Jurnal Sistem Informasi Bisnis 03(2025)
 p-ISSN: 2502-2377, e-ISSN: 2088-3587
On-line: http://ejournal.undip.ac.id/index.php/jsinbis/article/view/3279

Investigation of Traffic Characteristics and Arrival Patterns at Pertashop in Suburban Area of Semarang City

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Submitted: March 16th, 2025; Revised: April 17th, 2025;
Accepted: May 15th, 2025; Available Online: May 14th, 2025
DOI: 10.21456/vol15iss1pp21-337

Abstract

Pertashop, developed by PT. Pertamina, is a small-scale gas station business designed to meet the fuel needs of vehicles in suburban areas while maintaining fuel quality. Variations in land use functions can lead to different travel attractions, leading to varied arrival patterns and potential traffic flow disruptions, thus impacting road quality around Pertashop locations. This study seeks to investigate the traffic characteristics and arrival patterns at small-scale gas stations such as Pertashop, providing a basis for development planning and optimizing services in the suburban areas of Semarang City. Using qualitative and quantitative descriptive research methods, the study analyzes the relationship between land use factors and traffic characteristics on Pertashop vehicle service patterns. The findings indicate that the traffic flow around Pertashop follows the Underwood model, demonstrating that vehicles entering Pertashop hinder the traffic flow on surrounding roads.

Keywords: Investigation of Traffic Characteristics; Small-Scale Gas Station; Pertashop; Suburban Area of Semarang City; Traffic Flow Disruptions

1. Introduction

The limited number, travel distance and time required to get to the gas station, fuel needs in an emergency situation, also desires made Some people prioritize time effectiveness and practicality, which is the reason some people are reluctant to queue at gas stations (Ijaya et al., 2023). This phenomenon is the reason PT. Pertamina is developing fuel services on a smaller scale for people living outside the regular gas station service areas, namely the Pertamina Shop (PERTASHOP) service. The development of Pertashop as a retail fuel distribution network continues to use the same fuel quality and safety standards as gas stations. The storage capacity is appropriate and still prioritizes safety factors. Based on this, Pertashop can be an alternative for the petrochemical business in areas far from regular gas station services due to the ease of licensing and the small area requirements provided by PT. Pertamina when compared with regular gas stations. This has caused massive Pertashop development to occur in Semarang City, especially in suburban areas. Land use and transportation have an interactive relationship, because land use can determines the type of transportation facilities that will be used for movement in several activities. Land use is an important factor that should be account in transportation planning. According to (Kazaura & Burra, 2017) Changes in land use to change the function of business activities such as Pertashop can cause a decrease in the Degree of Saturation (DS) because the number of vehicles going in and out increases which can hinder traffic on the surrounding roads. Pertashop's limited land area can affect the queues at Pertashop not accommodate, especially during peak hours. Apart from that, the length of the queue can also affect people in choosing a place, in this case a place to fill up fuel, either a gas station or Pertashop. Therefore, it is necessary to calculate the trip attraction on Pertashop so that it does not affect the quality of the surrounding roads.

Differences in land use characteristics and traffic characteristics around Pertashop result in different attractions (number of vehicles entering) at each Pertashop. Land use consisting of residential areas, office centre, educational services, health centre, and others must be used as a basis for spatial analysis in transportation planning because it will have an impact on traffic in the area (zone) (Ortúzar & Willumsen, 2024; Tamin, 2000). Based on the problem above, this research focuses on the traffic characteristics of road around Pertashop and it's arrival pattern so we can know the effect of the Pertashop arrival pattern on the surrounding roads. This can be used as a basis for consideration in development planning and optimizing Pertashop arrival in Semarang City. This is included in planning a safe and sustainable transportation system in the land use development of small-scale fuel filling stations such as Pertashop.

