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Criteria for Setting Speed Limits to Sri Lankan Highways (Built - Up Areas)

V. Wickramasinghe, G.V.N.C. Silva and K.G.M. Lakmali

Abstract: Speed of vehicles is the pivotal factor in many of the road traffic accidents. Enforcing a suitable speed limit is a tool for enhancing the road safety. However, in Sri Lanka, the currently available posted speed limits are placed without much scientific investigation. Those limits are merely decided by selecting a vehicle category. According to the Gazette of the Demographic Socialist Republic of Sri Lanka, No.1763/26, June 22, 2012 [1] all vehicles are divided into two vehicle categories and proposed only two-speed limits for built-up areas, i.e., 40 km/h for motor tricycles and special purpose vehicles, and 50 km/h for all other vehicles . However, it is understood that road geometry, roadside friction, vehicle density, accident rates, average daily traffic values, etc., should be considered in deciding the speed limits. In that context, the current study is aimed to investigate the influence of such contributory factors on speed limits. Ten site locations with different geometric characteristics, vehicle compositions, and accident rates were selected in built-up areas. Using speed guns, speeds of randomly selected vehicles were recorded. Totally, 3000 vehicle speeds were collected. Initially, vehicles were divided into four categories as motor-bikes, three-wheelers, light vehicles, and heavy vehicles, and performed ANOVA tests to find out whether there exists any difference in 85th percentile speed values between each vehicle category. The intention was to group the vehicles into similar speed clusters. It was identified that motor-bikes and light vehicles (Car/Van/Jeep: CVJ) can be grouped as one cluster while three-wheelers and heavy vehicles (Buses/ Light good vehicles/Heavy good vehicles) as the other cluster. Next, in order to identify the influential factors towards the speed limit of each cluster, correlation with each factor on the speed was observed. From the results it was found that the speed limits of motor-bikes, three-wheelers, and the light vehicles and heavy good vehicles are heavily correlated with factors such as availability of bicycle lanes, availability of shoulders, availability of parking lanes, availability of centre median, the road markings, situation of two way or one way, and the roadside activities. Finally, a multiple linear regression model for each vehicle category was fitted and validated. The most significant factor in deciding the speed limit in built-up areas is the availability of bicycle lanes with a p-value of 0.000 at 5% level of significance. Roadside activities have a significant negative impact on the speed limit except for motor cycles with a p-value of 0.00 at 5% level of significance. These developed models are useful to review the existing posted speed limits in built-up areas.

Keywords: Built-up area, Speed limit, Traffic speed, Traffic safety

1. Introduction

Speed of vehicles is the pivotal factor in many of the road traffic accidents. Enforcing a suitable speed limit is a tool for enhancing the road safety. However, in Sri Lanka, the currently available posted speed limits are placed without much scientific investigation. Those limits are merely decided by selecting a vehicle category. According to the Gazette of the Demographic Socialist Republic of Sri Lanka, No.1763/26, June 22, 2012, [1], all vehicles are divided into two vehicle categories and proposed only two-speed limits for the built-up areas, i.e., 40 km/h for motor tricycles, special purpose vehicles, and 50 km/h for all other vehicles . However, it is understood that road geometry, roadside friction, vehicle density, accident rates, average daily traffic values, road marking, etc., should be considered in deciding the speed limits. In that context, the aim of the current study is to investigate the influence of such contributory factors on speed limits.

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The major objectives of the project are endorsed as follows:

1. To evaluate real operating speeds of different vehicle types on Sri Lankan highway system (Built-up areas).

2. To evaluate different factors that affect setting speed limits on Sri Lankan highway system (Built-up areas).

3. To develop speed predicting models, with vehicle categories, geometric and environmental characteristics for built-up areas.

Augeri et al. [2] found the relationship between crash occurrence and speed. They developed the "Decision Supporting System" (DSS). Brubacher et al. [3] found the relationship between crash occurrence and speed but they were trying to prove modern vehicles are able to safely travel at higher speeds. The arguments that they used were clearly identified and used when constructing the regression equations. For example, the percentage of speed limit violators are increased due to the lower posted speed limits on roads. Further, authors proved that speed violators contributed more towards increasing the accident rate.

Dissanayake & Liu [4] found the major role of the speed limits in different types of road systems and showed the benefits of posting proper speed limits. To prove their arguments, the authors used software-based applications. Software-based arguments and methods were used extensively for this project. They were used as a great source to make the software-based systems of this project. That guidance was very important to form a software-based regression equation.

