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RELATIONSHIP ANALYSIS BETWEEN OPTIMIZATION UNSIGNALIZED JUNCTION AND FUEL CONSUMPTION (Case Study: Degolan Junction, Sleman, Yogyakarta)

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ABSTRACT

Application of signalling at junction can make the delay time longer. The delay time at the junction will be related to the amount of fuel consumption of vehicles. In this study, research will be conducted on delays with fuel consumption at the Degolan Junction. The purpose of this study was to determine the comparison of vehicle fuel consumption between the unsignalized junction and signalized junction. Junction performance analysis was carried out based on IHCM 1997. The fuel consumption analysis is carried out based on the length of the delay using the equation from LAPI-ITB. Furthermore, data analysis was carried out using linear regression analysis. Based on the results of the analysis, it was found that the average fuel consumption at the Degolan Junction when the junction conditions were not signalled was 9.553 liters/junction. Meanwhile, when signalling is applied to the Degolan junction with details, alternative 1 produces an average fuel consumption of 40,144 liters/ junction, alternative 2 produces an average fuel consumption of 40,646 liters/ junction, and alternative 3 produces an average fuel consumption of 39,937 liters/junction. The results of the analysis show that the performance of the junction in the form of delay has an influence on fuel consumption.

Keywords: fuel consumption, intersection, delay time

1. INTRODUCTION

1.1 BACKGROUND

The increase in the number of vehicles is one of the causes of transportation problems. The (Central Statistics Agency, 2022) states that the number of motorized vehicles in the Special Region of Yogyakarta in 2020 is 3,020,175 vehicles and as many as 3,125,720 vehicles in 2021. This indicates that there is an increase in the number of vehicles by 3% from 2020 to 2021. An increase in the number of vehicles can lead to congestion. (Sriwati, et al, 2019) stated that an increase in the number of vehicles had a positive effect on traffic congestion.

One of the efforts to overcome traffic congestion is to implement traffic management. (Munawar, 2006) argues that one form of traffic management at junctions is to implement a traffic control system in the form of traffic lights. (The Directorate General of Highways, 1997) also stated that one of the efforts made to overcome traffic congestion at a junction is to apply signalling at the junction. However, signalling can make the delay time at a junction longer. Based on the research results of (Purnama and Iduwin, 2018) the value of the delay when the condition of the signalized junction is longer than when the condition of the junction is not signalled.

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The delay time at the junction will be related to the amount of fuel consumption of the vehicle. (Putra, 2012) explained that delay has a big influence on fuel consumption at signalized junction. In this study, research will be conducted on delays with fuel consumption at the Degolan junction. The location of the Degolan junction can be seen in Figure 1 as follows. From the results of this study, it is expected to know the amount of fuel issued by vehicles at both junctions when the junction conditions are not signalled and at the signalized junction conditions.

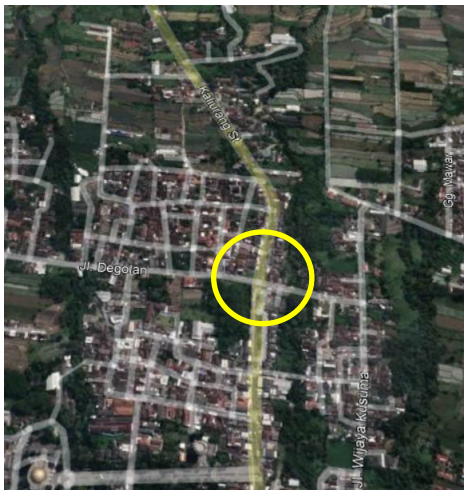

Figure 1 Degolan Junction

1.2 RESEARCH PURPOSE

The purpose of this study was to compare the consumption of fuel oil of vehicles between the conditions of unsignalized junction and signalized junction condition.

