

**Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads**

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**ADDIS-ABABA INSTITUTE OF TECHNOLOGY**

**SCHOOL OF GRADUATE STUDIES**

**SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING**

**EVALUATING THE EFFECT OF ROAD GEOMETRY AND POSTED SPEED LIMIT ON  
85<sup>th</sup> PERCENTILE SPEED OF ADDIS ABABA URBAN ROADS**

**BY: ADERAW SITOTAW**

August 2020

Addis Ababa, Ethiopia

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PERCENTILE SPEED OF ADDIS ABABA URBAN ROADS

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IN

ROAD AND TRANSPORT ENGINEERING

CIVIL ENGINEERING DEPARTMENT

ADVISOR: DR. GETU SEGNI

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# Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

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## Abstract

The main objective of the study was evaluating the effect of road geometry and posted speed limit on 85 percentile speed on urban road of Addis-Ababa. The output of this study is used for transport planner, geometric designer and traffic management agency for evaluation of existing urban road and identifying factors which are used for calming speed of vehicles.

The data was collected by field survey, manual pedestrian and side parking vehicle counting and video graphic survey for extracting operating speed calculation data for half hour duration on 23 selected road section. For all selected section, a total of 3779 free flow vehicle were obtained for 85 percentile speed determination in which on the average 160 free flow vehicles per section. The recorded video was played using VLC media player by play and pause in order to obtain entry and exit time of each vehicle for calculation of spot speed. After extracting all data and computing operating speed, the 85 percentile speed was determined using speed frequency distribution graph. After all necessary field data are collected and manipulated, multiple linear regression model was developed using STATA-14 software for predicting 85 percentile speed to use as initial guide line for planning and designing of urban roads. For this study road environment (number of lane, longitudinal grade width and height of median, walking width, road side object density and land use) and traffic factors (pedestrian volume, vehicle hourly volume and parking density) were considered.

Based on the result of analysis, the number of lane and road side object density were found to be increase the 85<sup>th</sup> speed by **3.43km/hr.** and **0.425 km/hr.** respectively whereas side parking density and hourly traffic volume are found to be reducing 85<sup>th</sup> speed by **1.27** and **0.018** km/hr. respectively. The degree of determination and root mean square error of the model were also 83.9% and 3.83km/hr. respectively. In order to check the **validation** of multiple linear regression model parameter effect, driver attitudinal survey was conducted. Based on the collected questionnaire data, factor analysis, was conducted. Factor analysis was done to form few factors from 15 original speeding reason based on correlation between each reason. Based on the result of analysis, 15 original speeding reason was grouped in to four few factors which are understandable and easy for interpretation. These are roadway and variable control condition, lack of knowledge and illegal driver behavior, speed limit condition and over load task of drivers.

Key word: **85 percentile speed, posted speed limit, speeding frequency and factor analysis**

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## **Chapter one: Introduction**

### **1.1. Background of the study**

Traffic safety is the main issue of the world because it affected not only economy but also social life. Speeding is one of the main causes of traffic crash which has contribution of 30% (WHO, 2018). Controlling the speed of the vehicle through posted speed limit is a best mechanism to reduce traffic crash (WHO, 2018).

Based on this principle, most urban road of Addis-Ababa have different posted speed limit ranging from 20 kmh to 70 kmh on specific section depending on the surrounding land use. Based on the observation of field survey in Addis-Ababa urban roads, 40kmh and 50kmh speed limit signs are mostly provided on non-access control urban road which are affected by variable control condition and road side environment. Even if there are posted speed limits in Addis-Ababa urban road, a study by (Hopkins university, 2016) shows that 43% drivers in Addis Ababa city exceeds the posted speed limit. Posted speed limits are decided by 85 percentile speed of the driver which is conducted by engineering study by comprising all road way geometry and traffic conditions. Therefore predicting 85 percentile speed accurately is important for planning, designing and evaluation of existing urban road.

