Bus Frequency, Impact on Speed of Urban Traffic at Kerb Side Bus Stop Based on Multiple Regression Analysis: A Case Study in Hyderabad

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Urban areas are associated with lot of vehicular volumes with many business, commercial, educational and recreational activities every day. Such activities will attract the people living in towns and villages alike. Due to urban attractions, the floating population and migration into the urban areas will increase resulting higher mobility of vehicles on the urban roads in the peak and non- peak hours. The number of registered vehicles per day in urban areas was found to be at a higher rate, resulting higher vehicular volumes on the urban roads. As per data, the rate of increase of vehicles in Hyderabad city is observed to be 8 - 10% per annum. The total numbers of vehicles of all categories in Hyderabad city are recorded to be more than 33 lakhs. This shows that Hyderabad is occupying fifth place in India having large number of vehicles.

Keywords: Reduction in Speed, Bus Frequency, Effective Road width and Traffic Volume.

Introduction

The present studies conducted to observe the influence of bus frequencies at Kerb side bus stops on the reduction of Speed for various traffic volumes and effective road widths. For this purpose, three Kerb side bus stops in Hyderabad city namely Bus Bhavan bus stop, A P Transco bus stop and Nalgonda X roads bus stop having variable road widths, traffic volumes, are selected and the required traffic data is collected both in the peak and non-peak hours to observe the change in speed for variations of traffic volumes, bus frequencies and effective road widths. Effective road width here is defined as the width of the road available at the Kerb side bus stop after the bus is halted. The data is then analyzed to observe the variation of Speed at the selected Kerb side bus stop locations for various bus frequencies and effective road widths under different traffic volume levels using Multiple Non- Linear regression modals. The analysis clearly indicates that the increase in bus frequencies at the Kerb side bus stop will have a lot of impact on the speed of through traffic along the corridor.

Regression Hyderabad is the capital of Southern India's Telangana State. It is one of the major centres for the technology industry. It is built with high number of residential colonies, restaurants, office headquarters, big shopping malls, education centres, industries, recreation centres, with other business and commercial activities. Hyderabad is the fourth most populous city of India. The current Population in Hyderabad Metropolitan city as per the records is 11.7 Million. The growth of population and migration is more in the city and is around 8% per annum

for the past 10 years. Hyderabad city has occupied fifth place in India having large number of vehicles. The density of road vehicles in Hyderabad is increasing day by day. The total number of vehicles in Hyderabad are recorded to be 33 lakhs. The rate of increase of vehicles as per data is found to be 10-20 % per annum. According to the latest statistics, 72% of the people in Hyderabad are travelling by public transport, which includes Buses, MMTS, Autos and Cabs. As per records, more than 4000 buses in Hyderabad are plying in different routes covering almost all areas. Everyday RTC buses make nearly 40,000 trips in the city carrying around 30 lakhs people. The annual growth rate of buses is between 3 to 5 % per annum. Most of the bus stops in Hyderabad city are located on the Kerb side along different corridors which are causing a lot of impact on the speed of other mode of vehicles passing through the corridor.

In general, the speed of vehicles moving along the corridor will be obstructed by the various obstacles on the road such as On- Street Parking, Kerb side bus stops, pedestrian crossing, side Streets, etc. The presence of these obstacles on the road will cause a lot of reduction in the Speed of through traffic along the corridor. The objective of the present study is to analyze the impact of bus frequencies on the reduction of speed at the Kerb side bus stops for various effective road widths and traffic volumes. Different Multiple Non- Linear Regression models are developed to analyze the variation of reduction in speeds of vehicles for various bus frequencies, traffic volumes and effective road widths.

Study Locations and Features

Three Kerb side bus stop locations in Hyderabad city having different road widths, namely Bus Bhavan bus stop, A P Transco bus stop and Nalgonda X Roads bus stop, are selected to observe the impact of bus frequencies on the reduction in the speed of other mode of vehicles that are passing through the corridor, for various traffic volumes and effective road widths. The presence of other location features such as On- Street Parking, pedestrian crossing and Side Streets are observed to be very minimal at the selected bus stop locations and hence are neglected. The following are the features of the selected Kerb side bus stop locations.

Bus Bhavan bus stop is located on a busy corridor which connects R.T.C. X Roads junction to O.U Road. The location is a five-lane road width with a divider at the center. The location is a highly commercial and recreation activity center with an approach road width of 9.4 m and an effective road width varying between 3.54 m to 4.75 m. Similarly, A P Transco bus stop is located in a busy corridor connecting Khairatabad junction and Somajiguda junction. The location is a six-lane road width with a divider at the center. The location is a highly commercial, recreational and official activity center with an approach road width of 12.9 m and an effective road width varying between 6.29 m to 7.97 m.

Further, Nalgonda X Roads bus stop is located in a busy corridor connecting Malakpet junction and Siadabad junction. The location is a four-lane congested road with a divider at the center. The location is a highly business and educational activity center with an approach road width of 8.2 m and an effective road width varying between 3.06 m to 4.08 m.

All the above selected locations are with lot of traffic volume every day in the morning and evening peak hours. The list of locations selected and their details from the data are given in table 1.