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2. Literature Review

2.1 Traffic Characteristic Around Pertashop

Pertashop is included in commercial land use because it is intended as a place for fuel trading activities such as other regular gas stations. Most studies that analyze the correlation between land use and traffic congestion find that commercial land use is the factor that has the most positive effect on congestion in urban areas (Bao et al., 2022; Izanloo et al., 2017; Zhang et al., 2017). his is due to vehicles entering exiting and stopping on the roads around commercial areas, which impedes the flow of traffic. This activity becomes a side obstacle that can reduce the quality of the road (Biswas et al., 2021; Pal & Roy, 2019; Salini & Ashalatha, 2020). revious research obtained the characteristics of road sections using an approach in the form of volume, speed, and density relationship models, namely linear greenshield, logarithmic Greenberg, and exponential underwood (Srivastava & Kumar, 2023). The model estimation uses regression analysis techniques to obtain the volume, speed, and density values during peak hours and outside peak hours (Kurniati et al., 2024). In addition, capacity calculations are carried out to determine the quality of service of road sections. Several studies have analyzed the quality of road sections using methods in the Indonesian Road Capacity Manual (PKJI) (Asan Beni Tokan et al., 2023; Wadu et al., 2019).

Several studies have analyzed the impact of vehicles entering and exiting gas stations on the surrounding roads (Da Costa, 2020), but no research has been conducted on small-scale gas stations such as Pertashop. Some things that distinguish between Pertashop and regular gas stations are the location and type of products sold. Based on location, Pertashop is generally located on roads with functions as collector and local roads, in contrast to gas stations located on arterial roads. The types of products sold at Pertashop are only non-subsidized products in comparison to gas stations that sell both subsidized and non-subsidized products, causing the number of vehicles attracted to Pertashop to be different from gas stations. This causes differences in the characteristics and affect of cars entering and exiting the road section around regular gas stations and Pertashop. Therefore, this research focuses on traffic flow characteristics to see the traffic flow condition, volume, speed and the road quality by degree of saturation (DS) value of road sections around Pertashop to determine the effect of vehicles entering and exiting Pertashop on the DS of the surrounding roads.

2.2 Trip Generation and Road Quality

Trip Generation consist of the number of arrivals as trip attraction and number of departures as trip production. Trip generation is a modeling stage by estimating the number of vehicles originating from one zone or land use to another zone. The amount of movement generated by a zone is directly proportional to the type and intensity of land use in that zone. Several things that are affectd by changes in land use are the amount of traffic flow, type of traffic (pedestrians, trucks, cars, motorbikes) and traffic at certain times (Nurdin et al., 2022). An example of traffic at a certain time is that the use of land as an office will have different peak hours from the use of land as a shop, where office land has peak hours in the morning and evening while shop land has all day long. Several researchers explain that there is a relationship between travel attraction and road capacity (Agustin & Waloeya, 2017, 2018). To determine the affect of travel attraction/generation due to changes in land use on the capacity of surrounding roads, it can be shown using the following interaction model:

$$V_{total} = \textit{no of trip atrraction} + \textit{no of trip production} + \textit{traffic volume} \quad (3)$$

This interaction model utilized to determine the relationship between vehicle generated by Pertashop on certain land use characteristics and the quality of the surrounding roads. The traffic flow on the roads round Pertashop as can be shown in Fig. 1.

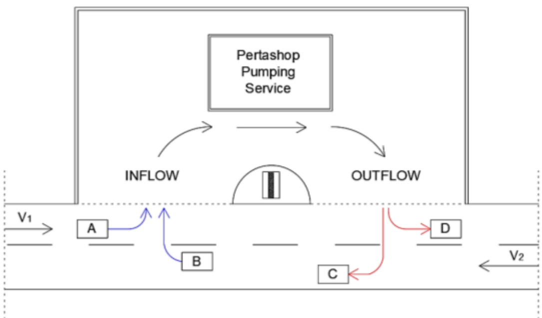

Fig. 1 Sketch of Traffic Flow on The Road round Pertashop

3. Research Method

3.1 Location

This research was conducted at 3 Pertashop observation locations in the suburban area of Semarang City. The research location is a small-scale gas station developed by PT. Pertamina is located in Gunung Pati sub-district and Banyumanik sub-district, Semarang City. The Pertashops studied were Pertashop Banaran (4P.50210), Pertashop Nongkosawit (4P.50203), and Pertashop Kanfer Raya 4P.50208. The research location points can be seen in Fig. 2

