Analysis of Traffic Speed Variance on a Three Lane Urban Road due to Road Side Bus Station and Taxi Stand – A Case Study in Wolayita Sodo Town, Ethiopia

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Speed is one of the most important traffic flow characteristics that affects the travel time. The management of traffic flow in urban areas is a challenging task for the planner as the flow is increasing day by day due to increase in human activities. The density of population increases in urban areas due to various employments, educational and business opportunities. A study is conducted in Wolayita Sodo town, Ethiopia at main bus station and taxi stand in CBD area to observe the variation of traffic speed during different traffic conditions. Taxi Stand is located close to the kerb side and is very near to the main bus station. The width of the road is getting affected due to the occupancy of taxi stand at the kerb side and is varying from time to time. Huge number of pedestrians will be crossing the road continuously from one side to the other side to catch the bus at the bus station. The location of bus station is so complicated and is suffering through traffic speed with the impacts of bus movements, taxi movements and pedestrian crossings. Traffic data is collected near bus station to analyze the variation of traffic speed for various roadway and traffic conditions.

Keywords: Pedestrian Crossing, Speed, Frequency and Regression.

A Multiple Non – Linear Regression Modal is developed to analyze the variation of traffic speed for various bus frequencies, taxi frequencies, pedestrian crossings and effective road widths. The results obtained from the model are useful to find out the solutions to enhance the speed of through traffic at the bus stop location.

Introduction

Traffic flow characteristics in urban areas are the dynamic parameters and varies continuously based on the roadway and traffic conditions. The presence of various obstructions on the road will suffer the through traffic flow thus lowering the speed of the vehicles and increases the journey time. The speed of the ongoing vehicles is governed by various influencing parameters that exist on the road. Mobility has been increasing significantly in the last few decades in the urban areas and will continue to increase (Janssen, Okker& Schuur, 2006). The delay due to congestion on motorways is increasing day to day. The traffic delay will increase the journey time and affects the day to day activity of the people. Traffic Congestion has a negative impact on the economy by decreasing productivity and on the quality of living condition of the people. This will also increase the pollution and degrades the environment. The increase in Congestion due to various obstacles on the road will make the riders to select alternate routes which may again affect the safety of traffic on other roads. Hence it is important to gain a clear understanding of traffic flow process and to improve the traffic conditions from the existing hurdles on the road.

It is observed that the traffic is heavy in peak hours in Wolayita Sodo bus station location causing lot of congestion and delays. Wolayita Sodo town is one of the big towns in South Central of Ethiopia. Wolayita is one of the 13 zonal administrations of the Southern region in Ethiopia and is located 300 kms South of Addis Ababa. Wolayita zone has 358 kms of all-weather roads and 425 kms of dry weather roads with an average road density of 187 kms per 1000 square kms. Wolayita Sodo has a population of 86,050 (2012 Census) in the town.

Need for the study

The main bus station in Wolayita Sodo town is located at the CBD area. A taxi Stand also exists very near to the bus station at the kerb side. Moreover, huge volume of pedestrians crosses the road continuously from one side to the other side near the bus station. The location is so complex with lot of obstacles on the road that affects the speed of the vehicles. The analysis of variation of speed under these heterogeneous traffic and roadway conditions at the bus station is highly essential for the planner to search the ways to solve the traffic problems and to smoothen the traffic flow. The present study is an attempt to fulfill the need.

Objectives of the study

The study is aimed to analyze the variation of traffic speed due to the presence of obstacles near the bus station. The following are the specific objectives of the study.

- To observe the frequency of buses, taxis and pedestrians at the bus station location
- To observe the variation of road width due to the occupancy of taxi stand at the kerb side near bus station
- To quantify the variation of through traffic speed due to these obstacles for various roadway and traffic conditions
- To evaluate different alternative solutions to improve the traffic flow rate at the location of bus station

Review of Literature

The impact caused by various influencing parameters on the road will change the Speed of the vehicles dynamically. The reduction in the Speed will affect the capacity of the road and declines the level of service of the road. It is hence essential to maintain better possible conditions on the road so as to minimize the travel time for the vehicles. A Study was conducted by Park, B-J, Zhang, Y and Lord, D (2010) to account for heterogeneity in Speed data and concluded that the Speed distributions might be more than two, depending on the time of analysis. Elhenawy, M and Rakha, H.A (2016) have conducted a study to estimate the expected travel time using Mixture Linear Regression. The study uses the mixture modal to estimate the speed distribution in order to describe the traffic conditions. The mean values of the two regimes i.e. Congested and Free flow conditions were described by a linear relationship with visibility and weather conditions. Lord, Manar & Vizioli (2005) studied the influence of volume, density and V/C ratios on the occurrences of crashes on rural and urban motorways. The data was collected by using loop detectors located at various sections of the rural and urban motorways. The study concluded that as the density of traffic increases, Crash frequency increases, reaches a maximum and then decreases again. Golob, Recker &Pavlis (2008) presented a method that assesses the relationship between traffic flow parameters and the type of crash, severity, location and number of vehicles involved. Data on traffic volume and lane occupancy from six motorways was obtained from loop detectors during a six-month period. The study found that when the left and interior lanes are congested, the likelihood of severe crashes decreases. If all lanes have similar traffic volumes, then congestion reduces crash severity by more than half. It was also found that the effect of congestion on severity is offset by unstable flow conditions such as the change from free flow to congestion.