Gayah [5], and Ezeblessing & Oyebola [6], found a variety of reasons for affecting posted speed limits, such as including the presence of citizen requests, school zones, perceived safety issues, special weather conditions, construction zones and political pressure. Due to these variety of reasons, posted speed limits have been lowered to values below engineering recommendations.

Yao et al. [7] and Silvano [8] found another important factor that can be directly affected by the speed limits. Access density, vulnerable road users such as older drivers, road geometry and roadside environment were considered as important factors. The points made here were highly utilized for selecting the most essential factors. Before starting the data collection, the factors mentioned here were analyzed and the most appropriate factors were selected that can be considered within our country region and the literature reviews were utilized to create a considerable number of contributory factors for the current study.

2. Methodology

2.1 Site Selection Criteria

Ten (10) road sections in built-up areas were selected to collect the speed data. Geometric characteristics were chosen differently from place to place when selecting the site locations. Those are, lane width, shoulder width, bicycle lane width, number of lanes, road markings, road side activities, road classes, 1-way or 2-way operation, etc. However, all selected locations are straight sections along level terrain.

This current research considers only "A", and "B" class roads. All the data were collected in the free-flow condition during off-peak hours on weekdays. Before selecting the site location, Google speed maps were checked to identify the most suitable location in the areas.

Figure 1 shows the selected site locations and Table 1 shows route numbers, township details and ADT (Annual Daily Traffic) values for the selected site.

Table 1 - Site Locations and ADT Values

Site Number	Route Number	Township	ADT (veh/day)
1	A02	Kalutara	34,069
2	A02	Wadduwa	34,069
3	A02	Panadura	32,241
4	A08	Bandaragama	12,381
5	A02	Moratuwa	36,840
6	B084	Kesbewa	15,471
7	B084	Piliyandala	22,724
8	B094	Maharagama	29,881
9	A02	Dehiwala	59,598
10	B062	Kotte	56,978

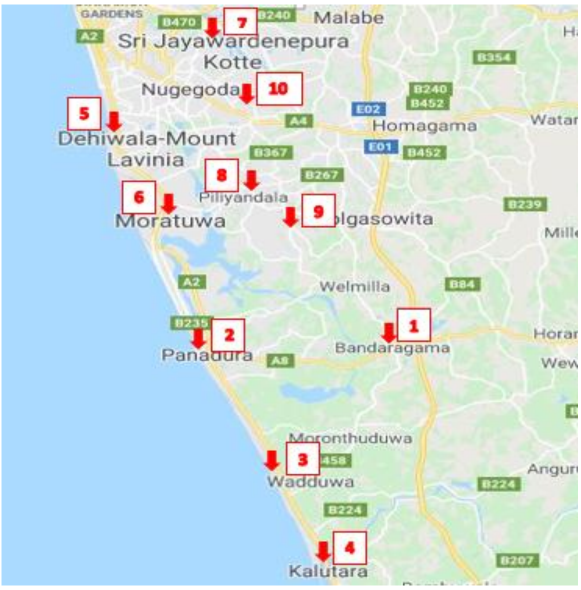

Figure 1 - Sites Location Map

2.2 Data Collection

Spot speed data was collected using radar guns with an accuracy of 1 km/h. A total of 3000 spot speed data were collected from 10 sites making it roughly 300 speed data values from each site. Besides, vehicle type, road geometric data such as lane width, number of lanes, bicycle lane width, parking lane width, road marking details, roadway operation (i.e., one-way and two-way), together with roadside activities were collected. As secondary data, ADT from the Road Development (RDA) and accidents from the respective police stations were collected.

Speed data were collected for randomly selected four types of vehicle categories such as motorcycle, three-wheeler, light vehicles (Car/Van/Jeep: CVJ) and commercial vehicles (buses, heavy and medium goods vehicles). Such speed data were collected covering both directions where applicable at the time such that impact of opposing vehicles on the speed of sample vehicles could be assessed.

2.3 Data Analysis

2.3.1 Initial Data Analysis

Initially all the collected speed data were summarized to obtain the 85th percentile speed. The 85th percentile value is frequently used in many countries to post the speed limits to road sections. Sri Lanka is not an exception. The 85th percentile value represents the highest and the safest speed for the road.

The initial analysis was done by using 4 steps.

- Step 1

Initially, collected data were categorized by considering only location and created the cumulative frequency polygons separately for each site.

- Step 2

To study further, the collected data were categorized by considering vehicle category and location. That sample was used to create some cumulative frequency polygons for each vehicle category in each location separately.