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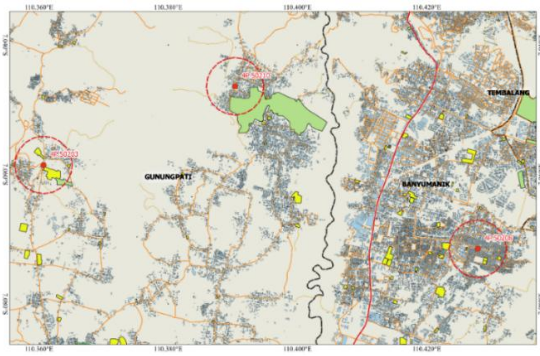

Fig. 2 Pertashop Research Location Map

3.2 Data Collection

The data collected in this study includes primary data and secondary data. Primary data in this study are land use functions, road characteristics, travel attractions, traffic calculations, and documentation. Primary data collection was carried out using a time stamp camera application on a mobile phone with the help of a tripod mounted at a height of ±2 m during Pertashop operational hours to obtain vehicle entry and exit times during the operational hours of each Pertashop point. Apart from that, the road sections around Pertashop are marked with speed markers to obtain the spatial average speed value (Us) on that road section. Determination of the length of the speed marking line follows regulation no. 001/BNKT/1990 Director General of Highways Directorate of City Road Development. A secondary survey was conducted by studying literature related to research that is relevant to this research. The secondary data collected is population data based on the Central Statistics Agency of Semarang City and regulations governing transportation and development of land use functions in Semarang City.

3.3 Descriptive Analysis

Descriptive analysis is a method of data analysis by describing or depicting data that has been collected with the aim of making generally accepted conclusions or generalizations (Sugiyono, 2015). Presentation of data in descriptive analysis can be in the form of tables, graphs, pie charts, pictograms, calculating mode, median, mean (measurement of central tendency), calculating deciles, percentiles, calculating data distribution through calculating averages and standard deviations, as well as calculating percentages. The strength of the relationship between variables in descriptive analysis can be done using correlation analysis, prediction using regression analysis, and making comparisons of the averages of two samples or populations. Descriptive analysis in this research was used to find the mean, variance and standard deviation of arrival and service data from Pertashop.

3.4 Traffic Characteristics

Traffic volume shows the number of vehicles passing through one observation point in one unit of time (day, hour, minute). In connection with determining the number and width of lanes, the traffic volume units commonly used are average daily traffic, planning hour volume, and capacity. Speed is the rate of movement over a certain distance in one unit of time (km/hour). In the movement of traffic flow, each vehicle travels at a different speed. In the calculation, average speed is divided into two, namely Time Mean Speed (TMS), which is defined as the average speed of all vehicles passing a point on the road during a certain period and Space Mean Speed (SMS), namely the average speed of all vehicles occupying a section of the road during a certain time period. Density is the number of vehicles occupying a section of road or lane, generally expressed in vehicles per kilometer per lane. Density can be calculated based on the speed and current values with the following formula.

$$V = U_s \,.\, D \quad (1)$$
$$D = V/U_s \quad (2)$$

Notes:
V = The number of Vehicle (veh/hr)
Us = Space Mean Speed (km/hr)
D = Density (veh/hr)