Table – 1

List of Study locations and their features

Bus Stop	Volume, Pcu / hr	Bus Frequency	Effective Road Width, Meter	Reduced Speed, Kmph	Road Width, Meter
Bus Bhavan	2964 to 4690	40 to 96	3.54 to 4.75	6.53 to 32.27	9.4
A P Transco	2890 to 5092	76 to 124	6.29 to 7.97	8.8 to 16.81	12.9
Nalgonda X Roads	886 to 2554	56 to 120	3.14 to 4.08	6.29 to 23.33	8.2

Data Collection at the Study Locations

Three Kerb side bus stop locations are selected in Hyderabad city having different road widths varying between 8.2 m to 12.9 m. All the bus stops are selected at the mid blocks of major corridors with divided roads and heavy traffic. The data collected from the field includes Traffic Volume, Bus Frequency, Effective Road Width, Speed of the vehicles before the bus stop and at the bus stop. At each bus stop location different traffic surveys are conducted to collect the data by the enumerators. The data is collected by manual method for 12 hours in a day for every 15 minutes consecutive intervals covering both morning and evening peak hours.

Reduction in Speed (RS): A Parameter known as Reduction in Speed is introduced in the study, which is defined as the difference of the speed of the vehicles measured at considerable distance before the bus stop (section 1) and exactly at the bus stop (section 2). The distance of the section 1 is carefully selected at the location sites such that the vehicles are moving at free speed and there is no influence of Kerb side bus stop on the movement of vehicles.

Hence Reduction in Speed = Speed of the vehicles before bus stop - Speed of the vehicles at the bus stop

More reduction in speed indicates more impact of Kerb side bus stop on the movement of other mode of through traffic.

Effective Road Width (ERW): Effective Road Width is defined as the road width that is remained at the bus stop location for other modes of vehicles to travel, after the bus has halted at the Kerb side bus stop. This effective road width is not constant and is varying from time to time based on the behavior of the driver, behavior of the commuters and other location factors. It is observed that at every selected bus stop, more than 50% of the available and valuable road width is occupied by the bus at the Kerb side bus stop, leaving the remaining 50% of the road width only for the other mode of vehicles. This affects the capacity of the road due to which the speed of the vehicles considerably falls down. Bus Frequency (BF): Bus Frequency is defined as the number of buses that are plying per hour into the bus stop location for catering the people to

different destinations. The increase in bus frequency in the bus stop locations creates more impact on the speed of other modes of vehicles. Hence as the bus frequency increases, the reduction in the speed of the vehicles also increases.

Analysis of Data

The data collected from the three Kerb side bus stop locations is analyzed to understand the reasons behind the reduction in speed at the bus stops and to formulate some guide lines for the erection of Kerb side bus stops to avoid reduction in speed of the vehicles. For this purpose, in the present study, Multiple Non-Linear Regression Modals are developed by taking dependent variable and independent variables from the data collected and are analyzed to understand the impact of bus frequencies at the bus stops on the reduction in speed of other mode of vehicles.

Development of Multiple Non – Linear Regression Modals: Multiple Regression modal is one of the well-known statistical methods of fitting a relationship between dependent variables and independent variables. In the study, Reduction in Speed (RS) is taken as a dependent variable and other influencing parameters such as Traffic Volume (Variable 1), Bus Frequency (Variable 2) and Effective Road width (Variable 3), are taken as independent variables. Multiple Non-Linear Regression Modals are developed for each selected Kerb side bus stop by considering the above dependent and independent variables and are tested for their validity. Fig 1 to 3 indicates the validity of the developed modals plotted by correlating the observed and predicted speeds at each bus stop.