- Step 3

Finally, those separated cumulative distribution polygons were drawn in the same polygon for each location separately.

- Step 4

To further clarity and easy visualization, the 85th percentile data at each site and each category was used to generate radial diagrams. This gives a chance to identity the effect of geometric features to speed variation.

2.3.2 ANOVA Test

On completing the initial data analysis step, ANOVA test was performed. To perform the ANOVA test, One-way ANOVA test method was used. It was carried out based on three assumptions given below. To perform the ANOVA test these three assumptions should be satisfied with the data set. These assumptions are:

1. Homogeneity of variance among groups;
2. Dependent variable should be normally distributed within each group; and
3. Independence of observations.

2.3.3 Model Fitting

In this section, stepwise multiple linear regression was performed. To carry out the model fitting work, 80% of data were used as training data and the other 20% of data were used to predict the model. Training data were randomly selected from each site. Further, to develop a speed prediction model and to identify the most significant parameters in deciding the speed limits, multiple linear regression analysis was performed for each vehicle category. Multiple linear regression analysis was performed to fix the speed prediction model for each vehicle category with most significantly contributing explanatory factors related to environment. As such, number of lanes, shoulder width, road side fiction intensity, availability of road marking, one-way and two-way road operations, gradient of the road stretch, availability of cycle lanes or parking lanes, were considered. SPSS software package was used for the analysis.

Categorical variables in the data set were represented by dummy variables. Table 2 shows the numerical notations used for the dummy variables.

Table 2 - Numerical Notations used for the Dummy Variables

Considered Factor	Numerical notation "0"	Numerical notation "1"
Situation of Two Way or One Way	One Way	Two Way
Road Markings	Road Markings - bad	Road Markings - good
Roadside Activities	Moderate Roadside Activity	High Roadside Activity
Road Class	Road Class "B"	Road Class "A"
Situation of One Lane or Two Lanes	One Lane	Two Lanes
Availability of Bicycle Lane	Bicycle Lane Not Available	Bicycle Lane Available
Availability of Parking	Parking Not Available	Parking Available
Availability of Center Median Barrier	Center Median Barrier Not Available	Center Median Barrier Available

2.3.4 Model Adequacy Checking

One of the major steps of this process was model adequacy check. To generate more accurate models for the data set, assumptions should be satisfied. Here, eight (8) assumptions of multiple linear regression model were checked under this section.

1. Check of Dependent variable measured on a continuous scale.
2. Check of Two or more independent variables.
3. Check of Independence of observation. (Residuals are uncorrelated)
4. Check of Linear relationship.
5. Check of Homoscedasticity.
6. Check of Multicollinearity.
7. Check of No significant outliers.
8. Check of Residuals are approximately normally distributed.

2.3.5 Model Validation

Model validation was checked by evaluating 20% of testing data. This 20% of the data set should be a random portion of the initial data set. This model validation process was done by using Excel. System generated four (4) models were used and compared the predicted speed values with the real mean speed values on each site. For each regression model, line graphs were created between actual mean value and model fitted value for comparison. They are the steps that were carried out in the data analysis.

3. Data Analysis, Results and Discussion

3.1 Initial Data Analysis Results

According to the steps 1, 2 and 3 of the initial data analysis, Cumulative Frequency Distribution was drawn by using collected data as shown in Figure 2.

Figure 3 represents the Cumulative Frequency Distribution for one vehicle category (Motor Cycle) at location 1 (Kalutara).

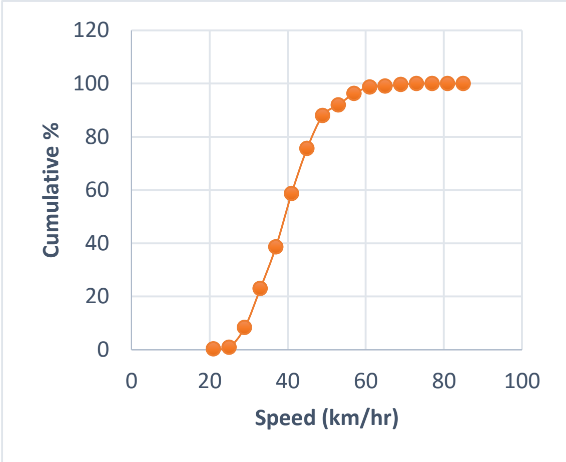

Figure 2 - Cumulative Frequency Distribution for all Vehicle Categories (Kalutara Area)

