Quantification of Traffic Congestion using the Concept of Queue length for Curbside Bus Stops on Two Lane Undivided Road

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ABSTRACT

The present study aims to quantify the traffic congestion using the concept of queue length for curbside bus stops on two lane undivided road. Curbside bus stops obstruct the traffic flow by reducing the carriage width. They are provided in areas where there is a practical difficulty for providing bus bays due to less ROW (Right of Way). At curbside bus stops, congestion occurs due to dwell time, frequency of buses, used carriage width and volume. In this study the factors responsible for queueing such as dwell time, used carriage width and volume were taken as an independent parameter to develop a queueing length model using Statistical Package for the Social Sciences (SPSS). Six curbside bus stops in Kollam district were taken for the study. A multiple linear regression model was fitted for developing queueing length model. The adjusted R^2 obtained from the model is 0. 748.Validation of the model was done with the field data. The predicted queueing length was used to formulate a congestion index in order to quantify the traffic congestion in the study area selected.

Keywords: Queueing Length, Dwell time, Congestion index

1 Introduction

Traffic congestion adversely affects the economy as well as the standard of living of people. Travel demand exceed the capacity more often during peak hours results in congestion. Further the events such as accidents, vehicle breakdown, adverse weather, inadequate signal timing contribute to this. Traffic congestion is related to various factors like volume, speed, density, road way width, shoulder width, side friction characteristics like pedestrian encroachment, on-street parking and bus stops. The side friction has a great impact on congestion.

Queueing may form behind the stopped bus on curbside bus stops. It is influenced by parameters like dwell time, bus frequency, road width, volume. Dwell time is the duration of time taken for passenger boarding and alighting. Thus, it is a common measure of efficiency in public transport. If the dwell time needed is more then it results into more congestion. During peak hours the queueing occurred due to curbside bus stops has a great impact on congestion. The dwelling bus creates a bottleneck condition near the bus stop [1]. If the bus stop is located near intersection the vehicles behind the buses might not able to clear the intersection on green times. This further worsened the situation.

The capacity of friction sections was low as compared to the base sections. For the analysis flow and speed data of four cities were taken [2]. A simulation model was developed to quantify the impact of bus stop on capacity and found that the capacity reduces in the bus stop area [3]. In curbside bus stops a reduction in speed was observed due to various dwell time and it affects the capacity of roads. A simulation model was formulated to analyze impact of curbside bus stops and bus bays under heterogeneous traffic flow. They validated the model by collecting data from the field like dwell time, road width, speed and volume [4]. The bus stops influences the speed of the traffic in that area [5]. Bus stops near the intersection obstructs the car flows [6]. Bus operations have negative as well as positive impact on congestion. Acceleration and deceleration rate of buses, road link length, bus stop location, traffic signal cycle time, type of bus stop,

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number of lanes, speed limit, dwell time, frequency of buses and traffic volume per lane were takes as the attributes The results found that the bus bay stops has less impact on congestion as compared to the curbside bus stops. If sufficient land was available then bus bay is a better option than curbside bus stops [7]. Travel time estimation model were developed using Multi-Linear Regression method in which traffic volume, composition, road side friction, intersection factors were taken as the independent variables [8]. A Travel time model was developed using multiple linear regression method to predict the congestion index. Road geometric data such as segment length, shoulder width, number of lanes and traffic data such as travel time, origin and destination volume were taken [9]. Bus bay reduces the travel time, delay and increases the average speed compared to the curbside bus stops [10]. It was observed that higher bus density results in more boarding or alighting activity which results in more traffic interruption [11]. Time savings can be possible if we reduce the number of steps on the door which makes the boarding and alighting process easier [12].

Objectives of the study are as follows:

- To develop queue length model for two lane undivided road.
- Quantification of congestion using the concept of queue length

2 Materials and Methods

The study area is six curbside bus stops from Karicode to Kadappakada. The methodology includes identification of curbside bus stops and the parameters for modelling, Data collection, Model development, Quantification of traffic congestion.