Fig 1

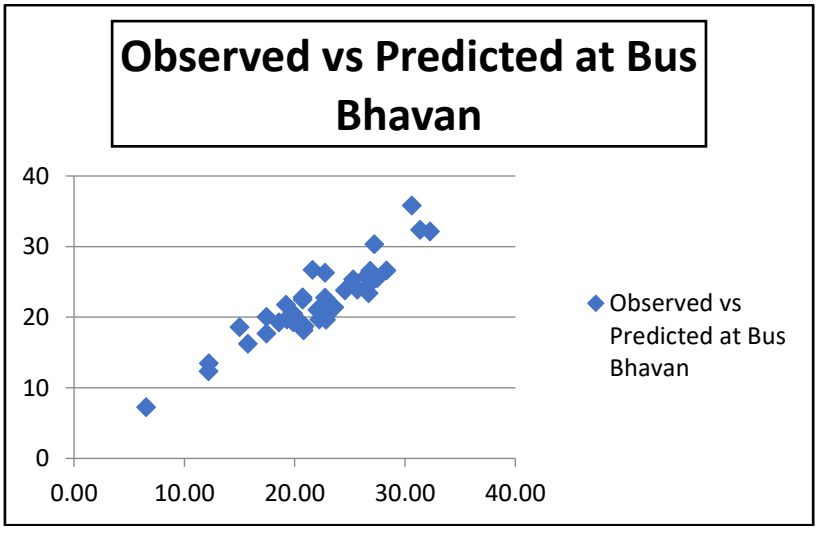


Fig 2

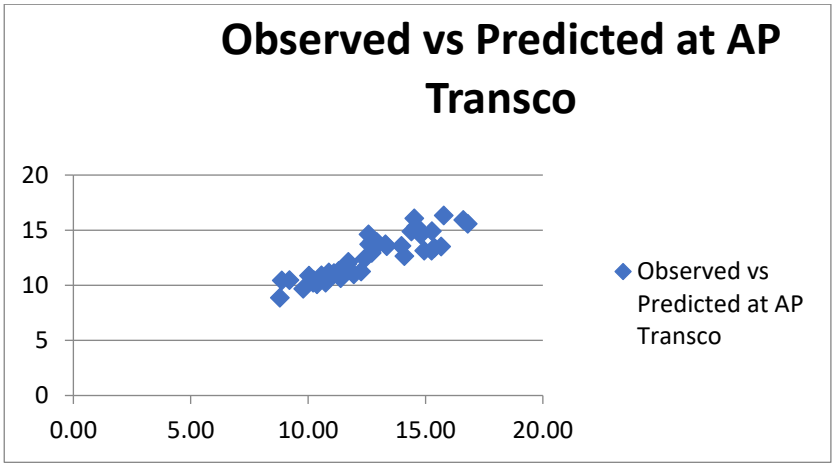
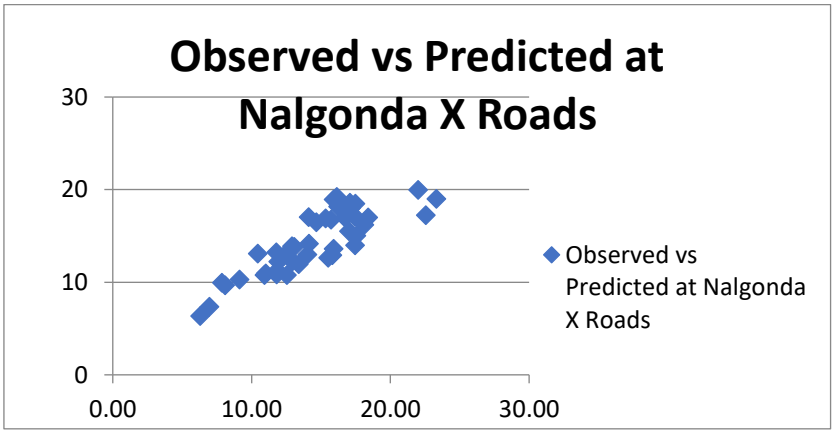


Fig 3



The Multiple Non-Linear Regression Modals are developed for all the selected bus stop locations and are as follows:

Bus Bhavan Bus Stop

Reduction in Speed (RS) = -4.53348 + 1.23720 * e^{Vol} + 0.97097 * e^{BF} – 0.67166 * e^{ERW}
R^2 = 0.8831 R = 0.9397 F (3.40) = 100.80

Parameter	t- ratio	P- level
Intercept	-6.84250	0.00000
Variable 1	5.46010	0.000003
Variable 2	5.93834	0.000001
Variable 3	-2.62202	0.012305

A P Transco Bus Stop:

Reduction in Speed (RS) = -2.49807 + 0.81022 * e^{Vol} + 0.50486 * e^{BF} – 0.41931 * e^{ERW}
R^2 = 0.8135 R = 0.9019 F (3.40) = 58.16

Parameter	t- ratio	P- level
Intercept	-5.00491	0.000012
Variable 1	6.20483	0.00000
Variable 2	4.51190	0.000055
Variable 3	-1.83494	0.073959

Nalgonda X Roads Bus Stop:
Reduction in Speed (RS) = -1.79103 + 0.74099 * e^{Vol} + 0.41104 * e^{BF} – 0.50367 * e^{ERW}
R^2 = 0.7981 R = 0.8933 F (3.40) = 52.72

Parameter	t- ratio	P- level
Intercept	-3.82495	0.0004449
Variable 1	5.13914	0.000008
Variable 2	2.25246	0.029849
Variable 3	-1.39628	0.170330

Result of the Analysis from Multiple Non-Linear Regression Modals: From the Multiple Non-Linear Regression Modals developed, the analysis is carried out to understand the variation of Reduction in Speed at the selected Kerb side bus stop locations for various traffic volumes, bus frequencies and effective road widths. Fig 4 to 21 indicate the variation of Reduction in Speed

(Y- axis) for various traffic volumes (X- axis), bus frequencies and effective road widths at all the selected bus stop locations. The graphs are generated from the analysis of Multiple Non-Linear Regression Modals obtained in all the selected Kerb side bus stop locations.