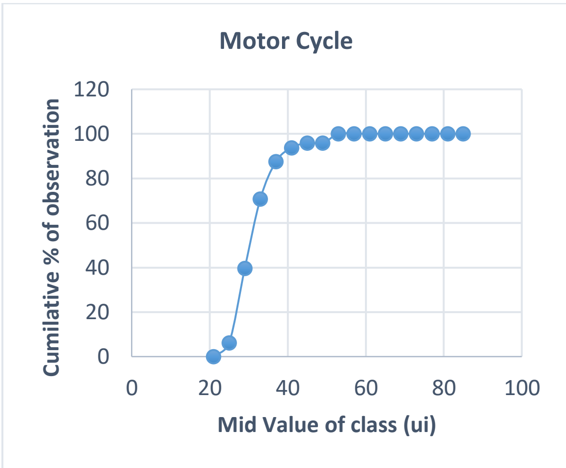

Figure 3 - Cumulative Frequency Distribution Polygon for Motorcycle in Kalutara

Figure 3 shows the cumulative Frequency Distribution polygon for Motor cycles. This gives different values for different vehicle categories at different locations. All vehicle categories were taken into one cumulative polygon as shown in Figure 4.

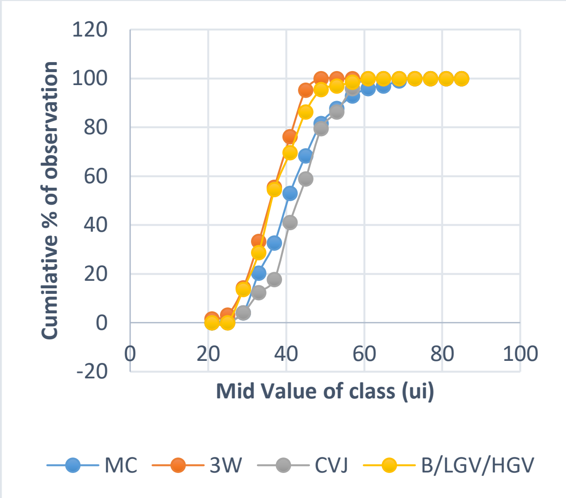

Figure 4 - Combined Cumulative Frequency Distribution Polygon

Figure 4 indicates all cumulative distribution polygons in the same polygon for one location. In this way, other cumulative polygons were created for other sites. Then, it was used to compare speed values between each vehicle category.

It was shown how the speed values of each vehicle category varied in each site. Cumulative Frequency Distribution polygons were used to get 85th percentile values of each site. These results showed some speed variations between each other. Apparently it happened due to the variance of the vehicle type. It was possible to gain a clear understanding of how 85th percentile values vary by vehicle category and by site location. Table 3 shows the results of the 85th percentile values of each site.

Table 3 - 85th percentile speed values of Sites

Location	85th percentile value(km/h)				
	MC	*3W*	*CVJ*	*B/ LGV/ HGV*	*General Value*
Kalutara	51.2	42.85	52.24	44.67	48.03
Wadduwa	40.04	32.87	38.36	32.97	36.81
Panadura	48.26	35.06	40.83	38.2	40.53
Bandaragama	44.16	39.5	45.27	42.43	43.67
Moratuwa	51.8	43.24	51.11	46.07	48.47
Kesbawa	47.03	41.9	45.2	40.71	44.35
Piliyandala	39.27	35.43	37.7	32.63	36.81
Maharagama	35.64	30.05	32.13	28.97	31.96
Dehiwala	40.08	32.96	40.53	35.26	36.91
Kotte	36.4	31.91	34.99	31.24	33.67

According to the results, the maximum 85th percentile value of the Motorcycle category showed at the Moratuwa location and it was about 51.8km/h, and it exceeds the posted speed limits for the motorcycles. The maximum 85th percentile value of the Three-wheelers was also indicated at the same location at Moratuwa and it also exceeds present posted speed limits. When considering the Car/Van /Jeep cluster, the maximum 85th percentile value occurred at the Kalutara location and it was about 52.24 km/h. The 85th percentile value of the Car/Van /Jeep cluster exceeded the posted speed limits at Kalutara and Moratuwa locations. When considering the bus/ light goods vehicles and heavy goods vehicles cluster, the maximum 85th percentile value occurred at Moratuwa, and it was 46.07km/h, but it did not exceed the posted speed limits.

3.2 Radar Diagram

Radar diagrams were used to graphically represent the behaviour of the current posted speed limits and 85th percentile values of each site (Figure 5). According to the last steps of the initial data analysis process, it was evident that some differences between the posted speed limits and the actual speed values. Because of this, the emerging question is whether speed limits have a direct influence on geometric characteristics.

