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Analysis of Traffic Speed on Urban Mid-Block Section Under the Influence of Roadside Frictions

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Abstract
The present study focuses on the effect of roadside frictions on the selected undivided urban midblock section. The objective of this study is to identify the significant variables that influence traffic speed in the mid-block section and using those significant variables creating a model for predicting the traffic speed. The analysis was based on the video graphic data collection on midblock sections of Kalimati, Gaushala, Kuleshwor and Maitidevi. The passenger car unit, traffic flow, traffic speed and the frequency of side friction variables was determined. Correlation matrix was generated for the correlation of different independent variables. Multiple Linear Regression (MLR) was used to predict the traffic speed at the mid-block section from the traffic flow and roadside friction variables. The regression model has adjusted R square value of 65.6%. The predicted speed showed good correlation with the observed speed with MAPE of 11.36%. Hence, the model proposed in this study will be useful for finding the traffic stream speed on undivided urban mid-block section under the condition of side frictions.

Keywords
Side Frictions, Passenger Car Unit(PCU), Correlation Matrix, Multiple Linear Regression(MLR)

1. Introduction

1.1 Background

Speed is the primary indicator of traffic performance of a roadway system for the transport planning, management and operation. It denotes the quality of comfort received by the traffic flow. It is one of the elements of the fundamental relationships in traffic flow theory, along with density and volume. It depends on a number of factors, including how drivers behave, the nature of the traffic, the physical characteristics, and the surroundings in urban corridors. Traffic characteristics are the traffic flow and density under heterogeneous conditions, whereas physical characteristics are concerned with road width, geometry, access, road conditions, intersection controls and environmental factors are visibility conditions, weather conditions, etc.. Speed has been identified as one of the indicator that designers can use to examine the consistency of road and expectancy of drivers on roadways. Speed models help designers figure out the operating speed of anroadway.

Roadside friction are the activities on the side of the carriageway or on the carriageway which would disrupt the normal flow of traffic. There is a significant impact of side frictions on traffic characteristics on urban roads. The Nepal Urban Road Standard-2076 (NURS -2076) has suggested the capacity of the road under various traffic conditions. According to NURS-2076, the capacity of the 4-lane 2-way road ranges 4000 PCU/h to 2000 PCU/h based on different traffic conditions like frontage access, standing vehicles, parked vehicle and cross traffic. The Indonesian Highway Capacity Manual (IHCM) has considered side friction as a roadside environment and activities for the determination of the capacity of the road. It defined side friction as the impact on traffic performance from roadside activities on the road segment as pedestrians walking, along it or crossing, stopping on the roadway, and vehicles entering and exiting the roadway.

Roadside frictions are the result of the unmanaged road infrastructure, increase in urban population, increase in vehicle ownership, limitation of urban road space, etc.. These road frictions, which are common in developing nations along with heterogeneous traffic condition, have a negative impact on the capacity of urban roadways and seriously jeopardize the safety of those who use the roads.

The growth of traffic in the road network of the cities of Nepal is the major concern for the traffic engineer. Urban roads in Nepal has highly mixed traffic conditions. In addition to heterogeneous condition, the flow of the vehicles are conflicted by various interruption on the road. Therefore, the focus of this study is on how roadside frictions affect the speed of the selected urban midblock segment in mixed traffic.

1.2 Research Objective

The general objective of this research is:

• To develop the traffic stream speed model considering road side frictions.

The specific objective of the research is:

• To determine road side friction factors that affect the traffic stream speed.

2. Literature Review

2.1 Introduction

There are many studies which have focused on the impact of roadside friction on speed [1][2][3][4]. In some studies, the passenger car unit (PCU) has been calculated for the heterogeneous traffic [3][5][6],whereas in other studies, each vehicle type has been considered individually [1][2][4] rather than into a common unit (PCU). Most of the studies were focused on the divided four lane two way road [5] [2][1] but the undivided two lane roads has been only considered in the few studies[6][7]. Although, undivided roads were considered but research was focused on the modelling of capacity and LOS in presence of roadside frictions rather than speed modelling.

