Journal of UTEC Engineering Management
Volume 02, Issue 01, 2024,91–99
https://doi.org/10.36344/utecem.2024.v02i01.008
Research Article

Capacity Reduction for Urban Road Due to Curbside Bus Stop: A Case Study of Srijana Chowk, Nepal

Suraj Thapa[1], Hemant Tiwari[2], Madhav Joshi[3]

[1]Freelance, Transport Engineer,

[2]General Secretary, Society of Transport Engineers Nepal (SOTEN)

[3]Freelance, Civil Engineer

INFO

Corresponding Author

Hemant Tiwari

Email

hemu.ioe@gmail.com

Article History

Received: 30 April 2024

Accepted: 18 June 2024

Orcid

https://orcid.org/0000-0003-4409-1787

DOI

https://doi.org/10.5281/zenodo.13169951

ABSTRACT

Curbside bus stops have a significant impact on traffic characteristics, including speed and roadway capacity. Srijana Chowk, the urban area within Pokhara metropolitan city, was selected for the study. The objective of the study is to evaluate the reduction in roadway capacity at the curbside bus stop at Srijana Chowk. The primary data was collected using videographic techniques. The analysis indicated that Srijana Chowk's curbside bus stop caused an average stream speed reduction of 6.23%. The capacity at the Srijana Chowk bus stop was 2532 PCU/hr and 2718 PCU/hr at the curbside and on the opposite side of the bus stop, respectively. Similarly, the capacity reduction was analyzed to be 16.62% and 6.84% by the Indonesian Highway Capacity Manual and Greenshield's model, respectively.

Keywords: Curbside Bus Stop, Greenshield's Model, IHCM, PCU, Road Capacity

Introduction

Bus stops are predetermined locations where passengers can board or disembark from the bus (Khatawkar and NT, 2015). They serve as the main point of access to the service schedule and transit system (Bian et al., 2015). They are places where buses load and unload passengers. They are an important part of the public transportation system. Usually, there are two types of bus stops in an urban city: curbside bus stops and bus bays (Luo et al., 2018). Curbside bus stops are the most prevalent type of bus stop all over the world (Bian et al., 2015). They are constructed on heavily trafficked urban roads where there is insufficient space for a segregated bus bay. For the curbside bus stops, buses occupy curb lanes when they load and unload passengers. The follow-up vehicles have to change lanes or wait for the end of the stopping service. Thus, the normal operation of traffic flow in curb lanes is seriously affected (Luo et al., 2018).

Roadway capacity is the maximum sustainable flow rate of passengers or vehicles over a predetermined period under predetermined conditions. It is determined by factors like traffic flow, speed, and density and quantitatively assesses traffic stream properties (Ben-Edigbe, 2011). In recent years, urban road networks have seen an increase in traffic demand and congestion, which makes it challenging for bus systems to offer sufficient transportation, particularly at stops. (Jin et al., 2019). Public transportation is the most economical means of transportation for the average person. One significant advantage of taking public transportation is that it reduces the number of vehicles on the road, which gradually lowers pollution. Pokhara's public transportation system is privately managed and serves the city as well as the surrounding townships and villages (Midun et al., 2023). Pokhara city's midblock bus stops are curbside due to space constraints, offering a cost-effective option. Factors like land use, bus routes, and intersection dynamics influence their placement. Pokhara City's population was 513,504 in 2021, growing steadily since then (CBS, 2021). To meet the growing population, the number of public and private vehicles has been increasing day by day in Pokhara City. Traffic congestion is worsening at curbside bus stops in Pokhara city as private automobiles vie for limited space with public transport. Without bus bays, bus stops reduce road width, slowing vehicles and increasing delays. Poor regulatory service management exacerbates congestion. Despite a growing number of public transport vehicles, inadequate curbside stops persist at Srijana Chowk, amplifying the problem in Pokhara city. So, a good regional-level strategy and good-quality service have become crucial for improving the public transportation sector in Pokhara (Midun et al., 2023). Common issues arise when bus drivers fail to utilize available road space effectively at curbside bus stops (Reddy, 2017). This lack of discipline reduces road capacity, impacts vehicle speed, and causes bottlenecks. Thus, studies on curbside bus stops are crucial to alleviate traffic impacts and reduce delays, especially under moderate to heavy traffic conditions (Jin et al., 2019).

