PAPER • **OPEN ACCESS**

Comparative analysis of vehicle speed on arterial roads with the greenshield model approach

To cite this article: Hendrata Wibisana *et al* 2025 *IOP Conf. Ser.: Earth Environ. Sci.* **1454** 012053

Comparative analysis of vehicle speed on arterial roads with the greenshield model approach

Hendrata Wibisana[1,*], Fithri Estikhamah[1], Nova Nevila Rodhi[2], Zainuddin[3]

[1]Departement of Civil Engineering, Faculty of Engineering and Science, Univertas Pembangunan Nasional "Veteran" Jawa Timur, Surabaya, East Java, 60294, Indonesia
[2]Civil Engineering Department, Faculty of Engineering and Science, University of Bojonegoro, Indonesia

*E-mail: hendrata.ts@upnjatim.ac.id

Abstract. Vehicle speed plays an important role in the traffic flow and road density. This parameter is often researched to obtain a model of the characteristics of an existing road section. This study aims to analyze vehicle speed on arterial roads using the Greenshield Model approach, which is a fundamental traffic model that describes the relationship between traffic density and vehicle speed. Through the collection of field data and statistical analysis, vehicle speed patterns and factors influencing them can be identified. The method used is t distribution analysis with the Greenshield Model approach to see the comparison of vehicle speed values on the Kenjeran highway and Kertajaya Indah road sections. The results show that the Greenshield Model can be effective in predicting traffic speeds on arterial roads, providing insights for better transportation planning and road design. Furthermore, the mathematical equation that can be produced on arterial roads is with an average speed value of 26.9 km/h and a standard error of 0.504 and an R2 correlation of 0.658. The conclusions of this study offer guidance for urban planners and transportation engineers in optimizing traffic flow and improving road user safety y=32.282-0.0347x.

1.Introduction

Arterial highways in big cities like Surabaya play a vital role in connecting various areas and supporting high mobility. Traffic characteristics on arterial highways are often complex due to the high volume of vehicles and the variability of travel patterns. The study of traffic behavior on arterial roads provides important insights for transportation planning, congestion reduction, and traffic safety improvement (1–3). This research was carried out in an effort to find an appropriate mathematical model that can describe the traffic flow to the speed of vehicles and the density of vehicles in the arterial road section, where the selected road section is an arterial road section that has a sufficient road width for traffic that has a high degree of saturation but is still within the limit where the congestion is not too significant because for a situation of total congestion, the Greenshield theory model is not can be done (4–6). The Greenshield model is one of the fundamental models in traffic flow theory that describes the relationship between vehicle speed and density with linear assumptions. This model is useful for predicting traffic behavior and planning traffic management (7,8). This model is believed to be an alternative in the completion

of traffic speed and volume-based traffic models. This model prioritizes the development of algorithms in traffic flow. In the context of traffic modeling, algorithms that use the Greenshield model usually involve steps such as entering the speed, density, and flow data of the road network to be modeled. Data is obtained from traffic monitoring systems using checkers, stopwatches and others. Next, the model is calibrated, namely determining the model parameters, such as free current velocity (Sff) and saturation density (Dj), based on the data collected. This involves fitting existing data with model equations to get the most appropriate parameter values (9,10)). For traffic simulation this research using the greenshield approximation where in using the Greenshield model to simulate traffic flow based on various density and traffic flow scenarios. These algorithms can help predict how changes in density will affect the speed and flow of traffic (11–13).

This model can be used by traffic planners to optimize road networks, design traffic management policies (14–17), and estimate the impact of changes in infrastructure or traffic patterns, which with the speed of free flow known from the empirical formula can predict the speed of vehicles in real time on the highway so that one of the efforts to minimize the impact of congestion is to install speed signs that must be met by passing vehicles.

The novelty of this study is built on the basis of the awareness of the researcher that the road section that is compared has not touched the analysis of vehicle speed between one road and another which has a similar road situation so that a simple method such as Greenshield is to be tried as a first step to predict the comparison of vehicle speed that occurs on both Kenjeran road and Kertajaya Indah road section.

2. Materials and Method

2.1. Research Location

The location for vehicle measurements takes the Kertajaya Indah highway and the Kenjeran Highway section, where these two road sections are the main roads in the city of Surabaya which are congested with vehicle traffic. This road section during the morning and evening rush hours often experiences congestion, but vehicles can still move slowly. In this study, to avoid congestion, measurements were taken at 10 a.m. where vehicles passing on the road were not too crowded.