85 percentile speed is an important parameter since it relates to safety, design and evaluation of urban road transport system. 85<sup>th</sup> speed is the observed operating speed of most driver in which 85 % of the driver is not exceeded (AASHTO, 2011). Posted speed limit condition, road way and side characteristics, traffic condition, and environment are the main generic factors which affect 85 percentile speed in turn affects safety, and operational efficiency especially in urban roads. Posted speed is the maximum vehicle speed for a particular location as displayed on a regulatory sign (AASHTO , 2011).

Several studies had been conducted on the effect of posted speed limit and roadway environment on 85<sup>th</sup> percentile speed of drivers which is used for planning, design and evaluation of efficiency of urban roads.

Based on the study of (Wang, et al., 2006), number of lane, width of carriageway, parking, median type, pedestrian walkway, and land use were found to be main factors affecting 85<sup>th</sup> percentile speed but in case of (Fitzpatrick, et al., 2001) study, only posted speed limit and number of lane are significant variable for 85<sup>th</sup> speed of straight urban section road. However, posted speed limit was

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not significant variable for studies done by (Ahmed M. Semeida, 2012) and (Wang, et al., 2006). (Rohaizan & Mashros,, 2016) was also found that drivers speed choices depend on posted speed limit of particular section. Therefore there is no universal agreement about the effect of posted speed limit and some urban road geometry since all of the above studies were conducted on specific cluster which consider only local driver driving condition.

All of them modeled operating speed as function of Posted speed limit and road way geometry including land use, side parking access and pedestrian walk facility but does not consider the parking density and pedestrian volume because the side parking and pedestrian facility without vehicle and pedestrian consider as travel way and free zone respectively. All of the above studies have considered only local driver which is depending on the culture and the environment of specific area.

In this research, the integrative effect of posted speed limit, roadway environment and variable control condition (traffic hourly volume and parking density) on 85<sup>th</sup> percentile speed of the driver at tangent section of Addis-Ababa urban roads were investigated with driver attitudinal survey.

To meet the objective of this research both multiple linear regression and factor analysis were employed for 85<sup>th</sup> percentile speed model and driver attitudinal survey analysis respectively.

### **1.2. Statement of the problem**

The majority of accidents are directly or indirectly linked to speeding. In the world 30% of fatal accidents, speed is an essential contributory factor which affects: accident risk, severity and environment (WHO., 2018).Therefore to avoid such type of traffic accident, it is necessary to identify, the driver degree of compliance for posted limit and the impact of road way features on operating speed of the drivers for control measurement based on driver speeding factors. The following researchers ( (Himes, et al., 2013), (M.A.Rahim, et al., 2015), (S.Wu & T.Xu, 2010) and (Wang, et al., 2006)) have studied and model operating speed with respect to either only posted speed limit or both posted speed limit and roadway geometry on urban roads. Most of them modeled 85<sup>th</sup> percentile speed as function of Posted speed limit and road way geometry including road side parking access and pedestrian facility but not parking density and pedestrian volume which may have better influence on operating speed.

Different types of studies were carried out on operating speed modeling which are mostly focusing on horizontal and vertical curve. According to results, most of the time drivers are exceeded speed

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limit on the tangent section than on the curved stretch of the road since drivers are more controlled on the curved section by the roadway geometry( (Ahmed M. Semeida, 2012).

And those models did not consider global driver behavior because driver behaviors are complex and dynamic which are highly affected by culture and habit of the environment. Due to this fact, studies should be done using driver behavior of specific area. Therefore, this study modeled 85 percentile speeds of drivers in Addis-Ababa straight urban road as function of posted speed limit, roadway environment, traffic volume and side parking density during free flow traffic condition. The results of this study could be used in engineering enforcement measurements so as to obey posted speed limit.

### **1.3. Research Question**

- ✓ What is the effect of road way geometry and posted speed limit on operating speed of Addis-Ababa urban road?
- ✓ What is the level of degree of compliance of driver on posted speed limit on Addis-Ababa urban roads?
- ✓ What are the possible frequent speeding factors of Addis-Ababa drivers?

### **1.4. Objective**

#### **1.4.1. General objective**

- The general objective of this research was to evaluate the effect of posted speed limit and roadway geometry on 85 percentile operating speeds of urban roads.