1.3 LITERATURE REVIEW

(Julianto, 2007) conducted a study on the performance analysis of the Bangkong and Milo Semarang signalized junctions based on fuel consumption. This study aims to determine the performance of the junction based on fuel consumption which is influenced by delay. From the results of the analysis, based on the results of the analysis, it was found that the need for fuel oil to travel the Brigjen Katamso road which is located between Milo Junction and Bangkong Junction from East to West and from West to East in the initial conditions requires fuel oil of 0.533 liters/pcu at a total delay of 1298.92 seconds/pcu. The results of data analysis show that the hypothesis presented in this study is proven where the fuel consumption for vehicles passing through two signalized junctions is smaller than the diversion route.

(Putra, 2012) conducted a study on the analysis of the relationship between signalled junction performance and fuel consumption in Surakarta City. This study aims to analyze the relationship between fuel consumption and the performance of signalized junctions in the form of delays in Surakarta City. From the results of the analysis, it was found that the value of the degree of saturation of several signalized junctions in Surakarta City was greater than 0.85 and the amount of wasted fuel consumption with details at the Stage Junction was 0.12 liters/pcu with a total delay of 307.80 sec/pcu. The Ngemplak junction is 0.13 liters/pcu with a total delay of 330.98 sec/pcu, and at The Gemblegan junction it is 0.12 liters/pcu with a total delay of 296.20 sec/pcu. The results of the analysis show

that delay has a major influence on fuel consumption at signalized junctions, meaning that the higher the delay value, the greater the wasted fuel consumption.
(Khafidz et. al, 2016) conducted a study on the relationship between delay and queue length on fuel consumption at the junction approach lane on the Surakarta City Arterial Street. This study aims to determine the relationship between delay and queue length on fuel consumption due to signalized junctions in Surakarta City. Based on the analysis and discussion, the conclusions obtained are the average value of delay, queue length and fuel consumption at each junction approach in Surakarta, respectively, the southern approach of Manahan Junction 95.4 seconds, 27.6 m, and 0.502 liters. , the southern approach of Sumber Junction is 100.8 seconds, 45.66 m, and 0.316 liters, the western approach is Panggung Junction 119.63 seconds, 63.2 m, and 0.701 liters and the western approach is Pedarigan Junction 74.23 seconds, 50.68 m and 0.416 liter.
(Fadhil, 2019) conducted research on the analysis of signalized junctions and the relationship between queue length and delay time on fuel oil consumption. The research was conducted at the UPN Yogyakarta Junction. This study aims to determine the performance of UPN signalized junctions and to determine the relationship between queue length and delay with fuel oil. From the results of the analysis, the degree of saturation at the Yogyakarta UPN Signalized Junction is greater than 0.85 which indicates this junction is in an oversaturated condition. The average delay value of the UPN junction is greater than 60 seconds/pcu and the service level of the junction is at level F. In addition, the total wasted fuel oil due to the queue length and the length of time delay at the UPN Junction is 444.653 liters.
(Sinambela et. al, 2021) conducted a study on the analysis of the relationship between signalled junction performance and fuel consumption. The research was conducted at the junction of A A. Maramis Road-Ringroad II Road in Mapanget District, Manado City. This study aims to determine the performance of the junction and determine the relationship between junction performance and additional fuel consumption for each junction user vehicle. From the results of the analysis, the degree of saturation is 0.837 and the average delay is 29.345 sec/pcu, with the level of service at the junction being in category D and the additional fuel consumption of the average crossing is 32,979 liters/junction-hour.

2. THEORITICAL BASIC

2.1 DELAY

Delay according to the (Directorate General of Highways, 1997) is the additional travel time required to go through a junction when compared to a path through a junction. The delay consists of Traffic Delay (DT) and Geometry Delay (DG).

2.2 JUNCTION SERVICE LEVEL

The level of service according to the (Republic of Indonesia, 2015) in the Regulation of the Minister of Transportation of the Republic of Indonesia Number 96 of 2015 is a quantitative and qualitative measure that describes traffic operational conditions. The level of service at the junction can be seen in Table 1 on the next page.