Data Collection at the study area

The traffic data such as traffic volume with composition, traffic speed, bus frequency, taxi frequency and pedestrian crossing are collected by manual methods. The effective road width is also measured at the location. The entire data are collected for about 12 hours in a day and for every 15-minute consecutive interval. The following methodology is adopted to collect the above data.

Traffic Volume

Classified traffic volume with composition is collected at the bus station location by drawing a reference line on the road and counting the number of vehicles that crosses the reference line as shown in the figure 1. The traffic volume data were later converted into Passenger Car Units (PCUS) by considering the equivalent PCU factors.

Traffic Speed

Traffic Speed is defined as the ratio of distance travelled by the vehicle to the travel time taken for the vehicle between the two sections. Two reference lines are drawn on the road at a distance of 30 meters as shown in the figure 2. The time of entry and time of exit of different types of vehicles are recorded for every 15-minute consecutive interval. The travel time is calculated by taking the difference of entry and exit timings. The ratio of the distance travelled by the vehicle and travel time will give the traffic speed of the vehicles

Bus Frequency (BF)

A reference line is drawn on the road near the bus stop location. The number of buses that crosses the reference line is recorded for every 15 minutes consecutive interval as shown in the figure 3, which gives the bus frequency.

Taxi Frequency (TF)

A reference line is drawn on the road near the bus stop location. The number of taxis that crosses the reference line and are arriving to taxi stand are recorded for every 15 minutes consecutive interval as shown in the figure 3. This gives the taxi frequency.

Effective Road Width (ERW)

Effective road width is defined as the available road width at the bus station location after the taxis arrive to the taxi stand and occupy the road. The occupancy of road by different taxis varies from time to time and depends upon the driver behavior and road condition. The effective road width is measured for every 15-minute consecutive interval as shown in the figure 3. For this purpose, reference lines are drawn perpendicular to the roadway at an interval of 1 meter from the center line of the road up to the kerb at the bus station location. As soon as any taxi arrives to the taxi stand, the available road width is measured by observing the position of the wheels of the taxi. This available road width is considered as the effective road width. The data is collected for number of samples for every 15 minutes consecutive interval.

Pedestrian Crossing (PC)

Pedestrian Crossing is the number of pedestrians that will cross from one side to the other side of the road at the bus station location to reach the bus station. The data is collected manually at the bus stop location for every 15-minute consecutive interval.

Development of Multiple Non – Linear Regression Modal

A Multiple Non-Linear Regression Modal is developed from the data collected at the bus station location. The traffic speed is considered as the dependent variable and all other influencing parameters such as traffic volume, bus frequency, taxi frequency, pedestrian crossing and effective road width are considered as independent variables. The regression modal developed is as follows:

$$\text{Speed} = 2.946804 - 0.227424 * e^{vol} - 0.256311 * e^{BF} - 0.283754 * e^{TF} - 0.387598 * e^{PF} + 0.436285 * e^{ERW}$$

$$R^2 = 0.9271 \qquad R = 0.9635$$

Validation of the Modal

The developed regression modal is validated by plotting a graph between the observed speed values and predicted speed values as shown in the figure 4. The predicted speed values are close to the observed speed values as represented in the figure 4, which indicates that the developed modal is validated.

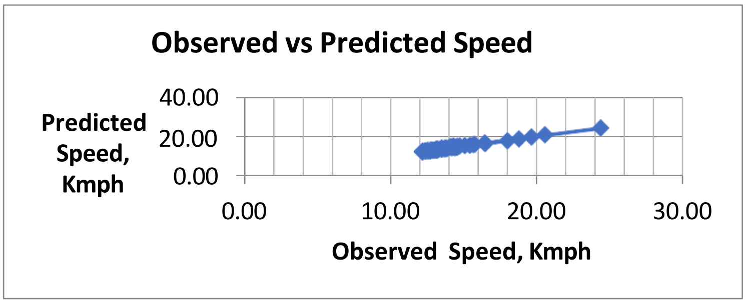


Figure 4

Analysis of data from the developed Multiple Non – Linear Regression Modal

In order to understand the variation of Traffic Speed at the selected bus stop location for various influencing parameters, the data is analyzed for different cases. The predicted traffic speed for all the cases considered is evaluated from the developed modal and is indicated as shown in the table 1.