#### **1.4.2. Specific objective**

- Identify the effect of road geometry and posted speed limit on 85 percentile speed.
- Identify driver's degree of compliance on posted speed limit.
- Identify possible driver speeding factors.

### **1.5. Scope and limitation of the study**

#### **1.5.1. Scope of study**

This study was subjected to selected straight tangent urban road which has posted speed limit of (40 and 50km/hr.) and well-defined roadway geometry.

### **1.5.2. Limitation of the study**

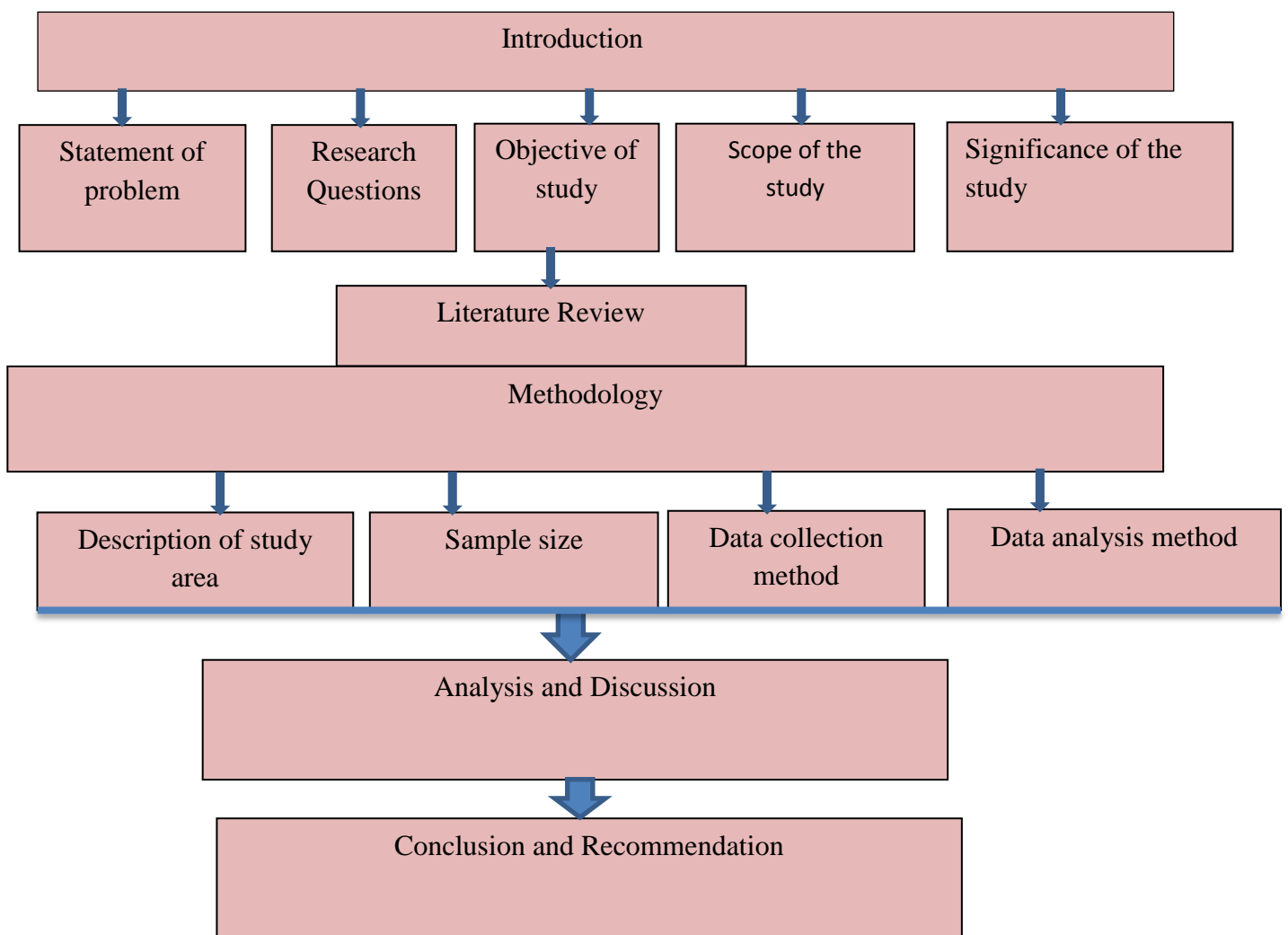
Even if the study has done on straight midblock road section, it did not consider the far distance of speed hump and intersections. This study included only straight tangent urban roads during free flow condition and the method of data collection and extraction was supported by video which was time intensive.