Table 1 Junction Service Level

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No.	Level of Service	Criteria
1	A	Delay lower than 5 seconds per vehicle
2	B	Delay more than 5 seconds to 15 seconds per vehicle
3	C	Delay more than 15 seconds to 25 seconds per vehicle
4	D	Delay more than 25 seconds to 40 seconds per vehicle
5	E	Delay more than 40 seconds to 60 seconds per vehicle
6	F	Delay higher than 60 seconds per vehicle

Source: Republic of Indonesia (2015)

2.3 ANALYSIS OIL FUEL CONSUMPTION

(Isnaeni, 2003) in research on fuel consumption and exhaust emissions, calculates fuel consumption using the formulation proposed by LAPI-ITB which has been converted into passenger car units (pcu).
Fuel consumption for vehicles with idle conditions is calculated by the formula as follow.

$$F = 140 \times 10^{-2} \text{ (liter/pcu-hour)} \quad (1)$$
$$F = 140 \times 10^{-2} / 3600 \text{ (liter/pcu-second)} \quad (2)$$
$$F = 3{,}889 \times 10^{-4} \text{ (liter/pcu-second)} \quad (3)$$

This means that the consumption of fuel oil for one pcu vehicle in idle condition (still with the engine running) is 3.889×10^{-4} (liters/second). So that the fuel consumption due to delays at the junction is as follows.

$$F = 3{,}889 \times 10^{-4} \times D_{TOTAL} \text{ (liter)} \quad (4)$$

Simple Linear Regression
A simple linear regression equation to determine the relationship between delay and fuel consumption is as follows.

$$Y = a + bX \quad (5)$$

Information:
Y = fuel consumption value (dependent variable)
X = delay value (independent variable)

3. RESEARCH DESIGN AND METHODOLOGY

The survey conducted in this research is in the form of vehicle volume data and geometry data. The analysis of the performance of the unsignalized junction and the performance of the signalized junction was carried out based on IHCM 1997 and obtained the junction performance parameters in the form of degrees of saturation and delay. Analysis of the consumption of fuel oil based on the length of the delay using the equation from LAPI-ITB. Furthermore, data analysis was performed using linear regression analysis with fuel consumption as the dependent variable and delay as the independent variable to determine the relationship between delay and fuel consumption.

4. ANALYSIS AND DISCUSSION

4.1 JUNCTION GEOMETRY DATA

Geometry data is data that provides information in the form of geometry conditions at the junction observed. The junction geometry data is obtained from observations at the research site and can be seen in Figure 2 as follow.

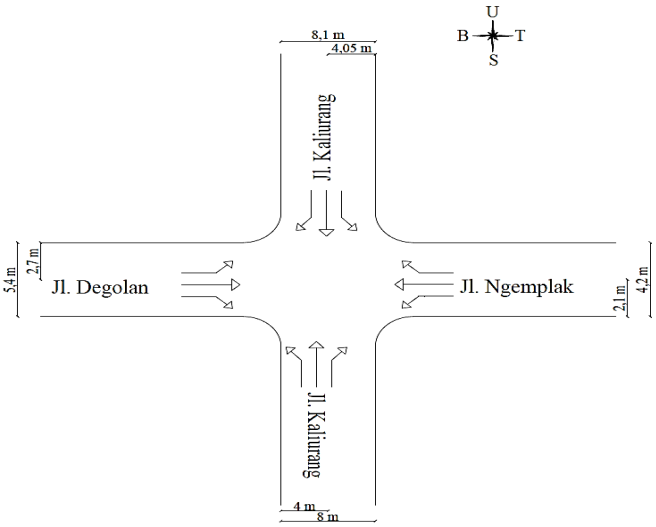

Figure 2 Degolan Junction Geometry

4.2 TRAFFIC VOLUME DATA

The types of vehicles observed were classified into 3 types of vehicles, namely motorcycles, light vehicles, and heavy vehicles. The traffic volume data from the survey will be converted from vehicles/hour to pcu/hour unit. Data conversion is carried out using the passenger car equivalence value (emp) which is sourced from IHCM 1997.

4.3 OIL FUEL CONSUMPTION

Average oil fuel consumption of Degolan Junction can be seen in Table 3 as follow.