The research method involves collecting empirical data on the speed and density of vehicles at the study site. Data is collected through field surveys and automated measuring devices during peak traffic periods. Data analysis was carried out using the Greenshield model to estimate the relationship between vehicle speed and density. Furthermore, model calibration is carried out to adjust to the specific conditions of Kertajaya road. Key parameters such as free current velocity and saturation density are determined through linear regression.

2.2. Volume Measurement

Traffic volume is measured by making observations every 15 minutes, where after the 15 minutes the total number of vehicles is recorded and collected until the total measurement time is 4 hours so that later 16 traffic volume data will be obtained. The measurement results are expressed in vehicles per hour which will be converted into passenger car units per hour. Measurement aids are used by checkers that are used for passing vehicle units.

2.3. Vehicle Speed Measurement

The speed of the vehicle is measured with a stopwatch measuring device within a span of 50 meters that has been marked beforehand, so that the passing vehicle is measured by looking at

the front and rear wheels of the vehicle that hit the limit of the sign, the speed observation value is seconds per 50 meters and after that it is converted into units of km/h.

2.4. Comparative Analysis

The comparative analysis was carried out after obtaining descriptive data from the Greenshield model on the Kertajaya road section and the Kenjeran road section. The data compared here is the density data of vehicles on Kertajaya and Kenjeran roads. After that, the free flow speed of the two road sections is compared by comparing the value of the free flow speed or Sff.

3. Results and Discussion

The results obtained from field observations for the Greenshield model obtained vehicle density data obtained from traffic volume divided by vehicle speed at each observation time. The results obtained are presented in Figure 1 for the Kenjeran Highway section.

Table 1. Vehicle density data on Kenjeran and Kertajaya Indah roads

Kenjeran Road	Kertajaya Road
Density (pcu/km)	**Density (pcu/km)**
143	240
128	182
178	165
218	202
220	101
120	122
126	173
95	192
140	237
162	181
169	174
118	186
120	236
157	197
212	225
167	137

From the results of the linear regression calculation for speed to density, a regression equation model is obtained: y=32.282-0.0347x, where x is the density of vehicles per kilometer of Kenjeran highway while y is the speed of vehicles on Kenjeran roads. From the regression equation, the value of the free current velocity and the maximum current density value can be calculated, namely for the free current velocity is Sff = 32,282 km/h while the saturated current density Dj = 929.6 pcu/km

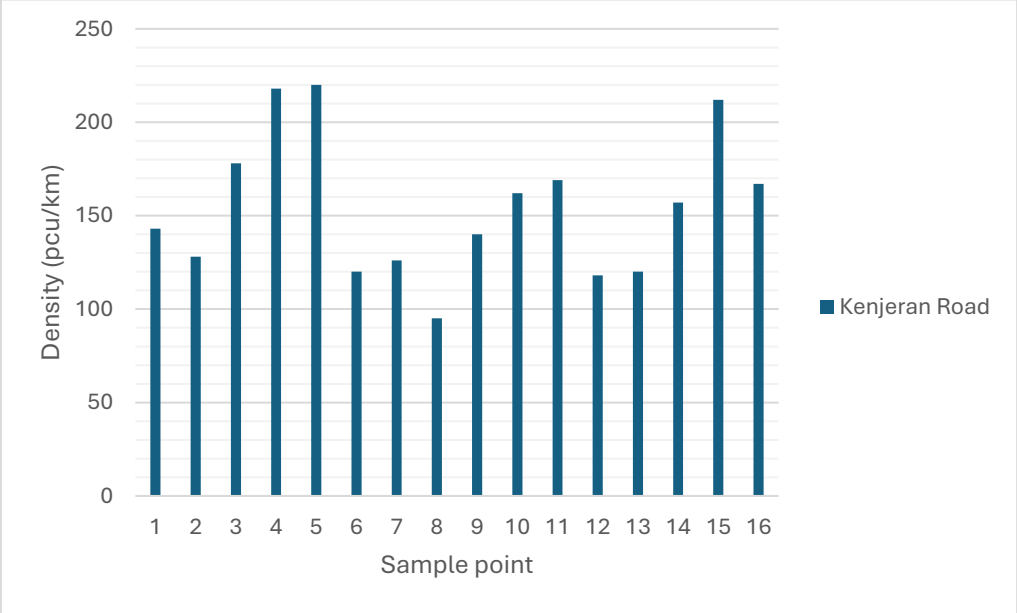

Figure 1. Results of vehicle density measurements on the Kenjeran Highway section on April 14, 2024

For density data on the Kertajaya Indah road section, it can be seen in Figure 2, where in the figure the measurements of the 1,9, 13 and 15 times have a high density value above the value of 200 pcu/km.