For the quantification of roadside frictions, the friction factors present in the road section has been combined into one common unit by the weight of respective friction variable [7][5][3]. The impact of roadside frictions were analysed in terms of one common unit of friction that is either Roadside Friction Index (RSFI), Side Friction (SF) or Friction (FRIC)[7][5][3]. Roadside Friction Index (RSFI) was used for the quantification of roadside friction as

$$RSFI = \sum w_i N_i$$

Where N_i is frequency of i^{th} type friction elements in a 100 m road length and w_i is weight factor for the i^{th} type side friction variable [7]. Other study quantified road side friction as Side Friction 'SF' (events/hr) was calculated as

$$SF = RW_1 * N_{PSPU} + RW_2 * N_{EE} + RW_3 * N_{WM}$$

Where, N_{PSPU} is the number of pedestrians and parked vehicles equivalent pedestrian units, N_{EE} is the number of entry- exit vehicles, N_{WM} is the number of wrong movement vehicles and RW is the relative weights of friction factor [5]. In another study all side frictions were calculated into single common unit 'FRIC' as number/200m/h.

$$FRIC = 1 * PED + 0.45 * BIC + 0.08 * NMV + 0.37 * PSV$$

where, PED is pedestrian cross flow, BIC is bicycle volume, NMV is non -motorized traffic volume and PSV is the parked vehicles [3].

In short, there are only few studies which has focused on the undivided four lane two way road for the modelling of the speed in presence of roadside friction. Therefore, the present study focuses on modelling of speed in mid-block section of undivided road in the presence of roadside frictions under mixed traffic condition.

2.2 Findings from the studies

The impact of individual friction factors on the traffic speed was studied on some literature. It was found that the most significant parameter was the dwell time of buses in comparison with frictions like number of parking manoeuvres and pedestrian flow[1]. The model was developed to predict the speed on road stretch from the predicted speed of individual friction parameters as

$$V_{comb} = 0.55 * V_{bs} + 0.27 * V_{park} + 0.18 * V_{Ped}$$

Where, V_{comb} is the speed (km/hr) for combined sections and V_{bs}, V_{park}, and V_{ped} are the speed (km/hr) for the road with side friction as bus stops, of pedestrian dense roads, on street parking. The speed for the traffic stream was modelled to be

$$V_{comb} = 43.53 - 0.39n_{man} - 0.59t_d - 0.08n_{ped} - 0.18n_c - 0.05n_{2w} - 0.27n_{3w}$$

Where, V_{comb} is speed (km/hr) for combined sections, n_{man} is number of parking manoeuvres per minute, t_d is dwell time (in seconds), n_{ped} is frequency of pedestrians per minute, n_c, n_{2w}, and n_{3w} are the frequency of cars, two wheeler and three wheeler respectively[1].

The average speed of vehicles at sections with bus stops, pedestrian and on-street parking was found to be reduced by 21%, 27% and 15% respectively. In the sections with a combination of all the friction factors, it was found that the reduction was higher (34%). Among all friction factors, the presence of pedestrians had the maximum reduction in speed than other frictions due to bus stops and on-street parking[2]. The developed model for the stream speed was

$$V_{comb} = 40.38 - 0.21n_{man} - 0.67t_d - 0.48n_{ped} - 0.26n_c - 0.15n_{2w} - 0.29n_{3w} - 0.22n_{hv}$$

Where V_{comb} is speed (km/hr) for combined sections, n_{man} is number of parking manoeuvres per minute, t_d is dwell time (in seconds), n_{ped} is frequency of pedestrians per minute, n_c, n_{2w}, and n_{3w} are the frequency of cars, two wheeler and three wheeler, n_{hv} is frequency of heavy vehicles[2].

In one of the study, it was found that the side friction reduced the average stream speed in all the study section. Stream speed was reduced by 49-57% in sections with bus stops and bus bays and on-street parking reduced traffic stream speed by 45- 67% [8].

A model was recommended in other study for calculating the speed for urban roads (undivided four lane two way) with high side friction as

$$Y = -0.132x_2 - 0.126x_3 - 0.280x_4 - 0.126x_5 - 0.153x_8 + 39.458$$

Where, Y is the speed (Km/h), x_2 is number of stopping city buses (veh/200 m/hour), x_3 is pedestrian movement (pedestrian/200 m/hour), x_4 is number of parking/stopping passenger car (veh/200 m/hour), x_5 is number of entry vehicles into the street (veh/200m/hour), x_8 is number of heavy vehicles per hour (veh/hour) [9].

From the literature review, it was found that the roadside frictions were selected based on the observation of the study site for its impact on the speed. Many studies were based on finding the relationship of speed of traffic stream by considering roadside frictions individually. In general, the side frictions are present in combination on the urban roads rather than individually. The speed of the traffic is impacted by roadside frictions in combination. Although few studies has considered the multiple side friction elements for modelling the traffic speed but are limited to the divided road section. Therefore, the present study attempts to model speed of traffic on the urban road considering all possible side friction elements on the undivided four lane two way road.

