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The Relationship Between Traffic Characteristics on Road Segments in Commercial Areas (Case Study: Basuki Rahmat Street, Palu City)

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Keywords
Greenshields; Greenberg; Underwood; Traffic Characteristics.

Abstract
Commercial areas generate substantial traffic movements that influence traffic flow characteristics on urban roads. Basuki Rahmat Street in Palu City is one of the city's primary commercial corridors, experiencing increasing traffic activity that affects the relationships among traffic volume, speed, and density. This study aimed to analyze the relationships between traffic volume and speed, traffic volume and density, and speed and density, as well as to determine the most appropriate traffic flow model for Basuki Rahmat Street, Palu City. Traffic volume and speed data were collected through field surveys conducted during peak periods and were analyzed using the Greenshields, Greenberg, and Underwood traffic flow models. Road performance was evaluated in accordance with the Indonesian Road Capacity Guidelines (Pedoman Kapasitas Jalan Indonesia [PKJI]) 2023 using road capacity, degree of saturation, and Level of Service (LOS) indicators. The results indicated that the peak traffic volume reached 1,015 passenger car units (pcu)/hour, while the road capacity was 5,630.4 pcu/hour, with a degree of saturation of 0.18, corresponding to Level of Service (LOS) B, which indicates stable traffic flow conditions. The analysis of traffic flow characteristics showed that increases in traffic volume and density resulted in a reduction in vehicle speed. Among the three traffic flow models evaluated, the Greenshields model provided the closest representation of the observed traffic conditions and the PKJI 2023 parameters, with a maximum traffic volume of 1,505.51 pcu/hour, an optimum speed of 57.96 km/h, and a traffic density of 28.98 pcu/km. Therefore, the Greenshields model was identified as the most appropriate model for describing the traffic flow characteristics of the commercial corridor along Basuki Rahmat Street, Palu City.

INTRODUCTION

The growth of commercial activities in urban areas increases traffic demand and has the potential to reduce road performance (Adil, 2025; Andika et al., 2022; Dikshit et al., 2023; Geremew, 2026; Karimi et al., 2022; Subair et al., 2024; Yang et al., 2023). Basuki Rahmat Street in Palu City is one of the city's primary commercial corridors, characterized by high traffic volumes, on-street parking activities, and frequent vehicle movements into and out of commercial premises, all of which contribute to roadside friction and influence traffic flow conditions. The relationships among traffic volume, speed, and density are fundamental parameters for analyzing traffic flow characteristics, road capacity, and Level of Service (LOS). Changes in one parameter inevitably influence the others; therefore, an appropriate traffic flow model is required to accurately describe these relationships (Chen et al., 2022; Huang et al., 2023; Liang et al., 2022; Shepelev et al., 2023; Sun et al., 2023). The Greenshields, Greenberg, and Underwood models are among the most widely used theoretical

models for analyzing the relationships among traffic volume, speed, and density (Aisyah & Arsyad, 2024; Andargie & Abedela, 2024; Bello et al., 2024; Kurniati et al., 2024; Nugroho & Puspito, 2025; Respati et al., 2025). However, their suitability varies according to the characteristics of individual road segments. Accordingly, this study aims to analyze these relationships on Basuki Rahmat Street, Palu City, using the three traffic flow models and to evaluate road performance based on the Indonesian Road Capacity Guidelines (Pedoman Kapasitas Jalan Indonesia [PKJI]) 2023. The findings are expected to provide practical input for traffic management and planning in urban commercial areas (Dhanasekaran et al., 2024; Jin et al., 2022; Mohsen, 2024; Musa et al., 2023; Nigam et al., 2023; Raihan et al., 2024).

The urgency of this study is highlighted by several factors that warrant timely investigation. Palu City has continued to experience economic growth, as reflected in the expansion of commercial facilities along Basuki Rahmat Street, including hotels, shopping centers, and banking services (Bahar et al., 2025). The concentration of these facilities has increased travel demand and vehicle movements, thereby adding traffic pressure to the corridor and influencing its operational performance (Bahar, Abuleb, & Ramlan, 2025). Furthermore, the transition from the Indonesian Highway Capacity Manual (Manual Kapasitas Jalan Indonesia [MKJI]) 1997 to PKJI 2023 requires updated analyses to ensure that traffic engineering and management decisions are based on current national standards. The lack of comprehensive traffic flow modeling for this important corridor creates uncertainty in transportation planning and operational decision-making. Without a robust understanding of the relationships among traffic volume, speed, and density, strategies to mitigate congestion, optimize road capacity, and improve Level of Service may rely on incomplete evidence. Therefore, this study provides empirical findings to support evidence-based traffic management in Palu City.