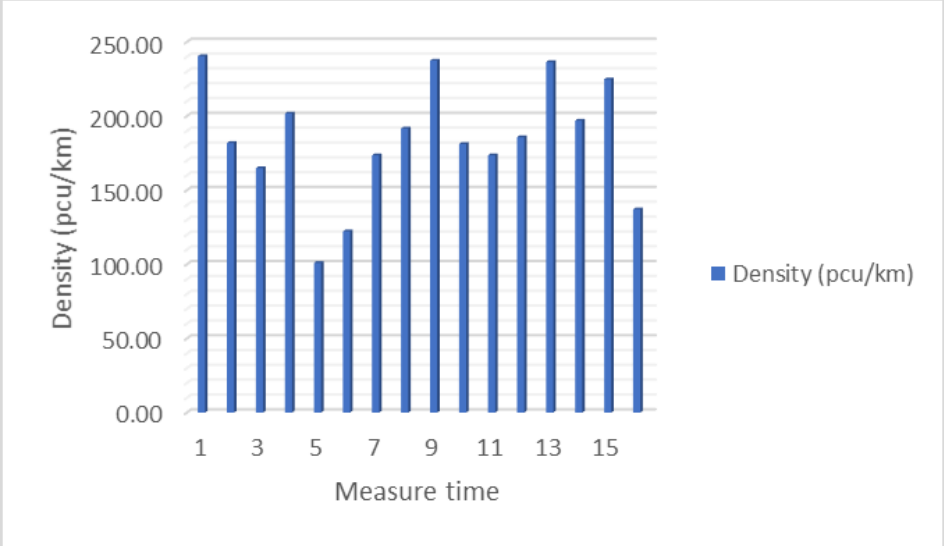

Figure 2. Results of vehicle density measurements on the Kertajaya Indah road section on April 14, 2024

Measurements with linear regression for the greenshield model on the Kertajaya Indah road section obtained an equation model: S=32,324-0,0391D, where D is the density of vehicles per kilometer of the Kertajaya Indah road section and S is the speed of vehicles passing on the highway section. From the results of the linear regression, it can be known that the value of the free flow speed on the Kertajaya road section is Sff = 32.324 km/h while for the density at the time of saturated flow is obtained Dj = 824 pcu/km.

For the comparative analysis of vehicle speed values on the Kenjeran road and Kertajaya Indah road sections, a t distribution is used where this distribution will compare the average values and variances of both speed measurements for the optimal speed analysis, and the results obtained from the calculation of the t distribution are obtained:

Table 2. Comparison of vehicle speed data on Kenjeran and Kertajaya Indah roads.

	Kenjeran Road Speed (km/h)	***Kertajaya Indah Road Speed (km/h)***
Mean	26,91	25,10
Variance	4,0638	4,1053
Observations	16	16

By using the analysis of the t distribution, the value of t calculation or t-stat = 2.317 was obtained, while the value of the T table or t-crit = 1.753 so that it can be said that the value of the calculated T is greater than the value of the T table so that the hypothesis is rejected so that the two speed measurements on different road sections have a difference in the average speed of the vehicle

From the analysis of the t distribution, the value of t calculation or t-stat = 2.317 was obtained, while the value of the T table or t-crit = 1.753 so that it can be said that the value of the calculated T is greater than the value of the T table so that the hypothesis is rejected so that the two speed measurements on different road sections have a difference in the average speed of the vehicle.

4. Conclusion

An understanding of traffic flow theory, specifically the Greenshield model, and its calibration using empirical data is essential for traffic analysis and management on arterial roads in big cities like Surabaya. With an average speed of 26.9 km/h and a standard error of 0.504, continuous efforts are needed to improve traffic performance through infrastructure improvements and the implementation of smart technology. Further studies can provide specific recommendations for more effective traffic planning and management. This research contributes to the literature on traffic flow models by providing empirical data that supports the use of the Greenshield model in arterial road conditions in large cities. These findings also offer a basis for the development of better transportation policies to overcome the challenges of congestion in urban areas, especially in big cities such as Surabaya.