Situated on a busy four-lane road that is often used by passengers, particularly those who work, the Srijana Chowk bus stop is an essential stop. It is ideal for studying how curbside bus stops impact road capacity due to their heavy traffic, which includes both private vehicles and public transportation. Therefore, the selection of this site has been crucial because of its features, which represent the dynamics of urban transportation in Pokhara City.

Objective

This study aims to evaluate the impact of curbside bus stops on the capacity of urban roads, with a concentration on the Srijana Chowk bus stop in Pokhara city. The primary goal is to quantify how the presence of this bus stop reduces road capacity under different roadway and traffic conditions and analyze traffic speed changes on both sides of Srijana Chowk. By identifying the critical factors contributing to capacity and speed reduction, the research seeks to provide a comprehensive understanding of the dynamics at play. The findings from this analysis will provide essential insights for traffic planning and management, especially in the context of curbside bus stops. These insights will assist in the development of effective strategies for managing urban roads, helping agencies make informed decisions and formulate policies to optimize traffic flow and minimize congestion in areas affected by curbside bus stops.

Methodology

This research employed a quantitative approach, framing research questions and employing statistical analysis. Data was collected from Srijana Chowk's curbside bus stop in Pokhara city, covering various vehicle types, including buses, microvans, motorcycles, cars, taxis, jeeps, utility vehicles, and trucks. Primary data encompassed traffic flow characteristics like volume, speed, composition, directional split, side friction, and geometric data such as carriageway and shoulder width. Primary data collection utilized a video graphic survey, with Station 1 at the bus stop and Station 2 opposite, and manual methods. The former involved setting up digital video recorders at strategic locations, while the latter involved field sheets. Steps included reconnaissance, trap length marking, camera installation, and recording during peak and off-peak hours over 12 hours on two working days. 15-minute classified traffic counts were made, and each vehicle category was counted separately. Sampling included 15% of the total volume for motorcycles and the entire volume for other vehicles, ensuring comprehensive data collection. A tape was used for measuring every feature in Srijana Chowk, including the 30 m bus stop length, 14 m carriageway width, 1 m shoulder width, and 2 m footpath width.

The data was recorded in Microsoft Excel and then converted to PCU/hr using PCU factors. This meticulous process ensured an accurate representation of traffic volume at a given bus stop location. Time mean speeds were computed using direct timing, with Section 1 covering the bus stop and Section 2 opposite it. Entry and exit times over 60-meter sections facilitated calculations of space-mean speeds. Density values were extracted at 60-second intervals for simplicity. Vehicles were counted every minute and converted to PCU per 60 m. The average density for each 15 minutes was calculated from these values, streamlining data collection and analysis. Speed-density relationships were calibrated and validated using Greenshield's model. Twelve hours of data were utilized: nine hours for calibration and three for validation. Each point represented 15-minute averages, resulting in 36 points for calibration and 12 for validation. Excel and Solver facilitated calibration, assessing correlation via the R2 value. A linear relationship between speed and density was established. This relationship determined free flow speed, jam density, and capacity at each side of the bus stop.

Road capacity at and opposite Srijana Chowk bus stop was estimated using calibrated and validated speed-density models derived from the Greenshields model. Excel and Solver aided model development, ensuring a linear equation. Actual capacities were calculated using this equation. ANOVA tests assessed differences between actual and calibrated capacities, with t-statistics, p-values, and t-critical values from t-distribution tables at a 95% confidence level determining significance. The comparison revealed capacity reductions at both locations, confirming the model's applicability.

Analysis of Capacity Based on Indonesian Highway Capacity Manual

The formula used for the calculation of capacity of the road has been taken from IHCM (1993). The value of base capacity has been taken from (Nurs-2076-Final.), and coefficients from (IHCM, 1993) tables.

$$C = Co*Fw*Fks*Fsd*Fsf*Fcs \quad \text{.............(1)}$$

Where, C = Capacity (PCU/hr.)

Co = Base Capacity (PCU/hr.)

Fw = Carriageway width adjustment factor

Fks = Kerb and shoulder adjustment factor

Fsf = Side Friction adjustment factor

Fsd = Directional split adjustment factor

Fcs = City size adjustment factor

The respective values of Fsf and Fcs are listed in Table 1.