The novelty of this study lies in its comprehensive evaluation of the three principal traffic flow models—Greenshields, Greenberg, and Underwood—applied specifically to Basuki Rahmat Street using the latest PKJI 2023 framework. Unlike previous studies that primarily focused on road performance indicators, such as the degree of saturation and Level of Service, this research examines the underlying mathematical relationships among traffic volume, speed, and density that determine these performance measures. Comparing the three models enables the identification of the model that best represents the traffic characteristics of a commercial corridor in a developing Indonesian city. In addition, this study provides calibrated model parameters that may be applied to future traffic forecasting and traffic management analyses. The integration of field survey data with PKJI 2023 parameters also represents a methodological contribution that can be replicated in other urban commercial corridors. Accordingly, this study offers new insights into the application of classical traffic flow models to a road segment experiencing rapid commercial development and increasing traffic demand, thereby contributing to urban transportation planning in rapidly growing Indonesian cities.

The purpose of this study is to analyze the relationships among traffic volume, speed, and density on Basuki Rahmat Street, Palu City, using the Greenshields, Greenberg, and Underwood models and to determine the model that most accurately represents the traffic flow characteristics of this commercial corridor. This research contributes to a better understanding of traffic flow dynamics in urban commercial areas by providing empirical evidence regarding the suitability of different traffic flow models for specific roadway characteristics. The findings

are expected to benefit transportation planners, traffic engineers, and policymakers by providing calibrated model parameters for traffic forecasting, road capacity analysis, and congestion management. Furthermore, the results may serve as a reference for similar studies in other Indonesian cities with comparable commercial land-use characteristics. The use of PKJI 2023 ensures that the analysis is consistent with current national standards, thereby enhancing the practical relevance and applicability of the research findings.

METHOD

A preliminary survey was conducted to collect field data and prepare for the main data collection. The survey was used to determine the survey schedule, data collection procedures, and observation requirements.

a. Geometric Data

The geometric characteristics recorded for the Basuki Rahmat Street road segment included:

- Road type
- Lane width
- Effective shoulder width
- Pavement surface condition

b. Traffic Volume Survey

The traffic volume survey was conducted to identify vehicle classifications, traffic volume, and directional distribution. The survey collected the following data:

- Vehicle classifications
- Directional distribution
- Average traffic volume

c. Travel Time Survey

The travel time survey was conducted to determine the observation section length and collect travel time data for estimating the average space mean speed

4. Subjects and Objects of Research

The subject of this study is the analysis of the relationship between volume, speed, and road density using the Grennshields, Greenberg, and Underwood models. The planning object is Jalan Basuki Rahmat, as shown in the figure below:

