated using equation (7). The price for 1 liter of Pertalite fuel is Rp.10,000.

Table 9. Fuel Oil Losses

Time	Monday					
	Lamongan-Surabaya			Surabaya-Lamongan		
	Total smp	Fuel Oil Losses (Liter/ smp)	Amount of Loss	Total smp	Fuel Oil Losses (Liter/ smp)	Amount of Loss
07:00–08:00	669	0,6146	Rp.4.111.942	599,4	0,2699	Rp.1.617.661
08:00–09:00	651,6	0,2473	Rp.1.611.146	710	0,1291	Rp.916.539
12:00–13:00	665,8	0,0909	Rp.605.012	852,2	0,0932	Rp.794.336
13:00–14:00	614,8	0,1139	Rp.700.134	905,8	0,0901	Rp.816.035
16:00–17:00	473	0,0612	Rp.289.618	942	0,1104	Rp.1.039.685
17:00–18:00	361,4	0,0940	Rp.339.680	829	0,0885	Rp.733.914
Total loss of 6 hours on Monday						**Rp.13.575.702**
Time	**Tuesday**					
	Lamongan-Surabaya			**Surabaya-Lamongan**		
	Total smp	**Fuel Oil Losses (Liter/ smp)**	**Amount of Loss**	**Total smp**	**Fuel Oil Losses (Liter/ smp)**	**Amount of Loss**
07:00–08:00	372,6	0,1650	Rp.614.678	444,6	0,5577	Rp.2.479.534
08:00–09:00	429	0,2473	Rp.1.060.745	558,8	0,3436	Rp.1.919.981
12:00–13:00	713	0,2075	Rp.1.479.332	643,2	0,2750	Rp.1.768.478
13:00–14:00	399,2	0,0636	Rp.253.771	554,8	0,1880	Rp.1.042.913
16:00–17:00	367,2	0,0655	Rp.240.589	600,4	0,3900	Rp.2.341.560

17:00–18:00	270,4	0,2566	Rp.693.900	485,6	0,4216	Rp.2.047.241
Total loss of 6 hours on Tuesday						**Rp.15.942.725**
Time	**Wednesday**					
	Lamongan-Surabaya			**Surabaya-Lamongan**		
	Total smp	**Fuel Oil Losses (Liter/ smp)**	**Amount of Loss**	**Total smp**	**Fuel Oil Losses (Liter/ smp)**	**Amount of Loss**
07:00–08:00	280,8	0,3904	Rp.1.096.215	318,8	0,5086	Rp.1.621.289
08:00–09:00	322,2	0,0686	Rp.221.158	384,6	0,2687	Rp.1.033.459
12:00–13:00	590,2	0,1997	Rp.1.178.511	643,8	0,2067	Rp.1.330.735
13:00–14:00	571,8	0,1560	Rp.892.008	658	0,1595	Rp.1.049.576
16:00–17:00	406,2	0,2765	Rp.1.123.184	465	0,1642	Rp.763.484
17:00–18:00	475,6	0,1775	Rp.843.952	509,2	0,2020	Rp.1.028.686
Total loss of 6 hours on Wednesday						**Rp.12.182.256**

Source: The Calculation Results (*Microsoft Excel*), 2023

CONCLUSION

Based on the data analysis conducted, the fuel consumption loss for Pertalite fuel type was obtained using the LAPI - ITB formula for the construction of a road segment of approximately 1.5 km. From the research conducted over 3 days, namely Monday, Tuesday, and Wednesday, with a research duration of 6 hours per day, the total loss amounted to Rp.41,700,638, with an average fuel loss for Pertalite fuel type of Rp.2,316,705 per hour. The breakdown is as follows: on Monday, the fuel consumption loss for private vehicles during the 6-hour research period amounted to Rp.13,575,702, with an average loss per hour of Rp.2,262,617. On Tuesday, the fuel consumption loss for private vehicles during the 6-hour research period amounted to Rp.15,942,725, with an average loss per hour of Rp.2,657,121. And on Wednesday, the fuel consumption loss for private vehicles during the 6-hour research period amounted to Rp.12,182,256, with an average loss per hour of Rp.2,030,376.

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