Table 1

Adjustment Factor for Friction Item

No.	Friction item	Side friction quantity				
		Very low	Low	Medium	High	Very High
1.	Pedestrian walking(ped/h)	0	0-80	80-120	120-220	>200
2.	Pedestrian crossing(ped/h/km)	0	0-200	200-500	500-1300	>1300

Surce-IHCM 1993

Table 2

Determination of the Range of Side Friction Factors

Side friction class	Very low	low	Medium	High	Very high
Fsf	1.00	1.00	0.97	0.90	0.86

Source-IHCM 1993

Table 3

Adjustment Factor for City Size

City Size (Population in million)	<0.5	0.5-1.0	1.0-3.0	>3.0
Fcs	0.80	0.86	1.00	1.03

Source-IHCM 1993

Literature Reviews

Effective bus bays are essential for urban convenience, minimizing congestion and wait times. In Pokhara, curbside stops serve buses, microbuses, and vans, vital for a city experiencing rapid growth (Muzzini and Aparicio, 2013). Traffic accidents in Nepal are mainly caused by factors like traffic volume and speed. To decrease accidents, a thorough examination of these factors is crucial for road safety (Tiwari & Luitel, 2023).

Highway capacity is the maximum flow rate at which vehicles or persons can travel, influenced by traffic, roadways, and control conditions (TRB, 2010). The average speed of vehicles across a particular distance is called the space mean speed (Reddy, 2017). For actual capacity calculation, IHCM (1993) adjusts ideal factors using adjustment factors for road conditions in developing countries. Capacity estimation is essential for the design, planning, operation, and design of road network sections. For capacity estimation, there are different direct and indirect empirical methods (Jain et al., 2020). The nature of traffic flow can be modeled to identify the type of traffic, which helps in making transportation planning decisions. There are fundamentally two classifications of these models, which include macroscopic and microscopic models (Bello et al., 2024). Macroscopic traffic flow models integrate microscopic models to formulate relationships among traffic flow characteristics, facilitating system-level analysis (Di Francesco and Rosini, 2015). Microscopic simulation methods can produce accurate estimations of speed-flow relationships since these models account for each vehicle's movement on a road (Arun et al., 2013). These models include Greenshields's, Greenberg's logarithmic, and Underwood's exponential, among others (Wijanarko, 2023).

Greenshield's model predicts uninterrupted traffic flow trends by relating speed to density. The R2 value obtained from Tiwari and Marsani (2014) was comparable to the value observed in Greenshield's model. The Greenshields model gives a marginally better goodness of fit compared to the other two models (Underwood and polynomial) both at calibration and validation (Gautam et al., 2023). Therefore, Greenshield's linear model successfully fits the observed data and is useful for modeling traffic flow.

Road widening boosted capacity by 14% to 24%, as demonstrated by Chandra and Kumar (2003). Road capacity is influenced by intensity, density, and speed; critical speed and density impact flow (Van Nes et al., 2008). On-street bus stops cause significant delays, reducing free flow speed by about 30% in India, as found by Reddy et al. (2008). Bus stops significantly impact traffic flow in Beijing, with effects linked to initial density and number, as discovered by Tang et al. (2009). In Beijing expressways, studying the impact of bus bays on curb lane capacity, Kwami et al. (2009) found that capacity decreases with higher bus frequencies. Simulating eight-lane expressway traffic, finding capacity dropped by 15% without virtual lanes and reducing speeds by 7%, was conducted by Madhu and Velmurugan (2011). Assessing the impact of bus stops on bicycle and vehicle speeds in urban China, significant reductions were noted (Zhang et al., 2015). Reductions of 8.10% to 12.86% were observed when curbside bus stops were studied for their impact on urban highway capacity in New Delhi (Chand et al., 2014). Analyzing roadside bus stops in Shimoga found that they block lanes, creating bottlenecks and reducing capacity (Khatawkar and NT, 2015). Investigating the effect of traffic mix on multilane highway capacity in India, declines in the share of certain vehicle classes were discovered (Chandra et al., 2016). Formulating a model estimating road capacity in Ahmedabad, incorporating width, speed, and traffic composition, was conducted by Raval et al. (2017). When assessing road capacity reductions at curbside bus stops in Hyderabad, reductions ranging from 1200 to 1625 PCU/hr were noted (Reddy, 2017).

Results and Discussion

Speed Comparison

The average speed experienced a reduction of 6.23% because the average speed opposite the bus stop exceeded the average speed at the bus stop, as referred to in Table 1. This data highlights that at Srijana Chowk bus stop, the average speeds are lower compared to the opposite side, which indicates a reduction in speed attributable to side friction.