3.5 Mathematical Relationship Model for Volume, Speed, and Density

The mathematical relationship of volume, speed and density can be expressed by equation (1). There are 3 types of mathematical models that can be used to represent the mathematical relationship between these three parameters, namely the Greenshields, Greenberg, and Underwood models (Timpal et al., 2018). The Greenshield model is the earliest recorded attempt to observe the characteristics of traffic flow on highways. In 1934, Greenshield conducted a study on a roadway outside of Ohio City, where traffic conditions qualified as uninterrupted and moving freely. Greenshield found that the relationship between speed and density is linear. Greenberg's model assumes that traffic flow is like fluid flow. Greenberg in 1959 conducted a study in a tunnel and analyzed the relationship between speed and density using the equation of continuity and fluid motion. With this assumption, Greenberg obtained the relationship between Speed and density in logarithmic form. The third model is a model proposed by Underwood as a result of a traffic study on the Merritt Highway in Connecticut. Underwood concluded that the mathematical relationship between Us and density follows an exponential function. The relationship of flow, speed, and density in each model can be summarized in mathematical ways, as follows:

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Table 1. Recapitulation of Greenshield, Greenberg, and Underwood Relationship Model Equation

Model	Relationship	Equation
Greenshield	Us-D	$\bar{U}_s = \bar{U}_f - (\bar{U}_f / Dj)D$
	V-D	$V = D \; x \; \bar{U}_f - (/\bar{U}_f / D_j) \; x \; \bar{U}_s{}^2$
	V-Us	$V = D_j \; x \; \bar{U}_s - (D_j / \bar{U}_f) \; x \; \bar{U}_s{}^2$
Greenberg	Us-D	$\bar{U}_s = \bar{U}_m$.ln (Dj/D)
	V-D	$V = \bar{U}_m \; x \; D \; x \; ln(Dj/D)$
	V-Us	$V = \bar{U}_s \; x \; Dj \; x \; exp(-\bar{U}_s / \bar{U}_m)$
Underwood	Us-D	$\bar{U}_s = \bar{U}_f$ .exp(-D/Dm)
	V-D	$V = D \; x \; \bar{U}_f .exp(-D/Dm)$
	V-Us	$V = \bar{U}_s \; x \; Dm \; x.exp(\bar{U}_f / \bar{U}_s)$

Where :
$\bar{U}_s$ = Space mean speed (veh/hr)
$\bar{U}_f$ = Free flow speed (km/hr)
$\bar{U}_m$ = maximum speed (km/hr)
D_m = Density in jam condition (pcu/km)
D = Density (pcu/km)
D_j = Density in jam condition (pcu/km)

4. Result and Discussion

4.1 Pertashop Arrival Pattern

This research uses the concept of parking accumulation calculations to determine the distribution pattern of Pertashop users. This aims to determine the number of vehicles waiting on the available Pertashop land at a certain time interval. So that the total capacity required for Pertashop land can be obtained to accommodate vehicles that will use Pertashop, especially at peak times. Fig. 3 explains that Pertashop Banaran has peak service hours in the afternoon, namely 04:00 pm to 05:00 pm, 83 vehicles. Apart from that, there were quite long intervals, from 07:15 am to 08:30 am, there was a vacancy in Pertashop services due to the filling of fuel tanks by the Pertamina team. Pertashop Nongkosawit occurs in the morning, namely 06:45 am to 07:45 am, namely 55 vehicles and Pertashop Kanfer Raya has peak service hours in the afternoon, namely 06:30 am to 07:30 am, namely 80 vehicles.