### **1.6. Significance of the Study**

This study used to identify driver's degree of compliance on posted speed limit of Addis-Ababa selected urban road and evaluate the effect of posted speed limit and road way geometry on operating speed and used to adjust roadway geometry on the stretch of posted speed limit section so as to maintain the posted speed limit. It is also used to identify the possible speeding reason of drivers by factor analysis. The output of this investigation used for the transport policy makers, urban road planner and traffic manager to take remedy action on geometric parameters and features on the position of the posted speed limit and to improve the method of controlling of operating speed of the drivers. It is also used to identify possible factors of driver speeding reason for more consideration of enforcement and education.

### **1.7. Organization of the Paper**

This study was organized in five chapters. Chapter one gives a brief overview of the general background of the study, statement of the problem, the general and specific objectives of the study, research question, and scope of study. Chapter two deals with a review of relevant literature. Chapter three describes research methodology including a description of the study area, data collection, extraction and analysis methodology, sample size determination and study design. Detailed data analysis and discussion of results is presented in chapter four. Conclusion and recommendations are drawn in the last chapter.



## **Chapter two: Literature Review**

### **2.1 Introduction**

In this section, several literature's was reviewed about the concept of operating speed and posted speed limit, the effect of posted speed limit; influence of road geometry and environment on operating speed. Several studies were conducted on the effect of either roadway geometry or posted speed limit on the performance of the driver. But there is few study on the aggregate effect of both speed limit and roadway geometry on operating speed of the driver because the effect of both characteristics act at the same time and place at stretch section of speed limit on operating speed of the drivers.

### **2.2. Operating speed and posted speed limit concept**

According to (AASHTO, 2011) A Policy on Geometric Design of Highways and Streets, Operating speed is the speed at which drivers are observed operating their vehicles during free-flow conditions. 85 percentile speeds is the measure of operating speed of most drivers on specific geometric features. Posted speed is the maximum lawful vehicle speed for a particular location as displayed on a regulatory sign (AASHTO, 2011). 85 percentile operating speed is determined by spot speed study on selected section of the road.

### **2.3. The relation between posted speed limit and operating speed**

Most researchers and transport agency assured that the posted speed limit is decided based on 85 percentile speed predominantly. The main question is the drivers are taking in account the posted speed limit when they are drive? The following researchers were carried out study on the relation between posted speed limit and posted speed limit.

According to study of (Fitzpatrick.k, et al., 2003) on the influence of posted speed limit on 85 percentile speed of different functional class of the road; the posted speed limit had strong statistical relationship with the 85 percentile speed for both urban and sub-urban arterial roads. (Fitzpatrick.k, et al., 2003) was also carried out research on the effect of each posted speed limit (starting from the lowest posted speed limit (30mph) on 85 percentile operating speed, it is found that 30mph posted speed limit experienced relatively more variation in the 85 percentile operating speed as compared with the range present at other posted speed groups.

According to the investigation of (M.A.Rahim, et al., 2015)about the relation b/n posted speed limit and operating speed on federal arterial road in Malaysia, found that the operating speed of drivers in

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most section exceeded the posted speed limit. Based on the finding of (S.Wu & T.Xu, 2010) on coordination between operating speed and posted speed limit on classified highway, there is strong relationship between operating speed and posted speed limit, and operating speed is always larger than posted speed limit. They also carried out study by vehicle class ; it was found that the operating speed of cars has little change when the posted speed limit increase and for trucks, the posted speed does not affect the operating speed rather geometric parameters of the road or in coordination.