2.1 Site Selection

The study was conducted in the six curbside bus stops from Karicode to Kadappakada during peak and offpeak hours. Two lane undivided roads are selected for the study.

2.2 Data Collection and Extraction

The field survey was done on six curbside bus stops to collect details of dwell time, queue length, carriage width used by vehicle and traffic volume. Volume survey were done through videographic method during peak and off-peak hours. One hour data of each peak and off peak were collected from each stop. The peak and off-peak hours were determined by conducting a pilot study. The video includes 12-hour video from 6 bus stop locations. The vehicle count was converted in terms of passenger car unit (PCU). The bus dwell time was note from the field using a stopwatch. The other data such as queue length and carriage width used by vehicle were measured with a measuring tape.

2.3 SPSS Software

SPSS software stands for Statistical Package for the Social Sciences. It is used in the study for the analysis of field data. A queueing length model was developed using this software. K-means clustering was done to find the range of the congestion index. SPSS is more advanced than Excel in which we can store, export data to word or pdf and can run the program easily.

2.4 Queueing Length Model

The dependent and independent variables were selected by referring to the journals. The independent variables were dwell time, carriage width used by vehicles and volume. The dependent variable selected was queueing length. Multiple linear regression model was fitted in the study. Total 300 data were collected in which 225 data (75%) were used for modelling and the remaining 75 data (25%) were used for validation. Validation was done with the field and predicted queue length data.

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2.5 Traffic Congestion Index

The queueing length predicted from the model were used to calculate the congestion index (CI). It is used to represent the state of congestion in the study area. Thus we can identify the most congested area and can do the necessary improvements to tackle the problem.

3 Theory and Calculation

Traffic congestion is one of the adverse situation facing day to day life. This study focus on the quantification of traffic congestion by determining the congestion index from the queueing length occurring at curbside bus stops. The scope of the study is limited to two lane undivided road. For the validation of the model Normalized root mean square error (NRMSE) and mean absolute percentage error (MAPE) were calculated. An equation for congestion index was devised from the offpeak and peak queue length to quantify the congestion.

3.1 Mathematical Expressions and Symbols

Normalized root mean square error (NRMSE) and mean absolute percentage error (MAPE) were calculated using the equation as follows:

$$NRMSE = \frac{RMSE}{\bar{X}O} \tag{1}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(XOi - XPi)2}{N}} \tag{2}$$

$$MAPE = \frac{100}{N}\sum_{i=1}^{N}\left|\frac{XOi - XPi}{XOi}\right| \tag{3}$$

Where $\overline{X_O}$ = is mean of observed values, X_O is the actual value, X_P is the predicted value, N is the number of observations.

Congestion Index is determined using the equation as follows:

$$CI = \frac{qo}{q} \times 100 \tag{4}$$

Where q_o is the off-peak queue length from the model, q is the peak queue length from the model. Its value ranges from 0 to 100.

4 Results and Discussion

Multiple linear regression model of queueing length and K-means clustering was done in the SPSS. From the predicted queueing length congestion index was formulated and classified based on the K-means clustering.

4.1 Queueing Length Model

The attributes considered for the model were dwell time, queueing length, carriage width used and volume. The dependent parameter taken for the study is queue length. Correlation was done to check the relation between independent and dependent variables also in between the independent variables. Pearson's correlation test is done to estimate the correlation. It was found that the correlation between queue length and dwell time is more than other parameters.

Table 1: *Model Summary*

Model	R	R Square	Adjusted R Square	Standard Error of Estimate
1	0.867	0.752	0.748	8.37339

Multiple linear regression model is fitted in the study using SPSS software. Modeling was done using 75% of the data collected. The model was developed with 95% confidence interval. Overall significance of the model was done and found that all parameters have significance value less than 0.05 which indicates the predicted model is good. F test, t test and R^2 were also determined. The adjusted R^2 obtained from the model was 0.748. It means the independent variables in the model can predict the dependent variable with an accuracy of 74.8%.