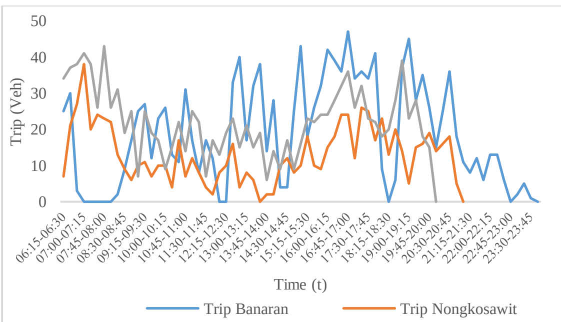

Fig. 3 Graphics of Pertashop Arrival Patterns

4.2 Land Use Characteristic Around Pertashop

Pertashop in this study are located on various land use characteristics. In accordance with the aim of developing Pertashop's small-scale refuelling business, it is located in areas that have limited access to large-scale gas station services. The following is data on land use characteristics in each Pertashop within a 1 km radius in accordance with the maximum distance provisions between Pertashop and other Pertamina fuel distribution building. Table 2 is a recapitulation of land functions around the Pertashop location.

Table 2. Land use Percentage round Pertashop

PERTASHOP	Land Use Percentage (%)				
	Housing	Education	Religious	Office	Commercial
Banaran	21.893	12.711	0.219	0.095	10.977
Nongkosawit	29.705	3.525	0.114	0.033	0.722
Kanfer Raya	62.649	2.535	0.522	0.982	13.662

Table 2 shows the proportion of residential land use functions around Pertashop Kanfer Raya of 62,649 per cent of the total land area within a radius of 1 km. The proportion of residential land functions is greater than Pertashop Banaran, which is 21,893% and Pertashop Nongkosawit, which is 29,705%. The proportion of Pertashop Kanfer Raya educational land functions is in the last position with a proportion of 2,535% of the total area within a 1 km radius. Based on this, we can see the differences between the three Pertashops studied, where the land use around Pertashop Banaran is characterized by land use being dominated by residential, commercial buildings and educational land use, this is in accordance with the results of observations in the field where the Pertashop location is in a commercial area close to Semarang State University (UNNES) and there is a residential location that is included in commercial land use due to the change in residential land use to rental housing for students. Pertashop Nongkosawit has a larger residential land area than Pertashop Banaran. However, the residential density around Pertashop Banaran is higher than Pertashop Nongkosawit because residential land has been converted into rental housing for UNNES students. Pertashop Kanfer Raya is in a residential location and close to commercial activity centers such as the Damar market, so it has the highest residential and commercial land use than another Pertashop.

4.3 Characteristics of Roads Around Pertashop

The road in front of all Pertashops examined is located on a secondary collector road with the type Jalan 2/2 UD or has two lanes without separation. By taking data on the number of vehicles during Pertashop operational hours, we can get peak hours by counting the vehicles passing in both lanes. In addition, the number of incoming vehicles (inflow) and the number of exiting vehicles (outflow) from PERTASHOP as well as the duration of each vehicle. Peak hours for the road in front of Pertashop Banaran occur in the afternoon at 04:15 pm to 05:15 pm, while the road in front of Pertashop Nongkosawit and Kanfer Raya occurs in the morning at 06:45 am to 07:45 am and 06.30 am to 07:30 am. Fig. 4 is a graph of peak hours in each pertashop.

Fig. 4 shows that Pertashop Banaran has the highest traffic volume than the other two Pertashops. This is caused by the large number of commercial buildings around this road section. The Banaran road section is also the road to Semarang State University (UNNES) so many students use this road section. Another thing that was found was that there was no significant decrease in volume during the survey period of the road section around Pertashop Banaran like other sections.