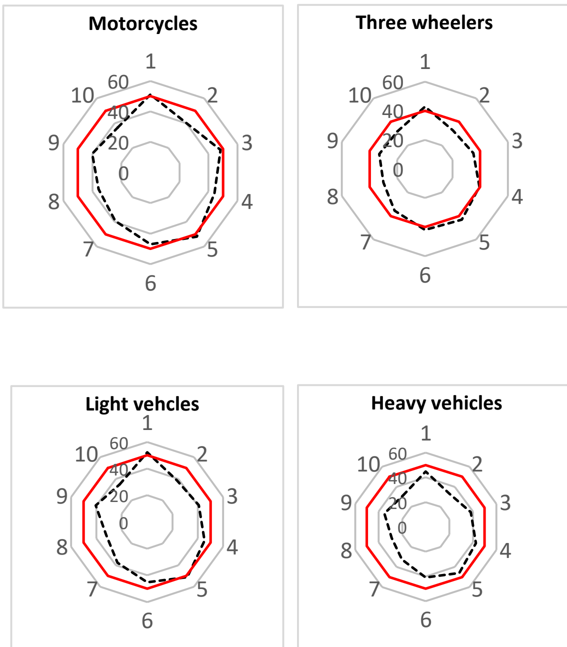

Figure 5 - Radar Diagrams for all Vehicle Categories

In Figure 5, the straight line represents the current speed limits and the dotted line represents the 85th percentile value of each site. According to Figure 5 results, there was a difference between posted speed limits and the 85th percentile value.

3.3 ANOVA Test Results

One-way ANOVA test was performed to check whether the mean speeds of the four vehicle categories were significantly different from each other. When it indicates the same mean values to vehicle categories, it represents that categories can post the same speed values. Basically One-way ANOVA method was used to compare mean values from more than two groups.

Assumption of homogeneity of variance check was done before proceeding to other assumption checks. Checking was done using a test of homogeneity of variances table. It shows the p-value as 0.002. It indicated that homogeneity of variance assumption was violated and the classical ANOVA Test cannot be applied. Then, Welch ANOVA method was used to compare group means. It has to prove only 2nd and 3rd assumptions.

Table 4 - Welch ANOVA Test Results

	Statistic	df1	df2	Sig.
Welch	110.116	3	1349.648	0

Table 4 presents the Welch ANOVA test results and it shows the p-value as 0.00 and it indicated at least one mean value was different. Then, whether 2nd Assumption of observations are Normally Distributed within each group was checked. Histogram showed a bell shape, and in the Q-Q plot, observations approximately laid around the line. It indicated that normality assumption was also satisfied. The last assumption of Independence of observations was checked by using scatterplot of Standardized Residual vs observation order, and it did not show any pattern in the plot where all the observations were randomly scattered. This indicates the independence of observations. Then the 3rd assumption was also satisfied.

Table 5 - Games-Howell Post Hoc Test

(I) Vehicle Category	(J) Vehicle Category	Sig.
MC	3W	0
	CVJ	0.961
	B_LGV_HGV	0
3W	MC	0
	CVJ	0
	B_LGV_HGV	0
CVJ	MC	0.961
	3W	0
	B_LGV_HGV	0
B_LGV_HGV	MC	0
	3W	0
	CVJ	0

Since Welch ANOVA test indicated that at least one group mean is different from others, to identify which group mean differs, Games-Howell post hoc test was conducted. Table 5 shows the results of the Games-Howell Post Hoc Test. According to the Post Hoc Test results, only motorcycle and light vehicle show no significant mean difference because it showed a p-value which is greater than 0.05 significance level. When posting the speed limits, these two (2) categories can be considered the same. But other group means were significantly different with each other as their p-values were less than 0.05 significance level.