Fig 4

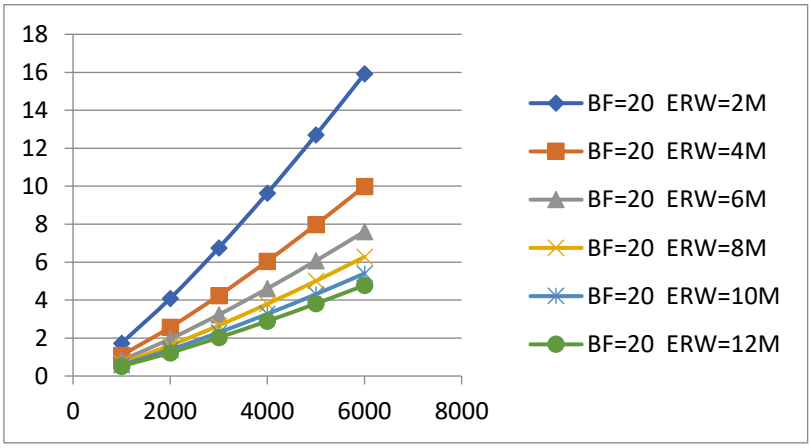


Fig 5

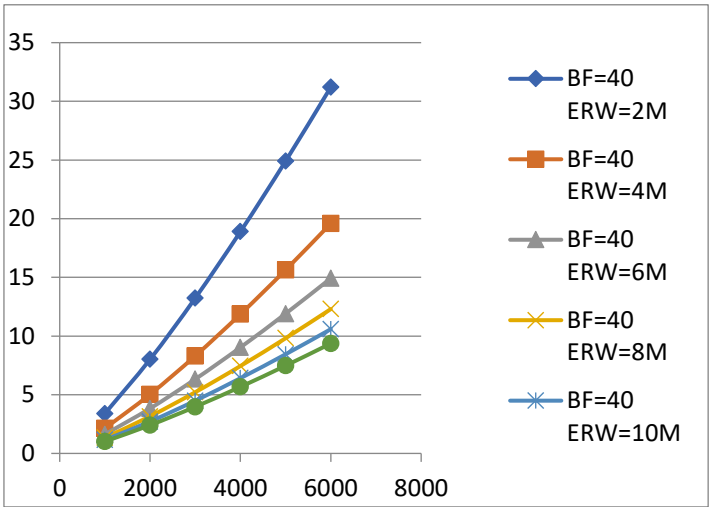


Fig 6

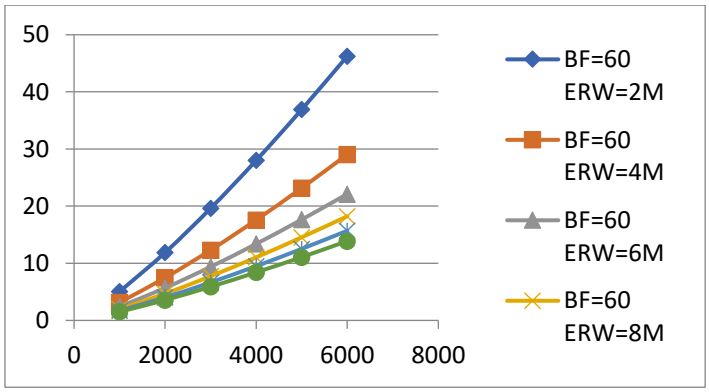


Fig 7

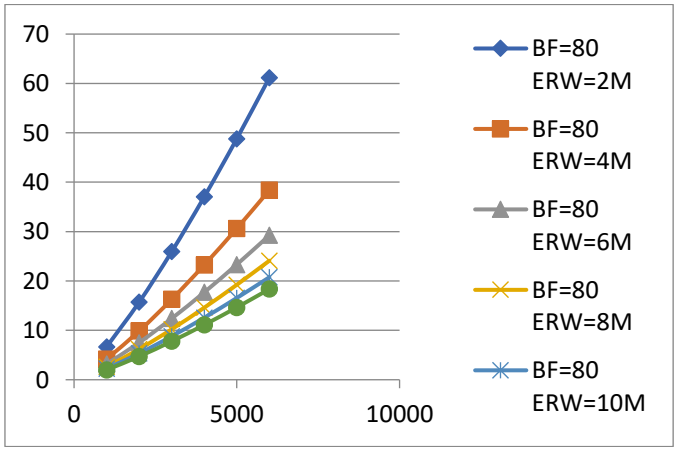


Fig 8

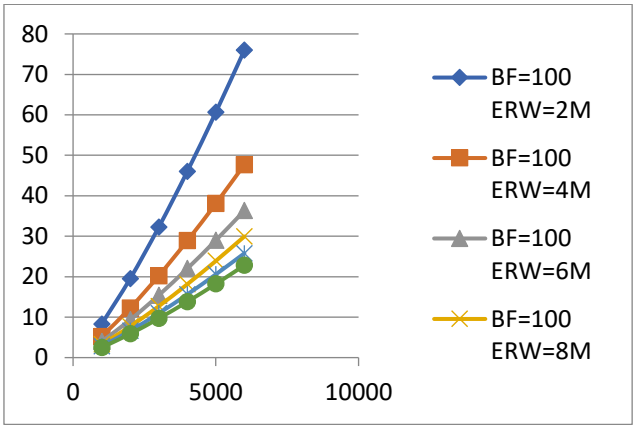
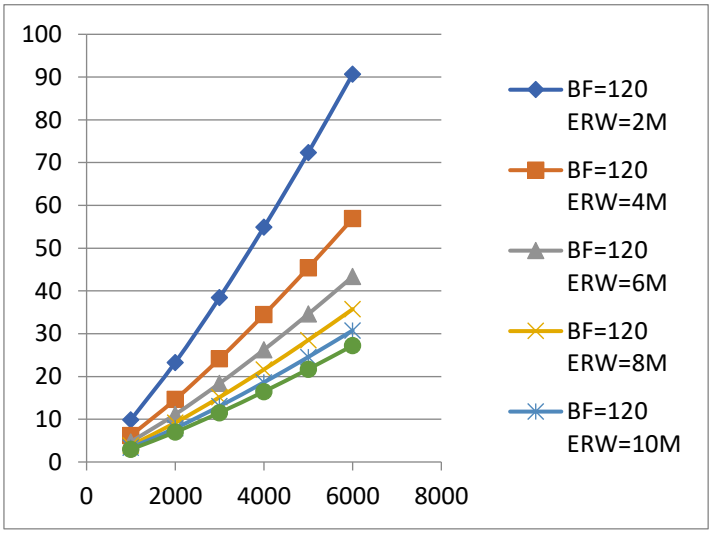