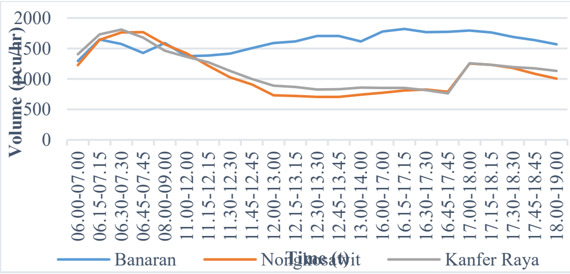

Fig. 4 Peak Hour Graph of road around Pertashop

Each research point has a different level of model suitability as seen from the largest coefficient of determination (R2) value among the Greenshield, Greenberg, and Underwood models. It was found that the Underwood model was the most suitable model for all sections at the observation point, namely Jalan Raya Banaran (in front of Pertashop Banaran), Jalan Raya Manyaran – Nongkosawit (in front of Pertashop Nongkosawit), and Jalan Kanfer Raya (in front of Pertashop Kanfer Raya). Table 3 shows that the speed of vehicles passing through Jalan Raya Banaran, Kanfer Raya and Jalan Raya Manyaran-Gunung Pati had different speeds. The highest vehicle speed occurs on the Manyaran-Gunung Pati road section and the lowest is on the Banaran road section.

Table 3. Recapitulation of the Underwood Model

Location	Underwood's Relationship Model			Maximum Value		
	Us-D	Vol-D	Vol-Us	Dm (pcu/km)	Um (km/hr)	Vm (pcu/hr)
Banaran	Us=43.434* $e^{(-0.008D}$	V=43.434*D* $e^{(-0.007D)}$	V= Us*125.294* (LnUf - LnUs)	125.294	15.979	2002.026
Nongkosawit	Us=53.652* $e^{(-0.009D}$	V=53.652*D* $e^{(-0.009D)}$	V= Us*107.711* (LnUf - LnUs)	107.711	19.737	2125.930
Kanfer Raya	Us=48.013* $e^{(-0.011D}$	V=48.013*D* $e^{(-0.011D)}$	V= Us*90.856* (LnUf - LnUs)	90.856	17.663	1604.798

Apart from that, it was found that Jalan Raya Banaran has the highest density and volume compared to other roads. Based on the research results, the road sections around Pertashop that were studied follow the underwood model which shows that traffic on the road sections around Pertashop is not in a free flow condition like the Greenshield model and is not in a high density condition like the Greenberg model (May, 1990). The Underwood model is usually valid for use in conditions on sections that have U-turns or vehicles making U-turns so that traffic flow is hampered (Arifanti & Radam, 2022; Rizki Fatonah et al., 2021). This is in accordance with the conditions of the roads around Pertashop.

Fig. 1 shows the flow of vehicle traffic in and out of Pertashop, where the flow of vehicles is in lane V1 obstructed by vehicles B and C cutting into vehicle V's lane1 while the vehicle flow is V2 obstructed by vehicle B which stopped in the middle of the road to queue to enter Pertashop and vehicle C which entered the flow of vehicle V2. The behavior of vehicles B and C is similar to the behavior of vehicles on a U-turn on a road section where a vehicle making a U-turn can slow down and result in delays (Zeng et al., 2024).

4.4 The Effect of Pertashop Service Patterns on the Degree of Saturation (DS) of Surrounding roads

The Degree of saturation (DS) of roads can be influenced by several factors, such as not only due to continuous movement carried out by various types of vehicles, but there are another factors that can influence traffic volume, namely the amount of movement caused by differences in land use and the movement of incoming and outgoing vehicles from a small alley.

Table 4 shows that Pertashop Banaran has the worst DS value of 0.9 at 3:00 pm to 4:00 pm with a total volume of 1836 smp/hour and at 7:00-8:00 pm with a total volume of 1874 smp/hour. At that time, the number of vehicles produced by Pertashop was 47,073 smp/h (2,564%) and 53,007 smp/h (2,829%). The highest number of vehicle movements attracted to Pertashop occurred at 04:00 pm to 05:00 pm (64,874 smp/h or 3.643%) with a DS of 0.87. This shows that even though the section of Jalan Raya Banaran has a DS value of 0.87 during the peak hours of operation of Pertashop Banaran, the attraction vehicles to Pertashop only affect 3.643% of the total traffic volume. Similarly, during peak hours on Jalan Raya Banaran, although the DS value is > 0.9, the pull vehicles only affect 2.564% and 2.829% of the total traffic volume. Pertashop Nongkosawit and Pertashop Kanfer Raya have good DS during the Pertashop operating hours. The Manyaran-Gunung Pati road section has the worst level of service B at 07:00 am to 08:00 am with a total of 44,763 smp/hour of pull vehicles which affects 2.849% of the total traffic volume. In addition, the peak hour of Pertashop Kanfer Raya occurs at 07:00 am to 08:00 am with a total volume of 74,320 smp/hour which affects 5.080% of the total traffic volume.