5. Acknowledgment

The researcher expressed his gratitude to the Civil Engineering study program of UPN Veteran East Java for providing measurement equipment facilities and borrowing a computer modelling laboratory so that this research can run well and correctly, as well as to civil engineering students who have helped in obtaining traffic volume measurement data

6. References

1. Aulia Sari Y, Gajah Mada J, Permai B, Ladi S, Sekupang K, Batam K, et al. Pengaruh gerak u-turn pada bukaan median terhadap karakteristik arus lalu lintas di ruas jalan raja h.

Fisabililah. Jurnal Teknik Sipil [Internet]. 2022 May 27 [cited 2022 Oct 11];16(4):302–11. Available from: https://ojs.uajy.ac.id/index.php/jts/article/view/5468
2. Wibisana H. Studi Hubungan Arus Lalu Lintas di Ruas Jalan Rungkut Asri Kota Madya Surabaya Dengan Metode Underwood. Jurnal Teknik Sipil [Internet]. 2007 [cited 2019 Jul 15];3(2):103–12. Available from: https://journal.maranatha.edu/index.php/jts/article/view/1282
3. Wibisana H, Utono N. Pemetaan Kecepatan dan Kerapatan Lalu Lintas di Ruas Jalan Arteri Kota Surabaya. Jurnal Teknik Sipil [Internet]. 2016 [cited 2019 Jul 15];12(2):121–45. Available from: https://journal.maranatha.edu/index.php/jts/article/view/1420
4. Wibisana, Hendrata. Analisa Tingkat Pelayanan Jalan Kawasan Kecamatan Rungkut Dengan Pemetaan Sistem Informasi Geografis. Kern : Jurnal Ilmiah Teknik Sipil [Internet]. 2011 [cited 2019 Jul 11];1(2). Available from: http://ejournal.upnjatim.ac.id/index.php/kern/article/view/1333
5. Sever D. Traffic engineering Highway Capacity Manual Transportation - Traffic engineering. 2015;(Hcs 2010):1–34.
6. Maerivoet S. Modelling Traffic on Motorways: state-of-the-art, numerical sata analysis and dynamic traffic assignment. Traffic. 2006.
7. Wibisana H., Utomo N. WD. Analisa Perlambatan Kecepatan Kendaraan di Penghujung Traffic Light Perempatan Jalan Dengan Menggunakan Persamaan Differensial Derajad Satu. (Studi Kasus Ruas Jalan Ir.H.Soekarno – Kertajaya Indah Surabaya). Aplikasi Teknik Sipil. 2017;15(2):61–6.
8. Ossenbruggen P, Laflamme E, Linder E. Congestion Probability and Traffic Volatility. Transportation Research Record: Journal of the Transportation Research Board. 2012;
9. Tamin OZ. Perencanaan dan Permodelan Transportasi, contoh soal dan aplikasi. First Edit. Bandung: ITB; 2003. 467 p.
10. Kustarto H, Wibisana H. Studi pendahuluan pemodelan arus lalu lintas di ruas jalan rungkut asri kota madya surabaya dengan metode underwood. Kern : Jurnal Ilmiah Teknik Sipil [Internet]. 2013 [cited 2019 Jul 11];2(2). Available from: http://ejournal.upnjatim.ac.id/index.php/kern/article/view/1373
11. Baur J, Dewey K, Steinberg G, Nitsche FO. Modeling the Effect of Vegetation Coverage on Unmanned Aerial Vehicles-Based Object Detection: A Study in the Minefield Environment. Remote Sens (Basel). 2024 Jun 7;16(12):2046.
12. Tscharaktschiew S, Evangelinos C. Optimal Transport Pricing in an Age of Fully Autonomous Vehicles: Is It Getting More Complicated? Future Transportation. 2022 Apr 6;2(2):347–64.
13. Lee J, Huang H, Wang J, Quddus M. Road safety under the environment of intelligent connected vehicles. Accid Anal Prev. 2022 Jun 1;170:106645.
14. He J. Rethinking Traffic Management : Design of Optimizable Networks. 2008;(June).
15. N. SS, I. N, S. S. Multi-Objective Human Resource Allocation Approach for Sustainable Traffic Management. Int J Environ Res Public Health. 2020 Apr 1;17(7).
16. Rosenow J, Asadi E, Lubig D, Schultz M, Fricke H. Long Range Air Traffic Flow Management with Flight-Specific Flight Performance. Future Transportation. 2022 Mar 29;2(2):310–27.
17. Wang H, Meng Q, Wang J, Zhao D. An electric-vehicle corridor model in a dense city with applications to charging location and traffic management. Transportation Research Part B: Methodological. 2021 Jul 1;149:79–99.