According to the study of (Rohaizan & Mashros., 2016) on the effect of Posted Speed Limit on Drivers Speed Choice during Off-Peak Period on three different sites which has varies posted speed limit from 60km/hr. to 80km/hr. It was found that driver speed choice is depend on the posted speed limit of the driver irrespective of driver attitude and driving style. Their speed distribution study showed that, both 15 and 85 percentile speed increase with posted speed limit and also the driver speed compliance changes with speed limit implies that driver speed compliance decrease with increase of posted speed limit.

(Zhang , 2015) was also carried out research on the Relationship between Speed Limits and Operating Speed on Straight Roads of Ordinary Provincial Arterial Highways. The researchers choose nine sections for operating speed study which has posted speed limit of 30km/hr., 40km/hr. and 60km/hr. and the result of analysis is done for different class of vehicle using SPSS statistical software. According to the result of the study, operating speed of car is greater than posted speed limit and the difference between operating speed and posted speed limit decrease, when posted speed limit is increase. But there is little difference between posted speed limit and operating speed of truck and when the posted speed limit increases , the difference between the operating speed and the posted speed limit becomes large incase of truck.

Based on the revised of (Fitzpatrick, et al., 2001) original submittal document, for suburban/urban areas , 86 and 95 percent of the vehicle on roadways has operating speed of speed limit plus 10 mph respectively. They also found that larger percentage of vehicle exceed speed limit on suburban/urban roadway than on rural non-freeway roadways for the following posted speed limit of 30.,35 and 40 mph which has only 28, 22, and 32 percent respectively of the vehicle are below posted speed limit. They also analysis 128 speed zone data, based on the result of analysis, 50% of the site has between 4 mph and 8 mph difference from the measured 85 percentile speed and ten percent of the site apply the posted speed limit recommended by MUTCD guide lines. Sixty seven

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percent of the site are having posted speed limit 5.8 km/hr. greater than the 85 percentile operating speed and 33 % of the site has posted speed limit rounded to nearest 5 mph increment.

(Kidd. & Radlj, 2001 and 2000) were reported summary statistics for the free-flow database and their principal finding found that 45% of all vehicles exceeded PSL; 12% of all vehicles exceeded enforceable speed limits (ESL) defined as PSL plus 9 km/hr.

Based on the above literature review, the posted speed limit is firstly decided based on 85 percentile operating speed but the operating speed of driver is greater than that posted speed limit. This indicates that, the negligence of driver or bad behavior of driver especially driver of passenger car. But all of the above study has some drawbacks because all of them carried out study regardless of method of speed enforcement, roadway geometry, roadside features and land use development. Based on different study conducted in different countries, the degree of compliance of posted speed limit varies with driver behaviors and method of enforcement of speed limit. Some operating speed models showed that posted speed limit is not a statistically significant variable, which implies that drivers are reckless for speed limit or never had awareness for speed limit.

### **2.4 The relation between roadway geometry and operating speed**

The three main principal components of road transport such as driver characteristics, traffic characteristics and road way and side features are the main influential factors of operating speed of drivers. Most studies are carried out on rural roads but few studies on urban and sub-urban roads.

(Poe. & Mason, 1996) Study operating speed of passenger car on 27 urban collectors in Pennsylvania at free flow condition when the time headway of the vehicle is 5 s or more, using mixed model approach and they found that degree of curvature, longitudinal grade, lane width, and roadside characteristics are the most significant variables which influence operating speed.

(Ali., et al., 1997) Investigate the relationship between free flow speed and geometric variables on 35 urban street segments located in Fairfax County Virginia and free flow speed is obtained using time headway of 7–8 s or more and a tail-way of 4 or 5 s. The study shows a statistically significant relationship between free flow speed and posted speed limits, median type, and segment length.