Table 2: *Validation data set*

Mean observed queue length (in metre)	Mean predicted queue length (in metre)	MAPE (%)	RMSE (%)
24.78	25.98	8.78	0.64

The validation is done with 25 % of the total data collected. It is checked by using the above equation of NRMSE and MAPE. The value obtained from the equation is less than 10%, which means the predicted model is good. The mean observed queue length from the field and predicted queue length from the model is shown in the table.

Table 3: *Coefficients*

Model	Coefficients	t	Significance
Constant	-54.106	-11.304	.000
Dwell Time	1.263	22.677	.000
Carriage Width Used	13.889	5.096	.000
Volume	0.017	6.401	.000

The model developed gives the expression.

$QL = -54.106 + 1.263 \times DT + 13.889 \times CWU + 0.017 \times Volume$

Where, QL is queue length (in metre), DT is dwell time (in seconds), CWU is the carriage width used by bus (in metre), V is the volume (in PCU/hr).

4.2 Traffic Congestion Index

Since the error percentage is less than 10% the predicted model can be used for determining the congestion index. The congestion index of six curbside bus stops were evaluated using the off-peak and peak queue length predicted from the model. It was found that the congestion index ranges from 50 to 90 in the locations selected. Thus, it can be used to represent the state of congestion in each bus stops taken under the study. The result shows that all selected area shows more than 50% congestion.

Table 4: *Congestion index of bus stops taken under the study.*

Location	CI
Karicode	54
Shappumukku	62
Moonamkutty	73
Kallumthazham	61
Randamkutty	90
Prathibha junction	67

The congestion occured due to curbside bus stop was found to be more in Randamkutty bus stop from the model. Mostly buses tried to occupy a small portion of shoulder width during boarding and alighting of

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passengers to avoid congestion. Here the above-mentioned bus stop, it has less shoulder width therefore the buses mostly occupy the carriage width fully. Thus, this bus stop results into more congestion.

Table 5: *Cluster centers*

	Cluster			
	1	2	3	4
CI	24.38	45.31	63.26	86.06

K means clustering was done in SPSS to classify the congestion index. It is used to represent the state of congestion level. It classify the observations to the nearest mean in one cluster. The nearest cluster values were averaged to classify the congestion index.

Table 6: *Congestion index*

Congestion index	Level of congestion
(0, 35)	Very smooth
(35, 55)	Smooth
(55, 75)	Mild congestion
(75,100)	Heavy congestion

As the state of congestion increases the average speed of the vehicles decreases. It results into delay, increase the usage of fuel and pollution. Since the congestion index obtained lies in the range of 50 to 90%, it can be concluded that the study area shows mild to heavy congestion. Thus, the quantification of congestion will help the policy makers for proper traffic planning and management.

5 Conclusions

The study aimed at quantification of traffic congestion for the selected curbside bus stop area. The quantification was done by determining the congestion index from the queueing length predicted from the model. A multiple linear regression was fitted for developing queue length model. The independent variables include dwell time, carriage width used by buses and volume. The adjusted R^2 obtained from the model was 0.748 which indicates the fitness of model. The model was validated by using NRMSE and MAPE and the error obtained is less than 10%. Thus, it can be concluded that the model is good for predicting the congestion index. Congestion index (CI) of six curbside bus stops was determined by considering the average offpeak and peak queue length value of each location obtained from the model. Its value ranges from 50 to 100 which indicates traffic is in congestion state. The congestion index was classified based on K-mean clustering in SPSS. Using this, level of congestion was predicted. It was observed that the selected areas show more than 50% congestion which indicates that the area considered for the study is in mild to heavy congestion. From the selected area, Randamkutty bus stop shows 90% congestion index because buses occupy the carriage width more and has less shoulder width. Curbside bus stops obstruct the traffic when buses stop at the bus stop. Thus, there is a need for bus bay to tackle the problem.

6 Publisher's Note

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