Table 4

Determination of the Range of Side Friction Factors

Individual Average space mean speed (Kmph)							Average Speed
Section	**Bike**	**Car**	**Taxi**	**Jeep**	**Utility**	**Truck**	
At Bus Stop	32.3	29.9	30.0	23.4	22.6	21.6	29.67 (At)
Opposite of Bus Stop	33.7	30.8	30.9	23.7	23.1	22.5	31.64 (Opposite)

4.2. Capacity Calculation Based on IHCM

Peak hour total walking pedestrians and total crossing pedestrians were 30 and 13, respectively, at Srijana Chowk, which were compared to Tables 1 and 2. Then, the side friction factor of total pedestrian walking was found in a range of 0.86 to 0.97, whereas total pedestrian crossing on carriageways varied in a range of 0.86 to 0.97 at curbside bus stops. The total number of inhabitants in Pokhara city was 513,504 as per CBS (2021). So, the city size adjustment factor was taken from Table 3 as 0.86 for Srijana Chowk. The width of the shoulder and kerb were 1 and 0.15, respectively. So, the value of Fks obtained was 0.98.

Table 5

Calculation of Directional Split Adjustment Factor (Fsd)

At Bus Stop	Opposite of Bus Stop	Proportion		Adjustment factor
Total Flow (PCU/12 hour)	Total Flow (PCU/12 hour)	At Bus Stop	Opposite of Bus Stop	
15548	17565.5	47	53	0.99

Table 6

Estimate Capacity as per IHCM

Co	Fw	FKs	Fsf	Fsd	Fcs	Capacity PCU/hr
4000	1	0.98	0.91	0.99	0.86	3037

Calibrated and Actual Capacity Based on Greenshield's Model

Greenshield's model was used to calibrate at the opposite side of the curbside bus stop. The collected data on speed, density, and volume was utilized for this calibration at Srijana Chowk's location. The resulting equation, along with its goodness-of-fit (R2) value, is closely linked to the model's accuracy. Using this equation, the linear relationship was determined and applied to compute the free flow speed and capacity.

Table 7

Calibrated Capacity at and Opposite Side of Curbside Bus Stop

Section	Calibrated Equation	R2	Free flow speed (Kmph)	Calibrated Capacity (PCU/hr)
At Bus Stop	V=-0.2852k+53.809	0.83	53.8	2538
Opposite of Bus Stop	V= -0.267k+54.255	0.89	54.3	2756

Table 8

Actual Capacity at and Opposite of Curbside Bus Stop

Section	Speed-Density equation	R2	Free flow speed kmph (kmph)	Actual Capacity (PCU/hr)
At Bus Stop	V=-0.2865k+53.865	0.82	53.9	2532
Opposite of Bus Stop	V=-0.2775k+54.925	0.88	54.9	2718

Data from 12 hours, including peak periods, was used to calculate actual capacity at Srijana Chowk.

Calibrated capacities were calculated using Greenshield's model. The observed speed data were compared with the speed obtained from the calibrated model, and based on it, the R2 value was obtained. The values obtained from the model were quite similar to those obtained from field measurement. Calibrated capacity values validate the capacity function obtained in a study region. The variation in calibrated and actual capacity, as indicated in Table 7, remains within 3%. The ANOVA test revealed a p-value of 0.488 for a two-tailed test, surpassing the significance level (α = 0.05), with the t-statistic lower than the critical t-value. Therefore, no significant difference was observed between the calculated and actual capacities.

Table 9

Percentage Variation Between Calibrated and Actual Capacity

Section	Calibrated Capacity (PCU/hr)	Actual Capacity (PCU/hr)	% Variation
At Bus Stop	2538	2532	0.2
Opposite of Bus Stop	2756	2718	1.4

Estimation of Capacity Reduction as per Greenshield's Model and IHCM

A capacity reduction of 6.84% was determined using Greenshield's model and 16.62% using IHCM at Srijana Chowk, as referred to in Table 7.

The study can be replicated at various scenarios of road and traffic characteristics to prepare the warrants of bus laybys.