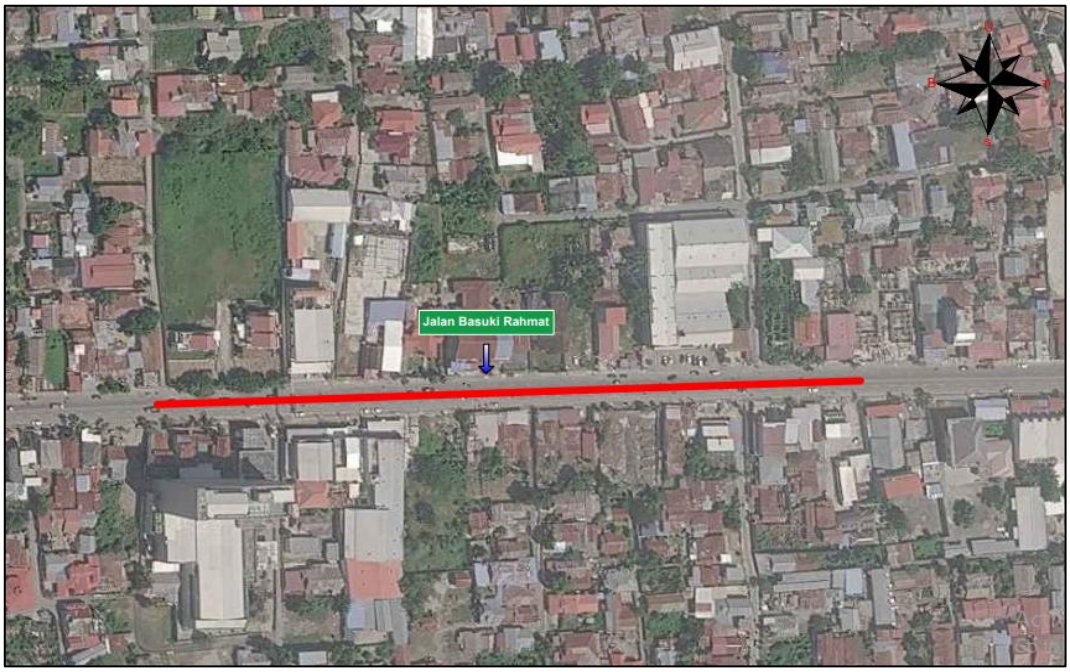

Figure 1. Research Location, Jl. Basuki Rahmat
Source: Google Maps

The data sources for this study consist of primary and secondary data. Primary data is data obtained directly by the researcher through field recording and measurements, while secondary data is data obtained from third parties.

Primary Data

Primary data is obtained directly from observations, measurements, and recordings in the field at the research location. The types of primary data collected include:

1. Geometric Data
   Road geometry data is obtained based on the results of observations and measurements in the field, which include the width of the traffic lane, number and width of lanes, shoulder conditions (sidewalks), signs and road markings.
2. Traffic Volume
   Traffic volume data is obtained from LHR calculations on road sections .
3. Side Obstacles
   Roadside activities that affect the smooth flow of traffic, including pedestrians crossing, vehicles stopping/parking, vehicles entering and exiting access.
4. Speed
   This survey was conducted to determine the average speed of each vehicle per 50 meters within the study area. This instantaneous speed survey was intended to determine the average speed of vehicles passing through a specific road section.

Secondary Data

Secondary data was obtained from technical agencies and literature references that support conceptual understanding and field context. The secondary data used include:

1. Land Use Map
2. Vehicle Number Data
3. Location map

RESULTS AND DISCUSSION

A traffic performance analysis on Jalan Basuki Rahmat in Palu City was conducted to determine the operational traffic conditions in a commercial area with high vehicle movement activity. The main parameters used in this analysis include traffic volume, vehicle speed, and traffic density, which are the main indicators in describing the characteristics of traffic flow on a road section. The following are the results of the analysis conducted on the Basuki Rahmat section.

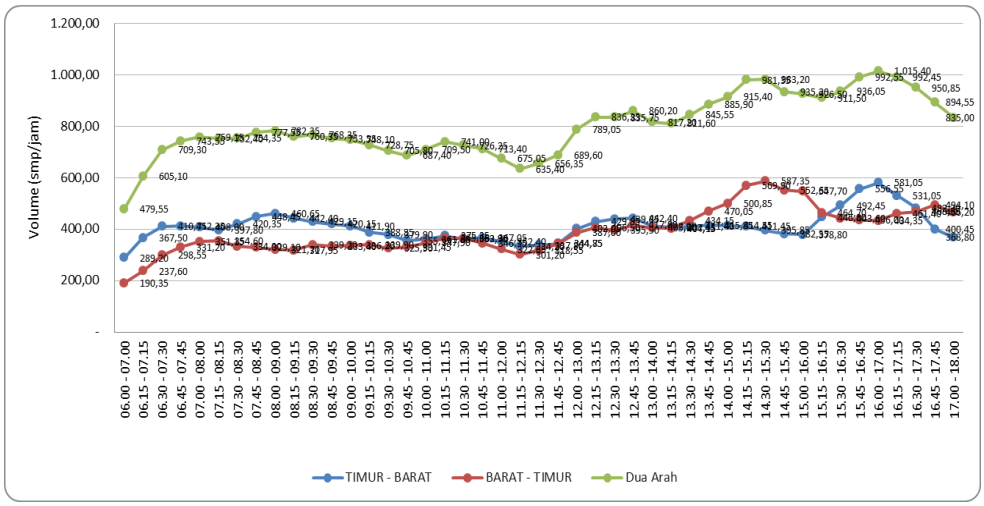

Figure 2. Traffic Volume Graph of Jalan Basuki Rahmat

Road Section Capacity Analysis

C = Co x FCLJ x FCPA x FCHS x FCUK

C = 6800 x 1.00 x 1.00 x 0.92 x 0.90

C = 5630.4 smp/hour

Therefore, the capacity of Jalan Basuki Rahmat is 5,630.4 smp/hour. This means that Jalan Basuki Rahmat has a flow rate no higher than the maximum flow.