Fig 9



From Fig 4 to 9, it is observed that at Bus Bhavan bus stop, the reduction in speed is increasing at a higher rate as the traffic volume and bus frequency is increasing and is decreasing as the effective road width is increasing. The effect of bus frequency on the reduction in speed is more predominant up to a particular range and after that range, the effect is minimal. As an example, for a traffic volume of 4000 Pcu/hr and an effective road width of 4m, the reduction in speed is found to be 6.05 Kmph, when the bus frequency is 20; 11.86 Kmph when the bus frequency is 40 ; 17.58 Kmph when the bus frequency is 60 ; 23.25 Kmph when the bus frequency is 80 ; 28.87 Kmph when the bus frequency is 100 and is 34.46 Kmph when the bus frequency is 120. This clearly indicates that the reduction in the Speed of vehicles at the Kerb side bus stop is a function of Bus Frequencies. The effect is more up to particular range and then it is minimal.

Further for the same traffic volume of 4000 pcu/ hr, When the effective road width is increased to 6 m, the reduction in speed is observed to be 4.6 Kmph when the bus frequency is 20 ; 9.03 Kmph when the bus frequency is 40 ; 13.39 Kmph when the bus frequency is 60 ; 17.70 Kmph when the bus frequency is 80 ; 21.99 Kmph when the bus frequency is 100 ; 26.25 Kmph when the bus frequency is 120. Similarly for a traffic volume of 4000 Pcu/hr, for an increased effective road width of 8m, the reduction in speed is observed to be 3.79 Kmph when the bus frequency is 20 ; 7.44 Kmph when the bus frequency is 40 ; 11.03 Kmph when the bus frequency is 60 ; 14.59 Kmph when the bus frequency is 80 ; 18.12 Kmph when the bus frequency is 100 ; 21.63 Kmph when the bus frequency is 120.

Fig 10

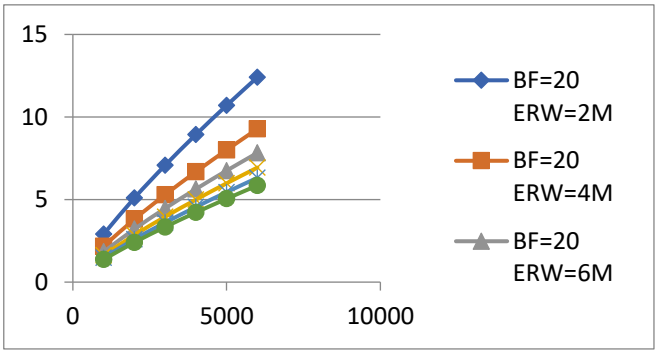


Fig 11

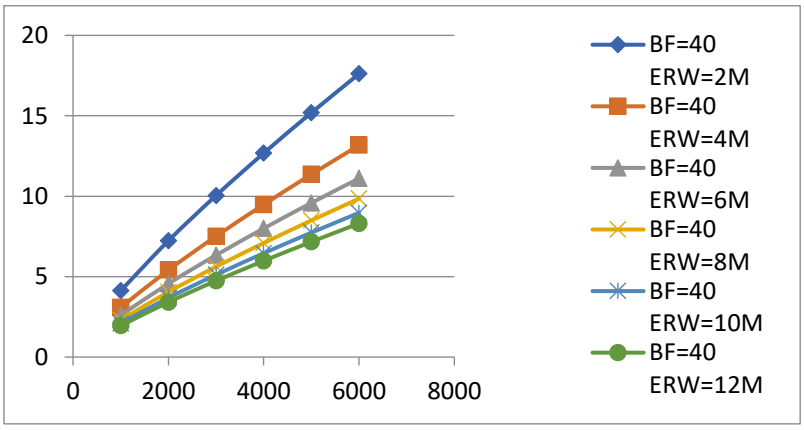


Fig 10 to 15 indicates the variation of reduction in speed for various traffic volumes, bus frequencies and effective road widths at A P Transco Bus Stop. Similar conditions exist in this bus stop location. As an example, for a traffic volume of 4000 Pcu/hr and an effective road width of 4m, the reduction in speed is found to be 6.68 Kmph, when the bus frequency is 20; 9.47 Kmph when the bus frequency is 40 ; 11.63 Kmph when the bus frequency is 60 ; 13.45 Kmph when the bus frequency is 80 ; 15.05 Kmph when the bus frequency is 100 and is 16.50 Kmph

when the bus frequency is 120. This clearly indicates that the reduction in the speed of vehicles at the Kerb side bus stop is a function of Bus Frequencies. The effect is more up to particular range and then it is minimal.