Both of the above researchers modeled operating speed at free flow condition on urban roads even if the type of model and number of tangent sections is different. In (Poe. & Mason, 1996) model, the posted speed limit is not significant but median type is the same for all tangent sections which contradicts the result of both (Fitzpatrick.k, et al., 2003) and (M.A.Rahim, et al., 2015). The model of

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(Ali., et al., 1997) is considered different median type, segment length and more free flow condition than (Poe. & Mason, 1996). Based on the study of (Krammes, 2000) the effect of rural road way geometry on 85<sup>th</sup> operating speed, carriage way width and annual average daily (AADT) were not significant but other studies assured that traveled way width is the most significant variable this may be due to less variability on traveled way width on rural road. The influence of road way environment and traffic volume on operating speed of four lane urban roads in Pennsylvania and North Carolina was also conducted by (Himes, et al., 2013). The result of the study was roadway width, median and right shoulder width found to be positive correlation with operating speed. Based on (Himes, et al., 2013) model, even if the median and shoulder width are provided for safety purpose, these gives greater flexibility and initiative for speeding up and he was contradict the research output of (Krammes, 2000) which was pavement width is not significant.

(Figuera & Tarko, 2005) also studied the relationship between various roadway and roadside design features and operating speeds on four-lane roadways in Indiana using linear regression model. The result was showed that increasing posted speed limit would initiate the driver for speed up. Therefore, there was a positive relationship between posted speed limit and 85<sup>th</sup> speed. This study is support the result of (M.A.Rahim, et al., 2015) and (Fitzpatrick.et.al., 2003).Both (Figuera & Tarko, 2005) and (Krammes, 2000) were conducted study on rural road but posted speed limit is the only highly significant by (Figuera & Tarko, 2005).In addition to median and pavement width, side access on tangent section was also found to be significant variables on 85 percentile speed based on the research done by (Ahmed M. Semeida, 2012)which was the influence of road geometry and speed limit on operating speed using both linear regression and artificial neural network. Posted speed limit was also found to be small effect on operating speed which indicates bad behavior of drivers. (Fitzpatrick, et al., 2001) was conducted study on the influence of roadway geometry including roadside development and traffic control devices on driver speeds of suburban arterial roads, with or without posted speed limit. They found that posted speed limit is the most significant variables for straight sections and in addition to posted speed limit. The analysis without posted speed limit also showed that median and roadside developments were significant for curve and lane width is the only significant variable for straight section.

(Wang, et al., 2006)was carried out finding on 95 percentile speed on urban tangent streets. The authors used more than 200 vehicles equipped with GPS instrument and consider driver age of 18 to 60 years old. They developed operating speed on tangent section which has posted speed limit

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ranging from 30mph to 40mph. The result of the study showed that number of lanes, the density and offsets of roadside objects, the density of T-intersections and driveways, raised curb presence, sidewalk presence, on-street parking, and land uses are the most significant variables on 95 percentile speed. From those number of lane per direction, on street parking and sidewalk are the most three significant variables in descending order (Wang, et al., 2006) model was better than other model because he consider road geometry, road side object and driver age and his method of data collection was GPS which is modern an able to give point to point operating speed of drivers.

### **2.5. Effect of road side environment on operating speed**

Road side object, land use, and off-set distance of road side object affect vehicle speed and crash risk in several ways. (horst & ridder, 2007) and (Martens, et al., 1997) were found that objects next to the road increase peripheral visual flow which would increase the drivers' perception of their own speed and lead speed decrease. They also showed that Off-set distance of road side object from the edge of the road forced drivers to slow down the driver because they feel the total clearance narrower. Most of the above studies were carried out the effect of roadway geometry with or without the posted speed limit using statistical analysis. For most studies sidewalk, street parking, number of lane, curb presence, roadside object, lane width and average offset of road side object are the most significant parameters. The only differences of the above studies were method of modeling and data collection. All researchers used multiple linear regression analysis because this regression is the most powerful without consider the number of sample. Mixed effect model and artificial neural network (ANN) are also used by researchers (Poe. & Mason, 1996) and (Ahmed M. Semeida, 2012) respectively. The main advantage of artificial neural network over linear regression is it increases degree of determination for the model.