Table 4. The Effect of Pertashop vehicles on the Degree of Saturation (DS) of Surrounding Roads

Time			Pertashop Banaran		Pertashop Nongkosawit		Pertashop Kanfer Raya	
			Impact (%)	DS	Impact (%)	DS	Impact (%)	DS
06:00	-	07:00	1.773	0.63	1.904	0.47	3.896	0.52
07:00	-	08:00	0	0.63	2.849	0.61	5.080	0.54
08:00	-	09:00	0.696	0.78	2.333	0.35	5.067	0.37
09:00	-	10:00	2.458	0.69	1.977	0.32	3.789	0.33
10:00	-	11:00	2.183	0.72	2.258	0.28	3.311	0.34
11:00	-	12:00	1.555	0.67	0.697	0.28	4.006	0.33
12:00	-	13:00	1.815	0.78	2.176	0.29	4.092	0.32
13:00	-	14:00	2.471	0.79	0.858	0.31	4.004	0.28
14:00	-	15:00	1.459	0.81	1.666	0.32	3.030	0.30
15:00	-	16:00	2.564	0.90	1.910	0.40	3.971	0.40
16:00	-	17:00	3.643	0.87	2.755	0.48	4.794	0.46
17:00	-	18:00	3.197	0.88	3.387	0.39	4.577	0.42
18:00	-	19:00	1.309	0.77	4.540	0.25	6.485	0.30
19:00	-	20:00	2.829	0.92	3.519	0.26	5.028	0.31
20:00	-	21:00	2.333	0.78	4.934	0.18		
21:00	-	22:00	1.118	0.64				
22:00	-	23:00	1.448	0.43				
23:00	-	00:00	0.573	0.27				

5. Conclusion

Pertashop Banaran, Pertashop Nongkosawit, and Pertashop Kanfer Raya have different arrival patterns. The peak hour for Pertashop Banaran service occurs in the afternoon from 04:00 pm to 05:00 pm with 83 vehicles. Pertashop Nongkosawit occurs in the morning, namely 06:45 am to 07:45 am, namely 55 vehicles and Pertashop Kanfer Raya has peak service hours in the afternoon, 06:30 am to 07:30 am, 80 cars.The traffic characteristics of the road around Pertashop follow the Underwood model which indicates that the traffic flow on the road around Pertashop is hindered by the attracted vehicles going to Pertashop. The type of road around Pertashop is a two-lane undivided road. This results in cars from the opposite flow having to stop in the middle of the road to enter Pertashop, thus hindering the traffic flow on that road section. Based on the analysis of the effect of Pertashop's service pattern on the DS value of surrounding roads, Pertashop Banaran has the highest DS value, in contrast to the other two Pertashops, this is because the road section around Pertashop Banaran is filled with commercial buildings and adjacent to Semarang State University (UNNES), leading to more side obstacles that affect the capacity of the road section around Pertashop Banaran greater than the other two Pertashops. The degree of saturation of the road section in front of Pertashop Banaran, Nongkosawit, and Kanfer Raya has a value of 0.9, 0.61 and 0.54 in the peak hour. Although the road sections around Pertashop Banaran have a DS value > 0.9 in the peak hour, the Pertashop only affects 2.59%. so it is necessary to consider the traffic conditions on the road sections around the Pertashop in the planning of Pertashop development, especially on roads with commercial buildings such as Pertashop Banaran by adding minimum road section width criteria to the Pertashop development requirements with the same typology.

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