Fig 12

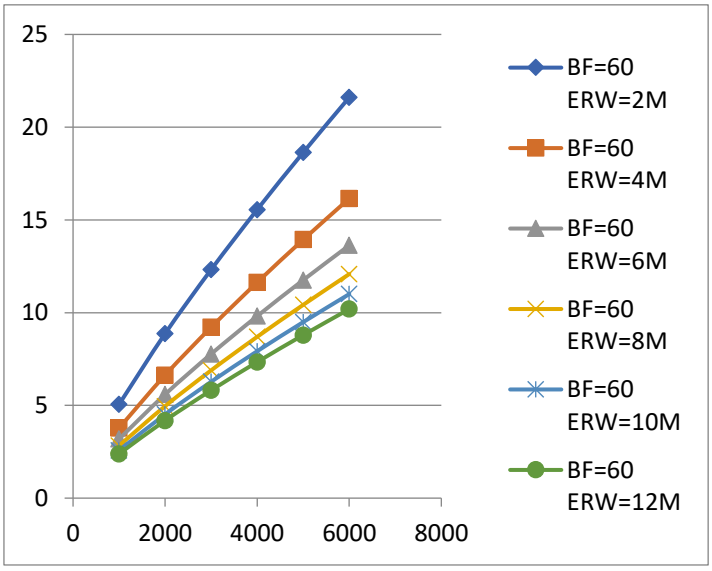
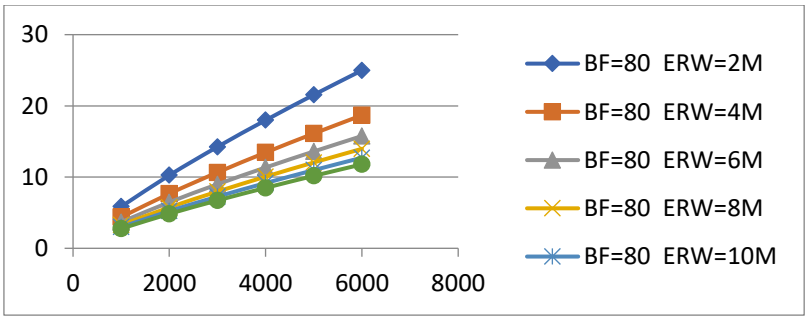


Fig 13



Further for the same traffic volume of 4000 Pcu/hr, when the effective road width is increased to 6m, the reduction in speed is observed to be 5.63 Kmph when the bus frequency is 20 ; 7.99 Kmph when the bus frequency is 40 ; 9.81 Kmph when the bus frequency is 60 ; 11.34 Kmph when the bus frequency is 80 ; 12.70 Kmph when the bus frequency is 100 ; 13.92 Kmph when the bus frequency is 120. Similarly for the traffic volume of 4000 Pcu/hr, when the effective road width is further increased to 8m, the reduction in speed is observed to be 4.99 Kmph when the bus frequency is 20 ; 7.08 Kmph when the bus frequency is 40 ; 8.69 Kmph when the bus frequency is 60 ; 10.05 Kmph when the bus frequency is 80 ; 11.25 Kmph when the bus frequency is 100 ; 12.34 Kmph when the bus frequency is 120.

Fig 14

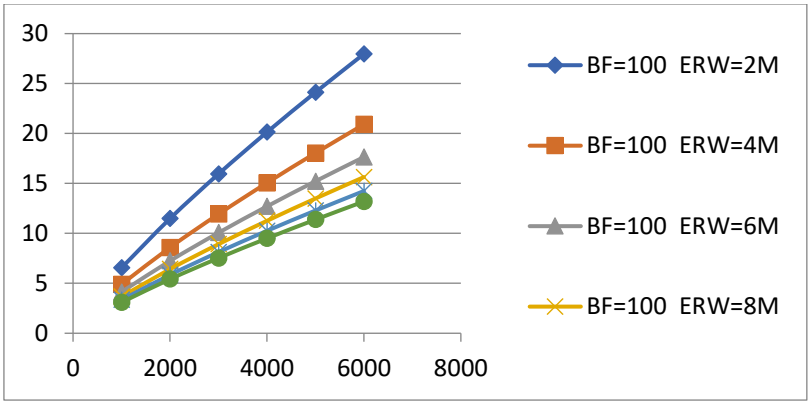


Fig 15

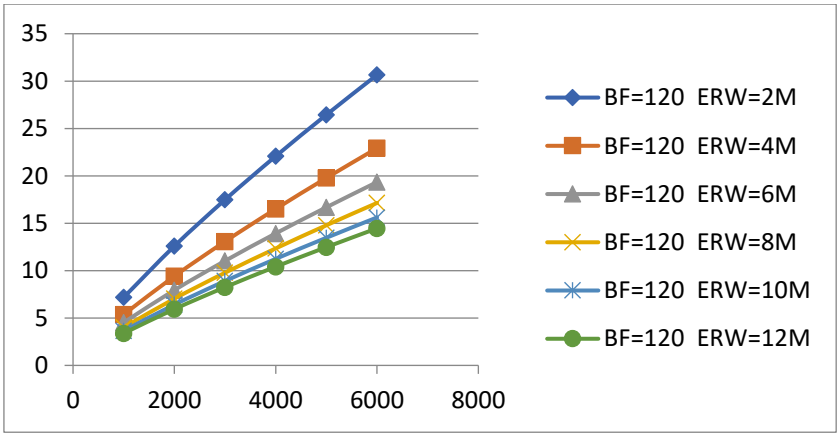


Fig 16 to 21 clearly indicates the change in speed at Nalgonda X roads bus stop for various changes in traffic volumes, bus frequencies and effective r5oad widths. In this case also, the effect of bus frequency on the reduction in speed is observed. As an example, for the same traffic volume of 4000 Pcu/hr and an effective road width of 4m, the reduction in speed is found to be 12.87 Kmph, when the bus frequency is 20; 17.11 Kmph when the bus frequency is 40 ; 20.21 Kmph when the bus frequency is 60 ; 22.75 Kmph when the bus frequency is 80 ; 24.94 Kmph when the bus frequency is 100 and is 26.88 Kmph when the bus frequency is 120.