3.4 Model Fitting Results

Tables 6 to 9 present the coefficients of selected significant parameters for Motorcycles, Light vehicles, Three-wheelers and Heavy vehicles respectively. According to Equation (1), when a bicycle lane is available, it is largely impacted on improving the speeds of the motorcycles. Not only that, when the centre median barrier is available, it helps to reduce speed violators from the opposite side. When parking is available and vehicles are parked at the designated locations, it also helps to mitigate the effect of improper vehicle parking. The shoulder availability affects motorcycle speed in different ways, such as when the shoulder availability for pedestrians and foot-cyclists, they are not trying to go on the vehicle lanes. Good road markings also help to improve the motorcycle speed, like when the good road markings are visible for each driver on the road and trying to follow the rules, it reduces the actions of speed violators. In that context, when A grade roads have some specific features such as good lighting at night, smooth road surfaces, standard road widths, and have good maintenance practices than B grade roads, driver speeds at A-class roads are relatively higher. Those are the positive impacts to improve the motorcycle speeds on the A-class roads. According to the Speed prediction model for three-wheelers (Equation 2), light vehicles (Equation 3) & heavy vehicles (Equation 4) cluster speed value largely depends on the availability of the bicycle lane. When a bicycle lane is available, it reduces the number of motorcyclists on the main lanes which helps to mitigate the conflicts with main vehicular flow. When parking slots are available at the road section, it helps to mitigate the effect of improper parking. If a shoulder is available, it helps to reduce pedestrians and the foot-bicyclists using the road, as it can used as a sidewalk. When good road marking is available, it improves visibility for every driver and it helps to identify and follow road rules. Then drivers try to follow those rules, else drivers try to drive as they wish.

Table 6 - Coefficients for Motor Cycles

Model Parameters	Coefficient	t value	p-value
Availability of Centre Median Barrier	0.068	2.144	0.000
Availability of Bicycle lane	0.403	5.828	0.033
Availability of Parking	0.114	3.296	0.001
Availability of Shoulder	0.201	5.420	0.000
Road Markings	0.242	6.938	0.000
Road Class	0.126	5.084	0.000

Table 7 - Coefficients for Light Vehicles

Model Parameters	Coefficient	t value	p-value
Availability of Bicycle lane	0.588	9.418	0.000
Availability of Parking	0.178	5.966	0.000
Availability of Shoulder	0.222	7.935	0.000
Road Markings	0.278	10.236	0.000
Road Class	0.247	13.390	0.000
Roadside Activities	-0.125	-4.242	0.000

3.5 Model Adequacy Checking

Initially 1st assumption of "Dependent variable measured on a continuous scale" was satisfied for all fitted models because vehicle speed was measured in km/h.

Table 8 - Coefficients for Three-wheelers

Model Parameters	Coefficient	t value	p-value
Availability of Bicycle lane	0.582	7.925	0.000
Availability of Parking	0.166	5.421	0.000
Availability of Shoulder	0.199	7.152	0.000
Road Markings	0.226	7.019	0.000
Road Class	0.196	9.146	0.000
Roadside Activities	-0.115	-3.345	0.001

Table 9 - Coefficients for Heavy Vehicles

Model Parameters	Coefficient	t value	p-value
Availability of Bicycle lane	0.520	8.087	0.000
Availability of Parking	0.145	4.607	0.000
Availability of Shoulder	0.210	6.891	0.000
Road Markings	0.241	8.307	0.000
Road Class	0.205	10.360	0.000
Roadside Activities	-0.115	-3.875	0.000

Estimated Log Speed Value for Motor Cycles = 0.068 (Availability of Centre Median Barrier) + 0.403 (Availability of Bicycle lane) + 0.114 (Availability of Parking) + 0.201 (Availability of Shoulder) + 0.242 (Road Markings) + 0.126 (Road Class) + 3.109

Estimated Log Speed Value for Three-wheelers = 0.582 (Availability of Bicycle lane) + 0.166 (Availability of Parking) + 0.199 (Availability of Shoulder) + 0.226 (Road Markings) - 0.115 (Roadside Activities) + 0.196 (Road Class) + 2.958

Estimated Log Speed Value for Light Vehicles = 0.588(Availability of Bicycle lane) + 0.178 (Availability of Parking) + 0.222 (Availability of Shoulder) + 0.278 (Road Markings) - 0.125 (Roadside Activities) + 0.247 (Road Class) + 2.989

Estimated Log Speed Value for Heavy Vehicle = 0.520 (Availability of Bicycle lane) + 0.145 (Availability of Parking) + 0.210 (Availability of Shoulder) + 0.241 (Road Markings) - 0.115 (Roadside Activities) + 0.250 (Road Class) + 2.976

However, high roadside activities negatively impact the vehicle speeds, because when a high population or shops exist near the roads, pedestrians try to cross roads. This has a huge impact to reduce vehicle speed. Another reason is, when shops exist, drivers try to park improperly on the roads. Shops are another reason to reduce the speed of the three-wheelers. These are the reasons to reduce the vehicle speed due to high roadside activities.