Table 3 Average Oil Fuel Consumption of Degolan Junction

No	Junction Condition	Average Oil Fuel Consumption (liter)
1	Unsignalized	9.553
2	Alternative 1	40.144
3	Alternative 2	40.646
4	Alternative 3	39.937

Based on Table 3, it can be seen that the average fuel consumption value when the junction is unsignalized is 9.553 liters. While the average value of fuel consumption for the application of alternative 1, alternative 2, and alternative 3 is 40.144 liters, 40.646 liters, and 39.937 liters, respectively. This shows that the average fuel consumption when the junction is unsignalized is less than the other three alternatives.

4.4 RELATION ANALYSIS BETWEEN DELAY AND OIL FUEL CONSUMPTION

To determine the relationship between delay and oil fuel consumption, a simple linear regression analysis was performed using SPSS (Statistical Package for the Social Sciences) software. The SPSS data input table is as follows

Table 4 SPSS Data Input

X	10,643	61,589	62,360	57,544
Y	9,553	40,144	40,646	39,937

X variable is delay value (second/pcu) and Y variabel is oil fuel consumption value (liter). The results of the analysis of the relationship between junction performance and average fuel consumption using SPSS26 software Enter Method can be seen in Table 5 to Table 7 as follow.

Table 5 Results of Correlations SPSS26 Enter Method between Delay and Fuel Consumption

Correlations

		Tundaan	BBM
Tundaan	Pearson Correlation	1	.998**
	Sig. (1-tailed)		.001
	N	4	4
BBM	Pearson Correlation	.998**	1
	Sig. (1-tailed)	.001	
	N	4	4

Table 6 Results Summary Model SPSS26 Enter Method Between Delay and Fuel Consumption

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.998[a]	.995	.993	1.305699

a. Predictors: (Constant), Tundaan

Table 7 Results of Coefficients SPSS26 Enter Method between Delay and Fuel Consumption

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3.173	1.588		1.998	.184
	Tundaan	.612	.030	.998	20.310	.002

a. Dependent Variable: BBM

Based on the analysis process presented in Tables 5 to 7, it can be seen the following information.

1. The theoretical value for the number of data is 4 and the significant level (α) of 5% is 0.950. As for the value of r_{count} based on Table 5 is 0.998. This means that there is a relationship between delay and fuel consumption.
2. Based on Table 6, the coefficient of determination R2 = 0.995. This shows that in this model the delay (X) has an effect of 99.5% on fuel consumption (Y) and the remaining 0.5% is influenced by other factors. The correlation coefficient (r) = 0.998 shows that there is a close relationship between the two variables, namely delay (X) and fuel consumption (Y).
3. From Table 7 obtained the following equation.

$$Y = 3.173 + 0.612\ X \quad (6)$$

With description X variable is delay value (second/pcu), and Y variable is oil fuel consumption value (liter).

5. RESEARCH RESULTS AND CONCLUSIONS

Based on the data analysis and discussion that has been carried out, the following conclusions are drawn.

1. The performance of the Degolan junction at the unsignalized junction results in a DS > 0.75 with a DS value of 0.809. This value is greater than the recommended value of the IHCM 1997 for signalized Junction, namely 0.75. So that an alternative is used in the form of the application of signalling at the Degolan junction with the DS value in each alternative producing DS 0.85. This means that the DS value is already smaller than the DS value recommended by the IHCM 1997 for signalized junction.
2. The level of service at the Degolan junction when there is no signal is B with a delay of 10,643 seconds/pcu. Meanwhile, when signalling is applied to the Degolan junction with details, alternative 1 produces a delay of 61.589 seconds/pcu, alternative 2 produces a delay of 62.360 seconds/pcu, and alternative 3 produces a delay of 57.544 seconds/pcu. Thus, the level of service at the Degolan junction using alternative 1 and alternative 2 is F and E when using alternative 3.
3. The average fuel consumption at the Degolan junction when the junction is not signalled is 9.553 liters/junction. Meanwhile, when signalling is applied to the Degolan Junction with details, alternative 1 produces an average fuel consumption of 40,144 liters/junction, alternative 2 produces an average fuel consumption of 40,646 liters/junction, and alternative 3 produces an average fuel consumption of 39,937 liters/junction.
4. The results show that the performance of the junction in the form of delay has an influence on fuel consumption with the relationship the greater the delay value, the greater the average fuel consumption value.

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