This clearly indicates that the reduction in the Speed of vehicles at the Kerb side bus stop is a function of Bus Frequencies. The effect is more up to particular range and then it is minimal.

Fig 16

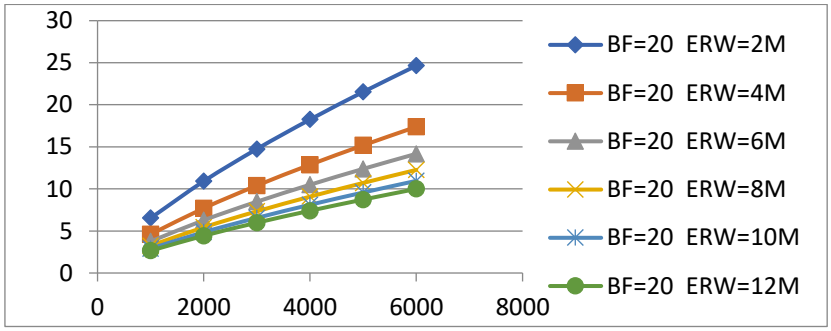


Fig 17

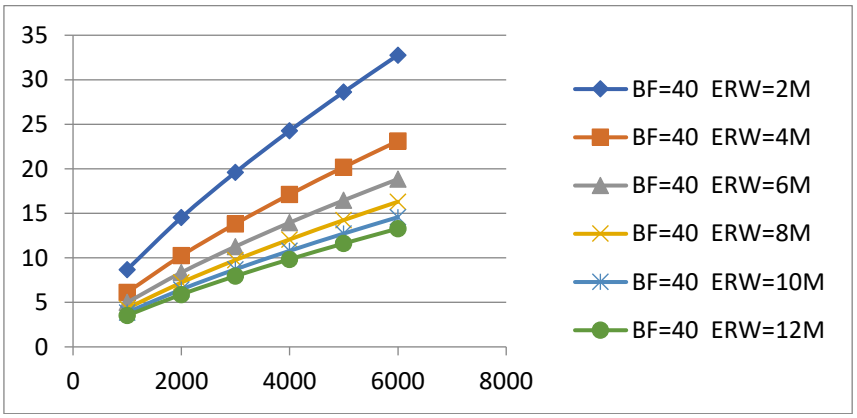


Fig 18

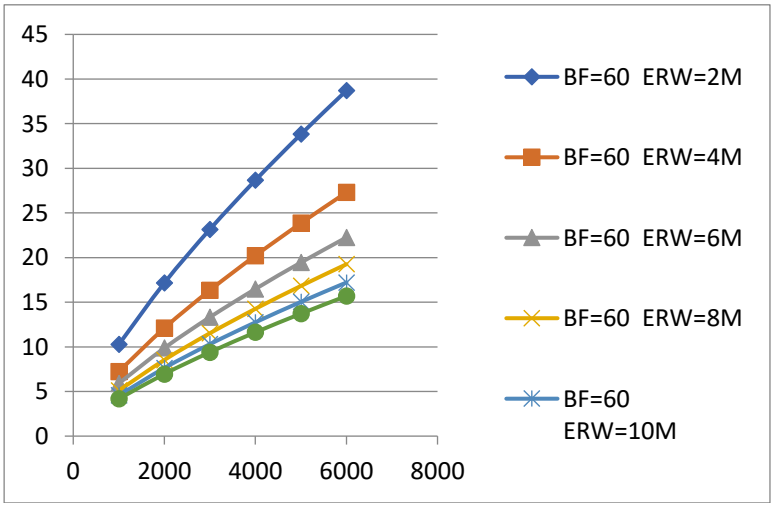
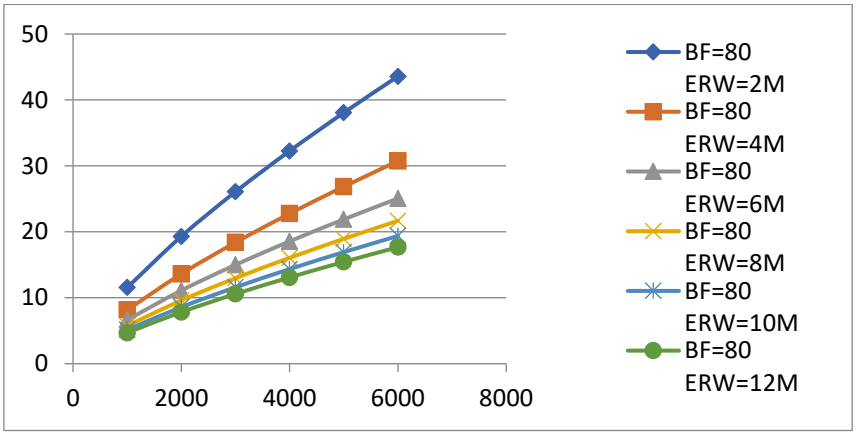
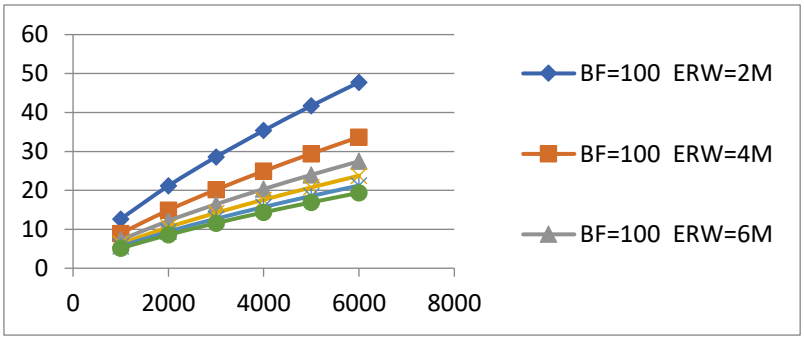