3. Methodology

3.1 Research Methodolody

The objective of the study is to develop a model to predict traffic stream speed in presence of roadside frictions. For this, the

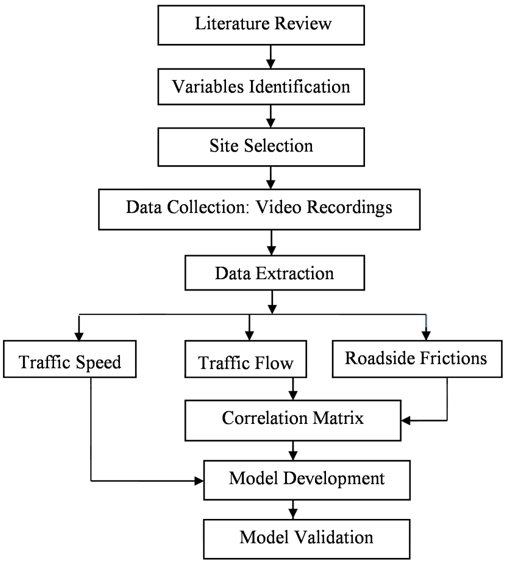

Figure 1: Research Design

video graphic technique was used to collect the data for the study. The classified traffic volume count, traffic speed and side friction elements were measured from the video recordings.The classified traffic volume count was multiplied with PCU factors to get flow (PCU/h) of the traffic stream. The heterogeneous traffic flow was converted to single unit from PCU factors. The independent variables were correlated to find the strength of correlation between the variables. The multiple linear regression was performed to develop the linear relationship between speed (dependent variable) and flow, side friction (independent variable). The developed model was validated from the observed speed data from the another road section whose data were not used for regression analysis. Hence, the validated model was used predict the traffic stream speed of the urban undivided mid-block section of the road. The research design is as shown in Figure 1.

3.2 Identification of Study Location

This study is focused on the predicting the speed on the mid-block section of undivided road having roadside frictions on it. Mid-block section is the road section in between the intersection of the road. The mid-block section should fulfill the following criteria to be selected:

- The road section should be sufficiently away (above 80 m i.e. stopping distance for speed 50 km/h) from the intersection so that the speed of the each vehicles are not affected by acceleration and deceleration while moving towards or away from the intersection.
- The geometric and pavement features of the road should not affect the traffic characteristics i.e. the mid-block section should be straight far from curves, no up or down gradient, pavement surface should be smooth, etc.
- The cross sectional features should be similar i.e. number of lanes, carriageway width, median width, footpath width, undivided carriageway (absence of median), etc.
- Presence of roadside frictions disturbing the traffic flow.

Table 1: Summary of Data

Parameters	Kalimati	Gaushala	Kuleshwor	Maitidevi
Speed (km/h)	23.9 - 31.7	29.1 - 41.5	27.9 - 35.6	27.9 - 35.6
Flow (PCU/h)	861 - 1823	433 - 1024	697 - 1592	460 - 1592
Pedestrian cross (No/100m/h)	28 - 171	24 - 313	152 - 348	115 - 348
Vehicle Entry (No/100m/h)	85 - 370	24 - 217	44 - 218	23 - 218
Vehicle Exit(No/100m/h)	28 - 399	24 - 241	44 - 239	23 - 239
Vehicle Cross(No/100/h)	85 - 370	24 - 120	44 - 327	23 - 327
Heavy Vehicle(%)	0.67% - 7.69%	0.77% - 2.97%	0.67% -3.01%	0% -3.01%
Bicyle (%)	0% -2.33%	0% - 6.36%	0%- 4.85%	0% -6.31%

Table 2: Mode Share of Vehicle

Vehicle Type	Kalimati	Gaushala	Kuleshwor	Maitidevi
Motorcycle	73.50%	75.62%	73.32%	78.97%
Car	10.58%	9.21%	8.71%	8.16%
4 wheeler	6.89%	4.34%	6.45%	6.14%
LCV	4.72%	2.98%	9.59%	2.96%
3 wheeler	0.00%	6.87%	0.00%	3.11%
Bus	4.13%	0.42%	1.79%	0.65%
Truck	0.18%	0.56%	0.14%	0.00%

- The weather condition, and road visibility should be normal sunny days.

Based on the criteria above, four undivided road sections i.e. Kalimati, Gaushala, Kuleshwor and Maitidevi were selected. All the road sections were four-lane two-way, and had similar cross section features like carriageway width, and sidewalk on both side of road.