Table 10

Capacity Reduction Based on Greenshield's Model and IHCM

<table>
<tr><th>At curbside bus stop</th><th>Opposite of curbsidebus stop</th><th rowspan="2">Theoretical capacity (PCU/hr) as per table 4</th><th rowspan="2">Capacity reduction (%) as per Greenshield's Model</th><th rowspan="2">Capacity reduction (%) as per IHCM</th></tr>
<tr><td>Capacity (PCU/hr)</td><td>Capacity (PCU/hr)</td></tr>
<tr><td>2532</td><td>2718</td><td>3037</td><td>6.84</td><td>16.62</td></tr>
</table>

Conclusion

This study provides a comprehensive investigation into the impact of the Srijana Chowk curbside bus stop on the urban road capacity of Pokhara city. Through meticulous capacity estimations utilizing the Indonesian Highway Capacity Manual (IHCM) and Greenshield's model, the analysis revealed a notable speed reduction of 6.23%, which subsequently led to significant capacity reductions of 16.62% according to the IHCM and 6.84% based on Greenshield's model. These findings underscore the critical implications of curbside bus stops on urban traffic flow and road efficiency, highlighting the need for strategic traffic management solutions in densely populated urban areas.

The results indicate that the current design of curbside bus stops contributes to substantial capacity losses, which can exacerbate traffic congestion and diminish the overall effectiveness of the urban transport system. Given the recent development of the Indo Highway Capacity Manual, it is evident that capacity reduction is a pressing issue that warrants immediate attention. The study recommends that curbside bus stops be managed more effectively and, where feasible, replaced with bus laybys, particularly in areas experiencing high capacity reductions. This shift could alleviate congestion and enhance traffic flow, thereby improving the overall functionality of the urban road network.

Moreover, the study suggests that future research should focus on microsimulation analyses to further explore the impacts of traffic flow dynamics in relation to curbside bus stops. Such analyses could provide deeper insights into the interactions between various traffic elements and help develop more effective traffic management strategies. The methodology employed in this study can also be replicated across different scenarios with varying road and traffic characteristics, which would be instrumental in establishing the warrants for implementing bus laybys in other urban contexts.

The findings of this research not only contribute to the existing body of knowledge on urban road capacity but also provide practical recommendations for policymakers and urban planners in Pokhara city and beyond. By addressing the challenges posed by curbside bus stops and exploring alternative designs, cities can enhance their transportation infrastructure, reduce congestion, and improve the quality of urban life for residents. As urban areas continue to grow and evolve, it is imperative that traffic management strategies adapt accordingly to ensure sustainable and efficient urban mobility.

Reference

Arun, A., Velmurugan, S., & Errampalli, M. (2013). Methodological framework towards roadway capacity estimation for Indian multi-lane highways. *Procedia-Social and Behavioral Sciences, 104*, 477–486.

Bello, M.A. (2024). Calibiration of greenberg and greenshield Model For Abuja Traffic. *3rd futlafia International Annual Conference*, p. 47.

Ben-Edigbe, J. (2011) Determining impact of bus-stops on roadway capacity. *Proceedings of the Irish transport research network*, Aug, pp. 1–7.

Bian, B. et al. (2015). Bus service time estimation model for a curbside bus stop. *Transportation Research Part C: Emerging Technologies*, *57*, pp. 103–121. https://doi.org/10.1016/j.trc.2015.06.011

CBS (ed.) (2021). *National population and housing census 2021*. Volume 01: National report. Reprint. Thapathali, Kathmandu: Government of Nepal, Office of the Prime Minister and Council of Ministers, National Statistics Office.

Chand, S., Chandra, S., & Dhamaniya, A. (2014). Capacity drop of urban arterial due to a curbside bus stop. In *International conference on sustainable civil infrastructure*.

Chandra, S., & Kumar, U. (2003). Effect of lane width on capacity under mixed traffic conditions in India. *Journal of transportation engineering, 129*(2), 155–160.

Chandra, S., Mehar, A., & Velmurugan, S. (2016). 'Effect of traffic composition on capacity of multilane highways. *Ksce journal of civil engineering, 20*, 2033–2040.

Di Francesco, M., & Rosini, M.D. (2015). Rigorous derivation of nonlinear scalar conservation laws from follow-the-leader type models via many particle limit. *Archive for rational mechanics and analysis*, *217*(3), 831–871.

Gautam, B., Adhikari, K., Tiwari, H., Pokhre, R. & Suna, R. (2023) Calibration of conventional macroscopic traffic flow models on Maitighar to Tinkune section', in. *International Conference on Engineering & Technology*, 164.