Fig 19



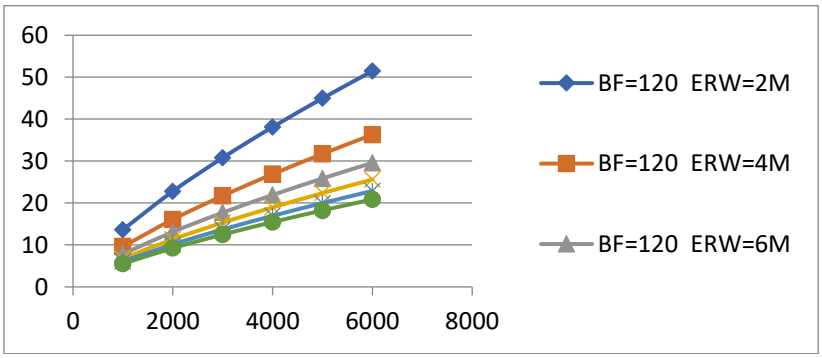
Further for the same traffic volume of 4000 Pcu/hr and an effective road width of 6m, the reduction in speed is observed to be 10.49 Kmph when the bus frequency is 2o ; 13.95 Kmph when the bus frequency is 40 ; 16.48 Kmph when the bus frequency is 60 ; 18.55 Kmph when the bus frequency is 80 ; 20.33 Kmph when the bus frequency is 100 ; 21.91 Kmph when the bus frequency is 120. Similarly for the traffic volume of 4000 Pcu/hr, when the effective road width is increased to 8m, the reduction in speed is observed to be 9.07 Kmph when the bus frequency is 20 ; 12.07 Kmph when the bus frequency is 40 ; 14.25 Kmph when the bus frequency is 60 ; 16.04 Kmph when the bus frequency is 80 ; 17.59 Kmph when the bus frequency is 100 ; 18.95 Kmph when the bus frequency is 120.

Fig 20



The above result clearly indicates that the impact of bus frequency and effective road width is more up to a particular incremental increase and then the effect is minimal. But at the same time, for higher bus frequencies, when the effective road width is more, the reduction in speed is less. As an example,in the case of Bus Bhavan bus stop, for a traffic volume of 4000 Pcu/hr and a bus frequency of 100, the reduction in speed is 28.87 Kmph, when the effective road width is 4m. But for similar conditions, the reduction in speed is 21.99 Kmph, when the effective road width is increased to 6m; 18.12 Kmph for an effective road width of 8m; 15.60 Kmph for an effective road width of 10m and is 13.80 Kmph for an effective road width of 12 m.

Fig 21



Similarly, in the case of A P Transco bus stop, for a traffic volume of 4000 Pcu/hr and a bus frequency of 100, the reduction in speed is 15.05 Kmph, when the effective road width is 4m. But for the similar conditions, the reduction in speed is 12.70 Kmph, when the effective road width is increased to 6m; 11.25 Kmph for an effective road width of 8m; 10.25 Kmph for an effective road width of 10 m; and is 9.49 Kmph for an effective road width of 12 m.

Further in case of Nalgonda X Roads bus stop, for a traffic volume of 4000 Pcu/hr and a bus frequency of 100, the reduction in speed is 24.94 Kmph, when the effective road width is 4m. But for the similar conditions, the reduction in speed is 20.33 Kmph, when the effective road width is increased to 6m; 17.59 Kmph for an effective road width of 8m; 15.72 Kmph for an effective road width of 10m and is 14.34 Kmph for an effective road width of 12 m.

This clearly indicates that the influence of reduction in speed is more for higher bus frequencies and is getting reduced as the effective road width is increasing. Moreover, as the effective road width is increasing further and further, even for higher bus frequencies, the effect is minimal as observed in case of increase in effective road widths of 10 m and 12 m in all the selected bus stop locations.

Summary and Conclusions

The study is conducted to analyze the impact of bus frequencies at the Kerb side bus stop locations on the reduction of speed of other mode of vehicles, by considering the influencing parameters such as traffic volume, bus frequency and effective road width under various roadway and traffic conditions in Hyderabad city. Multiple Non- Linear Regression models are generated at each selected bus stop location. Different graphs are developed from the Multiple Regression modals from all the data sets for the purpose of analysis.

From the graphs, it is concluded that the reduction in speed is more at the Kerb side bus stops, as the bus frequency and traffic volume increase and is considerably less for an increase in effective road width. Further it is concluded that the effect of variation of speed is more up to a particular range of increase in bus frequency and effective road widths and after that range, the effect is minimal as observed in case of an effective road widths of 10 m and 12 m. In the study it is concluded that for a given traffic volume, the effect of reduction in speed is more up to a bus frequency of 80 and an effective road width of 8 m, beyond which the effect is minimal. Hence it

can be concluded that for a traffic volume up to 4000pcu/hr, the reduction in speed is minimal at the Kerb side bus stops, when the bus frequency is equal to or less than 80 with an effective road width of 8 m or more.

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