### **2.6. Existing Posted speed limit guidelines and practice**

Posted speed is the maximum lawful vehicle speed for a particular location as displayed on a regulatory sign (AASHTO, 2011). The main purpose of speed limit is to inform drivers of the maximum speed in which a normally prudent driver can travel safely on the roadway. Speed limit practice is a tool used to control vehicle speeds forced to lower to mitigate the risks advocated by crash statistics. According to the investigation of (Parker.M.R., 1985) in different state and transport agency, he found that, 85<sup>th</sup> percentile speed, accidents, and pace speed and road side

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development are the most four influential factor in descending order. ( Institute of transport Engineer(ITE) , 1993 and 2007.)Technical committee on speed zoning guidelines recommended that speed zoning established on the basis of an engineering study and be set the nearest 5mph increment to the 85<sup>th</sup> percentile speed or the upper limit of the 10-mph pace. The ITE committee also recommends that the engineering study may consider other factors such as geometric factor, roadside development, pedestrian and bicycles activities, speed limit and accident experience.

(Federal Highway Administration. , 2000) recommends that posted speed limits should be within 5 mph (10 km/h) of the 85<sup>th</sup> percentile operating speed. If the speed limit is changed to reflect actual operating speeds, the relationship between design speed and posted speed will be altered.

By recognizing the complexity of speed limit (Fitzpatrick.k, et al., 2003) recommends that a speed limit should be established based on an engineering study with a re-evaluation at a maximum interval of every five years to account for changes and the speed limit should be set to the nearest 5 mph increment to the 85<sup>th</sup> percentile speed. A survey conducted by (Institute of transport Engineer(ITE), 2007) also found that the 85<sup>th</sup> percentile speed is the predominant factor used in setting speed limits (by ninety-nine percent of the agencies surveyed in United States) and the survey study also found that roadway geometry, accident experiences, and roadside development (in addition to the 85<sup>th</sup> speed) are considered by more than ninety percent of the agencies. Political pressure was also reported as a new factor. Due to these reasons, some jurisdictions allow deviations from the 85<sup>th</sup> percentile speed by 5 and 10 mph. For setting posted speed limit on particular road way location, road way geometry, side parking, access point, traffic volume, land use and accident history should be considered in addition to 85<sup>th</sup> percentile speeds which contribute predominantly( (FHWA, 2003).

### **2.7. The effect of speeding on traffic safety**

Speeding and traffic safety have absolutely inverse relationship because speeding not only increase traffic accident but also accident severity. Excessive speed is the core of road safety problem. The majority of accident is directly or indirectly linked to speed. In the world 30% of fatal accidents, speed is an essential contributory factor (WHO, 2018). According to (National Highway Traffic Safety Administration, , 2002)one third of all fatal crashes were related to speeding, that is, exceeding the posted speed limit or traveling too fast for the existing condition.

## **2.8. Driver and vehicle characteristics**

(Al-Omari.et.al., 2013 and 2015) were investigated the effect of driver & vehicle characteristics on speeds at a Tangent Section of a Rural Highway in Jordan. The study was takes place at free flow condition and midblock location to reduce external and vehicular factors. They were carried out study on specific section of tangent road which has posted speed limit of 80 KPH by considering driver characteristics (Gender, Age) and vehicle characteristics (Vehicle type, Vehicle Occupancy and Loaded and un-loaded vehicle). Based on the result of their Study, younger drivers have higher speed than older driver and male drivers has also greater speed than female drivers but not significantly large. Small cars (passenger cars) and newest cars had larger speed than largest and oldest vehicles respectively. The amounts of occupants and loads have inverse relationship with vehicular speed. (K.Kanitpong.et.al., 2013) was also done research on evaluating speed management and driver attitudes in Thailand. One of the objectives of the study is evaluating the factors which influence towards speeding behavior and speed choice of drivers. The researchers considers: driver socio-economic characteristics of driver, vehicle characteristics and controlling mechanism of speed in Thailand. Based on the result of the study gender, family status, occupation, education, vehicle type, vehicle age, travel distance and driving experience are found to be the most significant variables but no one variable are significant in case of speed choice of variables

## **2.9. Type of modeling used for speed study**

All of the above researchers used multiple linear regressions for operating speed modeling as function different road way factor and posted speed limit. The only difference of each of the above article is the method of data collection and objective of the study.