The 2nd assumption of "two or more independent variables" also satisfied for all fitted models. This is because when it comes to the data set, it has eight (8) categorical independent variables.
3rd assumption was checked by using Standardized Residual vs Vehicle observation number scatter plots. 4th assumption was checked by using scatter plots in between dependent variable and each of independent variable and 5th assumption was checked by using Standardized Residual vs Standardized Predicted value scatter plot, respectively.

Scatter plots for 3rd and 5th assumptions did not follow any pattern and observations were scattered randomly. Also, scatter plots in between dependent variable and each of independent variable showed linear patterns implying that there is a linear relationship between dependent variable and each independent variable. Then, all the requirements of 3rd, 4th & 5th assumptions were satisfied for all fitted models. 6th assumption of Multicollinearity was checked by using Pearson's correlation coefficient and it also implied that all independent variables are uncorrelated for all fitted models, because all the correlations were in between (-0.8) and (+0.8).

7th assumption of No significant outliers, high leverage point or highly influential points was checked by using Cook's Distances and the leverage values. All the Cook's Distance values were less than (4/n) and all the leverage values were also less than 2(k+1)/n. Then 7th assumption was satisfied for all fitted models as there are no outliers or influential points. Last assumption of Residuals are approximately normally distributed was checked by using Normal P-P plot. It also satisfied for all fitted models because observations were approximately lying around the line. Then all the assumptions were satisfied for all fitted models.

3.6 Model Validation Results

The last step of the process was the model validation. It can be explained as a process of checking whether the generated regression model accurately predict the values.

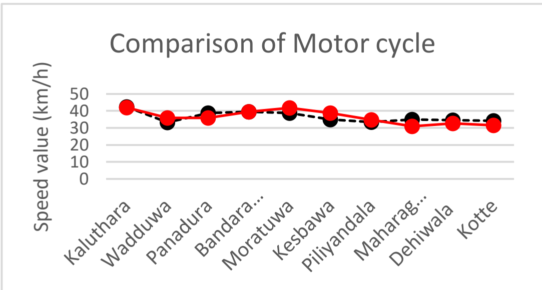

Figure 6 - Comparison of Fitted Value vs Actual Mean Value for Motor Cycles

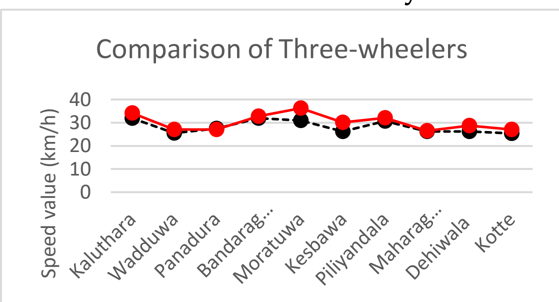

Figure 7 - Comparison of Fitted Value vs Actual Mean Value for Three-wheelers

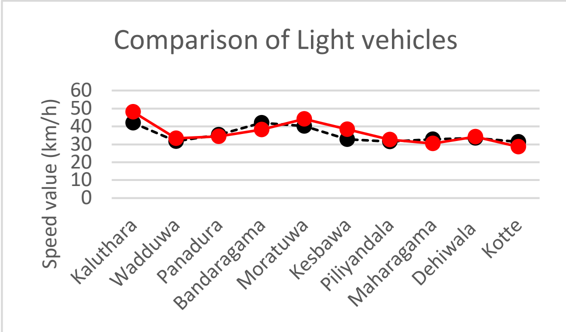

Figure 8 - Comparison of Fitted Value vs Actual Mean Value for Light vehicles

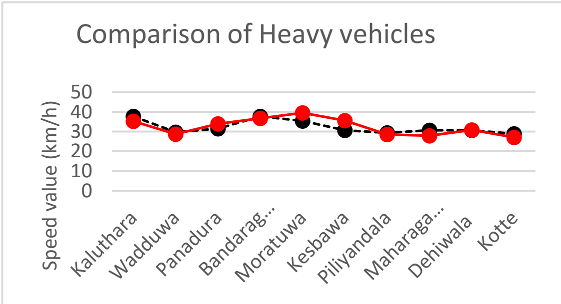

Figure 9 - Comparison of Fitted Value vs Actual Mean Value for Heavy vehicles

Table 10 - RMSE (Root Mean Square Error) for each Vehicle Cluster

Vehicle Category	RMSE Value
Motor Cycle	2.60
Three-wheelers	2.50
Light vehicles	3.44
Heavy vehicles	2.59

The continuous line represents the Actual mean value while the dotted line represents the fitted value. According to the above plots, it can be seen that fitted values from the regression models are approximately compatible with actual values of each site. Table 10 shows the RMSE (Root mean Square Error) of each fitted model under each vehicle category. Since these errors are not much higher, it indicates that fitted models predict the values which are approximately compatible with actual values. It was indicated, fitted four linear regression equations were compatible with the real situations. Then these equations can be used in each situation to post the compatible speed limits for each vehicle category in any of the build-up areas of Sri Lanka.