Table 1 clearly indicates the variation of traffic speed under the influence of various parameters such as traffic volume, bus frequency, taxi frequency, pedestrian crossing and effective road width. The influence of each parameter on the traffic speed is unique and varies based on the roadway and traffic conditions in the field. In all the above cases, the traffic speed is observed to be declined more for higher bus frequencies, taxi frequencies and pedestrian crossings and is increasing rapidly for every incremental increase in the effective road width. Therefore, the speed of through traffic at the bus station location is proved to be affected with the presence of various obstacles at the location.

Table 1

Case	*Volume PCUS*	*BF*	*TF*	*PC*	*ERW, Meters*	*Predicted Speed, Kmph*
1	500	20	40	50	8	19.07311
2	500	20	40	50	12	22.76394
3	500	30	40	50	8	17.19045
4	500	30	40	50	12	20.51697
fi	500	20	80	50	8	15.66762
6	500	20	80	50	12	18.69946
7	500	20	80	100	8	11.97635
8	500	20	80	100	12	14.29389
9	500	30	80	50	8	14.12111
10	500	30	80	50	12	16.85368
11	500	30	80	100	8	10.79419

12	500	30	80	100	12	12.88298
13	1000	20	40	50	8	16.29146
14	1000	20	40	50	12	19.44402
15	1000	30	40	50	8	14.68337
16	1000	30	40	50	12	17.52475
17	1000	20	80	50	8	13.38263
18	1000	20	80	50	12	15.9723
19	1000	20	80	100	8	10.2297
20	1000	20	80	100	12	12.20925
21	1000	30	80	50	8	12.06167
22	1000	30	80	50	12	14.39572
23	1000	30	80	100	8	9.219955
24	1000	30	80	100	12	11.00411

Recommendations made to improve the traffic conditions at the selected bus station

In order to improve the traffic flow characteristics at the selected bus stop location, three alternative measures are proposed.

Alternative 1

Recommended to shift the bus station from the existing location to any arterial road. This will reduce the impact of bus frequency at the bus stop location. It is observed that 50% of the pedestrian crossings at the bus stop location are only towards the bus station. Hence by shifting the bus stop from that location, 50% impact of pedestrian crossing at the location will be reduced.

Alternative 2

Recommended to shift the taxi stand from the bus stop location to any other part of road. This will reduce the impact of taxi frequency at the bus stop location.

Alternative 3

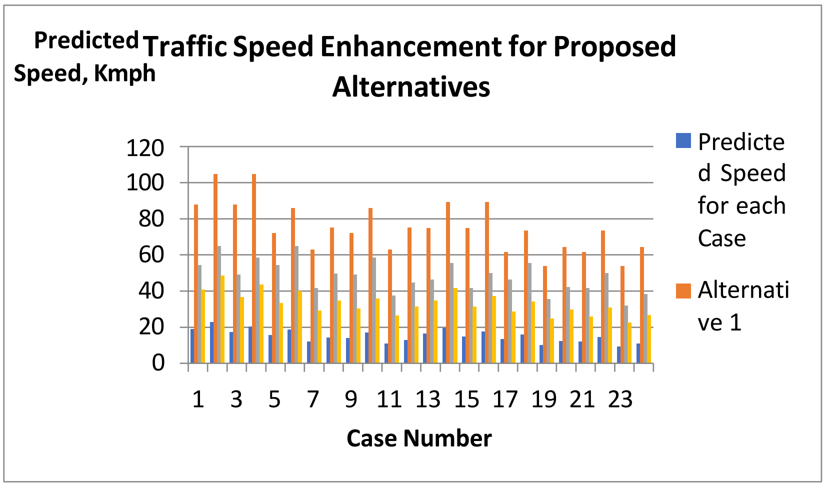
Recommended to erect an over bridge at the bus stop location for the pedestrians to cross the road from one side to the other side. This will reduce at least 50% impact of the pedestrian crossings.

The predicted traffic speed at the bus stop location is further evaluated for the above three alternatives for the above cases considered using the developed Multiple Regression Modal and the results are indicated as shown in the table 2

Table 2 clearly indicates the impact of bus frequencies, taxi frequencies and pedestrian crossings on the traffic speed for various traffic volumes and effective road widths. The results obtained in table 2 shows the improvement of traffic speed at the bus station location for various proposed alternatives. A graph is plotted between the Predicted Speed obtained from the modal for the existing conditions and the Predicted Speed evaluated for various proposed alternatives and is as shown in the figure 5.