4. Data Collection and Analysis

For the study, data were collected on four road sections. The video recordings were taken from the vantage points which would cover the entire section of the roads. The trap length was set on each road section. The video recording of the sites were conducted in between 11 AM to 5PM. The video was taken from the mobile phones at 720 pixel resolution at 30 frame per second. The equipment used for the primary data collection in the field were IPhone 12 pro, Samsung S9, and tripod stand. The summary of the data is presented in Table 1.

4.1 Traffic Volume

Five minutes of classified traffic volume count data had been collected on each site for the study period. All the vehicles passing through an imaginary screen line was counted categorically on the section of the roads. The proportion of vehicle on each category of all the sites are as shown in Table 2.

4.2 Sampling

As different mode have different range of speed, random sampling may not lead to the good result and thus stratified random sampling based on the proportion of different modes was adopted for the research work. The number of samples required to obtain the representative sample was determined by the formula

$$n = \frac{X^2 * N * (1-P)}{ME^2 * (n-1) + X^2 * p * (1-P)}$$

n = sample size required. X^2 = chi-square value for 1 degree of freedom at required level of confidence N = the population size,

Table 3: Estimation of PCU

Vehicle Type	PCU
Motorcycle	0.19
Car	1.00
4 wheeler	1.53
LCV	1.94
Tempo	1.09
Bus	3.94
Truck	3.79

P = the population proportion, ME = margin of error.

The samples of speed were measured for each category of vehicle within confidence of interval of 95% and with the margin of error of 5%. Out of 12422 vehicles in total, 4935 vehicle samples were taken categorically for speed measurement.

4.3 Traffic Speed

The space mean speed for each category of vehicle was calculated at 5 min interval. All the vehicles moving in given stretch of road in a specified time period is known as space mean speed and is calculated using the average travel time and roadway segment length. The space mean speed is calculated as given in equation below:

$$SpaceMeanSpeed(u) = \frac{n * L}{\sum_{i=1}^{N} t_i}$$

Where, u = space mean speed, km/hr, L = Trap length in km, t_i = Travel time of individual i^{th} over trap length in hours.

For the traffic stream speed, weighted stream speed was calculated from the classified traffic volume count and space mean speed of each category of vehicle as

$$V_m = \frac{\sum_i^N n_i v_i}{\sum_i^N n_i}$$

where, V_m is average stream speed (km/h); n_i is total frequency of i^{th} category of vehicle during each 5-min period; v_i is the space mean speed of i^{th} category of a vehicle during 5-min period (km/h); and N= total number of categories of vehicles considered.

4.4 Estimation of Passenger Car Unit

A Passenger Car Unit is a measure of the impact that a mode of transport has on traffic variables (such as headway, speed, density) compared to a single standard passenger car. This is also known as Passenger Car Equivalent. PCU for each category of the vehicle was determined as

$$PCU = \frac{(V_c/V_i)}{(A_c/A_i)}$$

Where, V_c and V_i are the average speed (km/h) of passenger car and vehicle category 'i' respectively. A_c and A_i are the respective projected area (m^2). The PCU was determined for each category of vehicle as shown in Table 3.

Flow (PCU/h) of traffic stream was determined by multiplying each vehicle category with their PCU factors.

Table 4: Correlation Matrix

	Flow	Ped_Cross	Entry	Exit	Cross	HV	Bicycle
Flow	1						
Ped_Cross	-.269*	1					
Entry	.571**	-.327**	1				
Exit	.488**	-.443**	.377**	1			
Cross	.563**	-0.114	.453**	0.207	1		
HV	.618**	-.468**	.395**	.437**	.318*	1	
Bicycle	-0.191	0.090	-0.242	-0.086	-0.029	-0.207	1
*. Correlation is significant at the 0.05 level (2-tailed).							
**. Correlation is significant at the 0.01 level (2-tailed).							

4.5 Side Friction Variables

The frictions on the road sections were extracted from the video recordings. The number of the frictions were counted on the trap length for each 5 minute interval of each site and converted to their respective unit. The trap length distance was different for each road section so in order to standardize the trap length for all road section, the unit was taken per 100 m for the frequency of friction variables. The friction variables observed in the field were a) The pedestrians crossing the road section within the considered trap length and their frequency was converted to Number /100 m / hour. b) The vehicles entering to traffic stream from on-street parking, roadside premises and access were categorized as 'Entry of vehicle' and their frequency was converted to Number /100 m / hour. c) The vehicles exiting from traffic stream to on-street parking, roadside premises and access were categorized as 'Exit of vehicle' and their frequency was converted to Number /100 m / hour. d) The vehicles making U-turns or any other crossing on road section were categorized as 'Crossing of vehicle' and their frequency was converted to Number /100 m / hour. e) The bus and truck, categorized as 'heavy vehicles' (HV), and was obtained from the classified traffic volume count within 5 minute interval and converted to percentage (%). f) The proportion of the bicycles, categorized as 'Bicycle', obtained from the classified traffic volume count within 5 minute interval and converted to percentage (%).