3.7 Discussion

According to the Sri Lankan Motor Traffic Act of RDA [9] only two different vehicle speeds are mentioned for vehicles such as 40km/h for three-wheelers and 50km/h for other categories like car/van/ jeep/ motorcycles/ buses/ lorries, etc.

According to this study, all the vehicles were grouped into four major vehicle categories such as Motorcycle, Three-wheeler, Light vehicle cluster (Car/Van/Jeep in the same cluster), and the heavy vehicle cluster (Bus/Light goods vehicles and the Heavy goods vehicles in the same cluster).

But according to the ANOVA results, light vehicle (Car/Van/Jeep) cluster and the MC (Motorcycle category) can be allocated the same speed limits because ANOVA results indicated there was no significant mean speed difference between these two categories. But, in the other cases, MC, 3W and the heavy vehicle (B/LGV/HGV) categories mean speed values were significantly different from each other. According to the result of the regression analysis, it indicates that motorcycle lane heavily impacts on the vehicle speed.

According to the initial data analysis, it seems that vehicle speed not only depends on the vehicle category but indicates some other geometrical features directly affecting the vehicle speed. Therefore, four regression equations were generated to identify the other geometrically contributory factors. The results show that, when the Bicycle lanes are available, Motorcycles move through the Bicycle lanes. They are not an obstacle to other vehicles. Then it is easier for motorcyclists and the other vehicle drivers too. When the roadside activities are high, it directly impacts the larger vehicles like three-wheelers, light vehicles, and heavy vehicles. But it does not impact the motorcyclists. Because motorcycles are smaller than the other vehicles they can easily avoid obstacles. Having parking, shoulder, and proper road marking also positively impact all vehicle categories. Having parking slots helps to mitigate impolite vehicle parkers.

Having a shoulder also mitigates effects of obstacles, as it is also used as a sidewalk. Then, pedestrians who walk on the roads have less connection between road lanes.

Road class also impacts the vehicle speed in such a way that when A-class roads have proper arrangements than the B-class roads, it positively impact all vehicle categories.

4. Conclusion

The primary aim of the research work was to find the explanatory factors desirable to be considered when deciding the posted speed limit for road sections in built-up areas apart from the two vehicle categories under the Gazette of the Demographic Socialist Republic of Sri Lanka, No.1763/26, June 22, 2012. Potential influencing factors like road geometry, roadside friction, road marking, vehicle density, vehicle composition, roadway operation, accident rates, and average daily traffic values were considered. Ten (10) locations were selected with diverse aforesaid features and cumulative speed frequency polygons were produced. The 85th percentile speed values obtained for each location exhibit significantly different explanations for the impact of different factor contribution for posted speed limit. Thus, in order to test the hypothesis that location specific factors influence posted speed limit, ANOVA test was performed, and further, posted speed limits for clustered vehicle groups were derived using multiple linear regression analysis. From the results, it was identified that speed behaviour of motorcycles and light vehicles have a similar pattern, thus can be made to be in one cluster while the rest of the vehicles moved to another cluster. Four different speed predicting models for motor cycles, three-wheelers, light vehicles and heavy vehicles were developed. Table 11 summarized the most positively and negatively affecting factors for predicting the posted speed limit in each vehicle category.

Table 11 - Most Positively & Negatively Influential Factors

Vehicle Category	Most Positively influencing factor	Most Negatively influencing factor
Motor-cycle	Availability of Bicycle lane (t-value = 5.828)	-
Three-wheelers	Availability of Bicycle lane (t-value = 7.925)	Roadside Activities (t -value = -3.345)
Light Vehicles	Availability of Bicycle lane (t -value = 9.418)	Roadside Activities (t -value = -4.242)
Heavy Vehicles	Availability of Bicycle lane (t -value = 8.087)	Roadside Activities (t -value = -3.875)

According to the results of all vehicle categories, posted speed limit is positively influenced by the availability of a bicycle lane and negatively influenced by roadside activities in built-up areas. Apart from them, road marking and road class also positively impacted on posted speed limit. The developed regression models for each vehicle category was tested and confirmed to receive high predicting accuracy. Thus, it can be concluded that developed models can be used in deciding posted speed limits on built-up areas combining location specific factors.

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