Table 2

Cas e	*Volume PCUS*	*B F*	*T F*	*PC*	*ERW Meters*	*Predicted Speed for existing conditions, Kmph*	*Predicted Speed for Alternative 1, Kmph*	*Predicted Speed for Alternative 2, Kmph*	*Predicted Speed for Alternative 3, Kmph*
fi	500	20	80	50	8	15.667	72.065	54.326	33.439
1	500	20	40	50	8	19.073	87.730	54.326	40.708
2	500	20	40	50	12	22.763	104.70	64.839	48.585
3	500	30	40	50	8	17.190	87.730	48.964	36.689
4	500	30	40	50	12	20.516	104.70	58.439	43.789
6	500	20	80	50	12	18.699	86.011	64.839	39.910
7	500	20	80	100	8	11.976	63.007	41.527	29.236
8	500	20	80	100	12	14.293	75.199	49.563	34.893
9	500	30	80	50	8	14.121	72.065	48.964	30.138
10	500	30	80	50	12	16.853	86.011	58.439	35.971
11	500	30	80	100	8	10.794	63.007	37.428	26.350
12	500	30	80	100	12	12.882	75.199	44.670	31.449
13	1000	20	40	50	8	16.291	74.935	46.403	34.771
14	1000	20	40	50	12	19.444	89.436	55.383	41.499
1fi	1000	30	40	50	8	14.683	74.935	41.823	31.338
16	1000	30	40	50	12	17.524	89.436	49.916	37.403
17	1000	20	80	50	8	13.382	61.555	46.403	28.562
18	1000	20	80	50	12	15.972	73.467	55.383	34.089
19	1000	20	80	100	8	10.229	53.818	35.470	24.972
20	1000	20	80	100	12	12.209	64.232	42.334	29.804
21	1000	30	80	50	8	12.061	61.555	41.823	25.743
22	1000	30	80	50	12	14.395	73.467	49.916	30.725
23	1000	30	80	100	8	9.2199	53.818	31.969	22.507
24	1000	30	80	100	12	11.004	64.232	38.156	26.862



It is observed from the figure 5 that the traffic speed at the bus station location is increasing at a higher rate with alternative 1 followed by alternative 2 and alternative 3 in all the cases. Hence it is recommended to shift the bus station from the existing location at CBD area to any arterial road.

Summary and Conclusions

The traffic in urban areas is highly congested due to the presence of various obstacles on the road. The traffic speed on the road is a function of these obstacles and is varying from time to time based on the roadway and traffic conditions. A study is conducted at the bus station location in CBD area at Woliata Sodo town, Ethiopia to evaluate the variation of traffic speed for various influencing parameters. A taxi stand exists very near to the bus station and huge pedestrians will be crossing the road continuously from one side to the other side to reach the bus station and taxi stand. The traffic speed at the bus station location is getting reduced from time to time due to the impact of bus station, taxi stand and pedestrian crossing.

In order to observe the variation of traffic speed at the bus station location and to evaluate the possible alternative solutions to improve the traffic speed at the bus station location, the traffic data is collected at the bus station location for about 12 hours in a day at every 15 minutes consecutive intervals. The traffic data includes traffic volume, traffic speed, bus frequency, taxi frequency, pedestrian crossing and effective road width.

A Multiple Non- Linear Regression Modal is developed by considering the traffic speed as dependent variable and the influencing parameters such as traffic volume, bus frequency, taxi frequency, pedestrian crossing and effective road width as independent variables. The modal developed is validated and is used to evaluate the predicted traffic speed at the bus station location for various influencing parameters. The analysis is carried out by considering different cases.

Three alternatives are proposed to improve the traffic speed at the bus station location. Alternative 1 is proposed to shift the bus station location from the existing CBD area to any arterial road. Alternative 2 is proposed to shift the taxi stand from the bus station location to any other part of road, where as Alternative 3 is proposed to erect an over bridge at the bus station location to facilitate the pedestrians to cross the road from one side to the other side.

It is observed that 50% of the pedestrians are crossing the road from one side to the other side to reach the bus station and taxi stand. The predicted traffic speed for all the three proposed alternatives is evaluated by using the developed Multiple Non- Linear Regression Modal and the results are obtained. The results indicate that the traffic speed at the bus station location is increasing at a higher rate with alternative 1 as followed by alternative 2 and alternative 3. From the analysis, it is hence recommended to shift the bus station from the existing CBD area to any arterial road of the town.

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