5. Results and Discussion

The data from three road sections were used for model development and one road section data was used for validation of the model.

5.1 Correlation Matrix

The correlation matrix was obtained to know the strength of correlation between the independent variables. The independent variables were flow, pedestrian crossing, entry of vehicle, exit of vehicle, crossing of vehicle, proportion of heavy vehicles, and proportion of bicycle. The data of the three road sections were used for generating the correlation matrix. The correlation matrix is as shown in Table 4.

From the correlation matrix in Table 4, no two independent variables had strong correlation with one another. So, all the independent variables were taken for the multiple linear regression analysis.

Table 5: Summary of Model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
6	.819f	0.671	0.656	2.06490
f. Predictors: (Constant), Flow, Entry				
Dependent Variable: Speed				

Table 6: Coefficients of Variables

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
6	(Constant)	40.308	1.114		36.188	0.000
	Flow	-0.007	0.001	-0.611	-6.102	0.000
	Entry	-0.015	0.005	-0.318	-3.169	0.003
a. Dependent Variable: Speed						

5.2 Multiple Linear Regression

Using all the independent variables, the models were generated from SPSS software. The significance test was conducted to each of the predictors at 95% confidence interval. Variable having p-value of less than or equal to 0.05 and t-test value less than 1.96 was considered as a significant variable. The six models were generated. In all the models, traffic flow and 'entry of vehicles' were found significant and other independent variables were found insignificant. The model with significant variables and with higher value of r-square was chosen as the developed equation. The summary of model is presented in Table 5 and coefficients of significant variables is presented in Table 6. The developed model is

$$Speed = 40.308 - 0.007 * Flow – 0.015 * Entry$$

The R- Square value = 0.656. The 65.6% variance of the dependent variable is explained by the independent variable.

Significance F= 0.000 . The p-value is less than the significance level (0.05), sample data provides sufficient evidence to conclude that regression model fits the data better than the model with no independent variables (i.e. intercept-only model). The predictor variable flow and entry of vehicle in the model fits the data better than the intercept only model.Thus, the F-test determines all of the predictor variables are jointly significant.

The side friction variable 'entry of the vehicle' and traffic flow were found significant at p-value less than 0.05 and t-test value less than 1.96. The speed of the traffic stream is affected by the entry of the vehicles from the on-street parking, roadside premises and access.

The traffic stream speed in absence of roadside friction and flow is 40.308 km/hr (free flow speed). The stream speed in absence of flow (flow = 0) and maximum observed roadside friction (Entry of vehicle = 370 Number/100m/h) is 34.758 km/h i.e. stream speed reduces by 13.768% w.r.t. free flow speed. Also, in case of maximum observed flow (1823 PCU/h) and maximum observed roadside friction (Entry of vehicle = 370 Number/100m/h), the stream speed is 21.997 km/h i.e. stream speed reduces by 45.42% w.r.t. free flow speed.

5.3 Validation of Model

The model was calibrated from three road sections of Gaushala, Kuleshwor and Kalimati and for the validation, Maitidevi road section was used. The speed was predicted from the speed model for the Maitidevi road section as shown in Figure 2.

The regression analysis between the predicted and observed traffic stream speed yielded the following results.

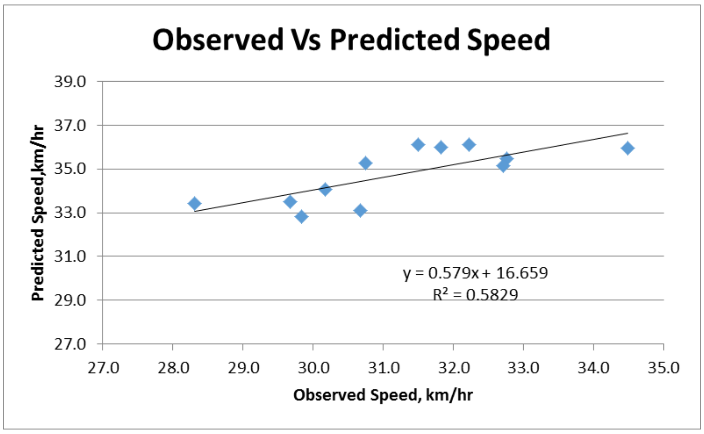

Figure 2: Predicted Vs Observed Speed

R square value = 0.5829 (i.e. 58.29 % variance of original field data is explained by the variance of field data obtained from the MLR equation)