IHCM. (1993). *Indonesian highway capacity manual urban and semi-urban traffic facilities january 1993*. Directorate General of Highways Ministry OF Public Works

Jain, M.P. Ajinkya, M., Shriniwas S., Arkatkar, G.,& Joshi, J.(2020). Capacity estimation on two lane hilly roads under heterogeneous traffic condition in India. *Transportation Research Procedia, 48*, 3197–3210. https://doi.org/10.1016/j.trpro.2020.08.161.

Jin, H., Yu, J., & Yang, X. (2019). *Impact of curbside bus stop locations on mixed traffic dynamics: a bus route perspective*. *Transportmetrica A: Transport Science*, *15*(2), 1419–1439. https://doi.org/10.1080/23249935.2019.1601789.

Khatawkar, R., & NT, C. K. (2015). Impact of road side bus stops on capacity of roadway. *International Journal of Avanced Technology in Engineering and Science, 3*(7), 147–157.

Kwami, A.V., Kuan, Y.X., & Zhi, X. (2009). Effect of bus bays on capacity of curb lanes. *Journal of American Science, 5*(2), pp. 107–118.

Qingyu, L., Tianyao, Z., Wenjing, W. Hongfei, j., & Jin, L. (2018). Modeling the effect of bus stops on capacity of curb lane. *International Journal of Modern Physics* (*IJMPC*), *29*(03), 1-20.

Madhu, E., & Velmurugan, S. (2011). Estimation of roadway capacity of eight-lane divided urban expressways under heterogeneous traffic through microscopic simulation models, *International journal of science and technology education research, 1*(6).

Midun, S., Thapa, S., Regmi, S., Acharya, S., Pachhain, S., Ale, S., & Duwadi, S. (2023). Passengers flow analysis of public transit service in Pokhara. *International Journal on Engineering Technology*, *1*(1), 181–191. https://doi.org/10.3126/injet.v1i1.60942

Muzzini, E. and Aparicio, G. (2013) *Urban growth and spatial transition in Nepal: An initial assessment*. World Bank Publications.

National Research Council (U.S.). Transportation Research Board. (2010). *HCM 2010: Highway capacity manual*. Transportation Research Board. https://books.google.com.np/books?id=tzrvtqeacaaj.

Raval, N.G., Gundaliya, P., & Rajpara, G. (2017). Development of model for estimating Capacity of roads for heterogeneous traffic condition in urban area. *International Journal of Advance Research in Engineering, Science & Technology, 4*(5).

Reddy, D.R.R. (2017). Evaluation of rate of the reduction in road capacity at Kerb side Bus Stop in Urban areas under Mixed Traffic conditions – a case study in Hyderabad city. *IOSR Journal of Mechanical and Civil Engineering*, *14*(04), 01–08. Available at: https://doi.org/10.9790/1684-1404020108.

Reddy, R., Rao, S., & Rao, C. (2008). Modelling and evaluation patterns on the impact of on-street parking in reference to traffic mobility, *J Indian Roads Congr*, *69*, 101–109.

Tang, T.Q., Li, Y., & Huang, H.J. (2009). The effects of bus stop on traffic flow. I*nternational Journal of Modern Physics* C, *20*(06), 941–952.

Tiwari, H., & Luitel, S. (2023). Re-orienting towards safer roads infrastructure in Nepal. *Journal of Recent Activities in Infrastructure Science, 8*(3), 4–27.

Tiwari, H., Marsani, A. (2014). Calibration of conventional macroscopic traffic flow models for Nepalese roads: A case study of Jadibuti-Suryabinayak section. In *Proceedings of IOE Graduate Conference 2014*, Proceedings of IOE Graduate Conference 2014.

Van Nes, N., Brandenburg, S., & Twisk, D. (2008). 'Dynamic speed limits; effects on homogeneity of driving speed. In *2008 IEEE Intelligent Vehicles Symposium*. 2008 IEEE Intelligent Vehicles Symposium (IV), Eindhoven, Netherlands: IEEE, pp. 269–274. https://doi.org/10.1109/IVS.2008.4621229.

Wijanarko, D. (2023). Analysis of traffic volume on road level of service Index Using greenshield and greenberg METHODS. In *International SEMINAR*, pp. 171–179.

Zhang, F., Li, Z., Zhao, D., Wang, Y., Wang, W., & Li, J. (2015). *Influences of various types of bus stops on traffic operations of bicycles, vehicles, and buses* (No. 15-3437).