Greenshield Linear Regression Model

Based on the data on volume, density and speed of vehicles that have been obtained, then analyzed using linear regression, the following results were obtained:

Table 1. Results of the Greenshield Linear Regression Model

Connection	Equality
GREENSHIELD METHOD	
Vs – D	$57{,}96 - \frac{57{,}96}{103{,}19}\ x\ D$
V – D	$103{,}19\ V_s - \frac{103{,}19}{57{,}96} V_s^2$
V - Vs	$57{,}96\ x\ V_s \frac{57{,}96}{103{,}19} D^2$

Greenberg's Logarithmic Model

Based on the data on volume, density and speed of vehicles that have been obtained, then analyzed using logarithmic regression, the following results were obtained:

Table 2. Results of the Greenberg Logarithmic Model

Connection	Equality
GREENBERG METHOD	
Vs – D	$1851Ln\left(\frac{1100}{D}\right)$
V – D	$1851.D.Ln\left(\frac{1100}{D}\right)$
V - Vs	$V_s\ x\ 1100\ x\ e\ \frac{-V_S}{1851}$

Underwood Exponential Model

Based on the data on volume, density and speed of vehicles that have been obtained, then analyzed using exponential regression, the following results were obtained:

Table 3. Results of the Underwood Exponential Model

Connection	Equality
UNDERWOOD METHOD	
Vs – D	$60{,}25\ .\exp\left(\frac{-D}{77{,}84}\right)$
V – D	$V_s.77{,}84.L_n\frac{(60{,}25)}{V_s}$
V - Vs	$D.\ 60.27exp\frac{(-D)}{77{,}84}$

Capacity Calculation

Then the maximum 2-way volume (Vmax) is obtained which is the road capacity, which can be seen in the table below.

Table 4. Calculation of Maximum Volume of Model Capacity and PKJI

Connection	Max Volume (smp/hour)	Speed (km/h)	Density (smp/km)
Greenshield	1505	57.96	28.98
Greenberg	1788	12.97	112.13
Underwood	1730	22.23	77.84
PKJI	1015	45.06	22.52

CONCLUSION

Based on the research findings, several conclusions can be drawn. The road performance analysis of Basuki Rahmat Street in Palu City, conducted in accordance with the Indonesian Road Capacity Guidelines (Pedoman Kapasitas Jalan Indonesia [PKJI]) 2023, indicated a road capacity of 5,630.4 passenger car units (pcu)/hour, a peak traffic volume of 1,015 pcu/hour, and a degree of saturation of 0.18. These results corresponded to Level of Service (LOS) B, indicating stable traffic flow conditions. The relatively low degree of saturation suggests that the existing road capacity was sufficient to accommodate current traffic demand. However, roadside friction generated by commercial activities may pose challenges to maintaining this level of performance as traffic demand increases.

Several recommendations are proposed for future research. First, longitudinal studies examining changes in traffic characteristics over time would provide valuable insights into the evolution of traffic patterns associated with commercial development and economic growth in

Palu City. Second, extending the analysis to include additional traffic flow models, such as the Drake model or multi-regime traffic flow models, may provide a more comprehensive understanding of traffic flow relationships, particularly under higher levels of congestion. Third, comparative analyses of weekday and weekend traffic conditions would help identify variations associated with commercial activity patterns. Fourth, the effects of specific commercial activities, such as market days or special events, on traffic flow characteristics warrant further investigation. Fifth, applying the proposed methodology to other commercial corridors in Palu City would facilitate comparative analyses and help identify location-specific factors influencing the suitability of traffic flow models. Finally, integrating traffic flow modeling with transportation planning tools, such as microscopic or mesoscopic traffic simulation models, would enhance the practical applicability of the findings. These research directions would contribute to a more comprehensive understanding of traffic flow characteristics in urban commercial areas across Indonesian cities.

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