Root Mean Square Error (RMSE) = 3.66 (i.e average differences between values predicted by the model and actual values), Mean Absolute Percent Error (MAPE) = 11%, Mean Absolute Error (MAE) = 3.51, Chi square calculated value = 19.68, and Chi square critical value at 5% significance = 4.63

The RMSE value is 3.66 which shows that the predicted traffic speed is slight deviant from the regression line i.e. there is slight difference between the observed and predicted speed. Similarly, the MAE and MAPE is 3.51 and 11.36%. Generally, the MAPE value from 10% to 20% is considered good for the accuracy of the model. The Chi-Square tests shows that the calculated value of Chi-square is greater than the critical value at 5% of significance level. So, null hypothesis is accepted i.e. there is no significant difference between the values of predicted and observed traffic stream speed.

6. Conclusions and Recommendations

6.1 Conclusion

The present study proposed speed model for undivided four lane two way urban mid-block section under the influence of roadside frictions.

1. This study identified the potential side friction parameter having influence on the traffic stream speed. The speed on urban mid-block section is affected by the traffic flow and entry of vehicle from on-street parking, roadside premises or access.

2. The developed traffic stream speed model showed R-square value of 65.6%. The predicted speed showed the good correlation with the observed speed at MAPE of 11%.

3. The passenger car unit was determined for each vehicle category on the undivided urban mid-block section.

4. The traffic stream speed in absence of roadside friction and flow is 40.308 km/hr.

5. The stream speed in absence of flow (flow = 0) and maximum observed roadside friction (Entry of vehicle = 370

Number/100m/h) reduces by 13.768%. Also, in case of maximum observed flow (1823 PCU/h) and maximum observed roadside friction (Entry of vehicle = 370 Number/100m/h), the stream speed reduces by 45.427 %.

6.2 Recommendation

The outcome of this study will certainly justify the implementation of policy measures to manage the vehicles from on-street parking, access to road and roadside premises. These all can be managed by providing service roads in urban streets in future cities of Nepal. Also, for the mitigation, it is recommended to provide the raised median which discourages the vehicles and pedestrians to cross road haphazardly. Decision could be made to restrict the on-street parking along the urban streets so that the roadside frictions could be reduced.

References

[1] S Salini, Sherin George, and dan R Ashalatha. Effect of side frictions on traffic characteristics of urban arterials. *Transportation research procedia*, 17:636–643, 2016.

[2] S Salini and R Ashalatha. Analysis of traffic characteristics of urban roads under the influence of roadside frictions. *Case studies on transport policy*, 8(1):94–100, 2020.

[3] Masatu LM Chiguma. *Analysis of side friction impacts on urban roads: Case study Dar-es-Salaam*. PhD thesis, KTH, 2007.

[4] Hareshkumar Dahyabhai Golakiya, Manish Patkar, and Ashish Dhamaniya. Impact of midblock pedestrian crossing on speed characteristics and capacity of urban arterials: civil engineering: transportation engineering. *Arabian Journal for Science and Engineering*, 44:8675–8689, 2019.

[5] Pallavi Gulivindala and Arpan Mehar. Analysis of side friction on urban arterials. *Transport and Telecommunication Journal*, 19(1):21–30, 2018.

[6] Subhadip Biswas, Satish Chandra, and Indrajit Ghosh. Side friction parameters and their influences on capacity of indian undivided urban streets. *International journal of transportation science and technology*, 10(1):1–19, 2021.

[7] Sudipta Pal and Sudip Kr Roy. Impact of roadside friction on travel speed and los of rural highways in india. *Transportation in Developing Economies*, 2:1–12, 2016.

[8] Amudapuram Mohan Rao, S Velmurugan, and KMVN Lakshmi. Evaluation of influence of roadside frictions on the capacity of roads in delhi, india. *Transportation research procedía*, 25:4771–4782, 2017.

[9] Ahmad Munawar. Speed and capacity for urban roads, indonesian experience. *Procedia-Social and Behavioral Sciences*, 16:382–387, 2011.