### **2.9.1 Multiple linear regressions**

Multiple linear regressions is a method of data analysis used to predict or estimate the relation between continuous dependent variable and two or more explanatory variable which has linear relationship with response variable. In linear regression model, the unknown model parameters can be estimated from linear function which is developed based observed data ( (Simon P, et al., 2003)). Multiple linear regressions are formulated in the form of:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \dots + \beta_nX_n$$

**Where:** Y=dependent/response variable

$\beta_0 = \text{constant coefficient}$

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$\beta_1, \beta_2 \dots \beta_n = \text{slopes of explanatory variables}$

Multiple linear regression coefficients are estimated by either ordinary least square and maximum likelihood method (( Simon P, et al., 2003)). Before regression analysis is done, the following five assumptions of multiple linear regressions should be checked.

- I. The relation between response and explanatory variable should be linear. This linearity can be checked by scatter plot of dependent variables versus independent variable.
- II. There should not be strong linear relationship between independent variables (multicollinearity). It can be evaluated by either correlation coefficient or variance inflation factors. To avoid strong relationship between independent variable, the correlation coefficient and variance inflation factor should be less than 0.6 and 10 respectively.
- III. Residuals should have constant variance along predicted value (homoscedasticity). It can be checked by plotting predicted and residual value on scatter plot.
- IV. Outlier data should be excluded from the analysis because it is different from the value estimated by the regression model.
- V. The dependent variable should be continuous and normally distributed. The normal distribution of independent variable can be observed by plotting histogram and normal residual P-P plot.

### 2.9.2. Existing urban road operating speed model

(Poe. & Mason, 1996)	$V_{85} = 49.59 + 0.5 \cdot DC - 0.35 \cdot G + 0.74 \cdot W - 0.74 \cdot HR$	$R^2 = 0.99$
(Fitzpatrick, et al., 2001)	With posted speed limits: $V_{85} = 29.180 + 0.701 \cdot PSL$	$R^2 = 0.53$
	Without posted speed limits: $V_{85} = 18.688 + 15.050 \cdot WD$	$R^2 = 0.25$
(Terris, et al., 1996)	Low-speed urban streets : $V_{85} (1) = 53.5 - 0.265D$ .... Aggregated speed data $V_{85} (2) = 53.8 - 0.272D$ ..... Individual speed data $V_{85} (3) = 52.18 - 0.231D$ ..... Panel analysis	$R^2 = 0.82$ $R^2 = 0.63$ $R^2 = 0.80$
(Wang, et al., 2006)	$V_{85} = 31.565 + 6.491(\text{lane.num}) - 0.101(\text{roadside}) - 0.051(\text{driveway}) - 0.082(\text{intersection}) + 3.01(\text{curb}) - 4.265(\text{sidewalk}) - 3.189(\text{parking}) + 3.312(\text{landuse1}) + 3.273(\text{land use2})$	AIC=9361.64 BIC=9425.782

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V85, PSL, AD, MED, L1 and L2 are v85th speed, posted speed limit, access density, school and residential respectively. (Poe. & Mason, 1996) (Fitzpatrick, et al., 2001) and (Wang, et al., 2006) these entire models were done on urban tangent road section and better than other type of model but they are not consider longitudinal grade, parking density and pedestrian volume which expected highly influence operating speed of driver.

### **2.9.3. Summary of literature review**

Generally, different researchers and transport agencies studied the relation between road way geometry, posted speed limit and operating speed by considering drivers in different urban and sub-urban area. Based on the result of literature review, there is no uniform agreement on the effect of posted speed limit on 85<sup>th</sup> percentile speed. This indicate that, it is affected by driving culture and knowledge level of driver about traffic safety and traffic rules especially posted speed limit condition. However, all transport agencies setting posted speed limit by considering 85<sup>th</sup> speed as predominant factor, in turn it affected by road way geometry, roadside development (land use) and accident experience because these factors are greatly influence the speed choice of drivers. Political decision is another main current issue allows deviations from the 85<sup>th</sup> percentile speed, with most being between 5 and 10 mph (8.1 and 16.1 km/h).

Even if Africa vehicle population is 1% of the world which is very small, it contributed 13% fatal crash and speeding is the critical factor which accounts 30% world fatal accident (WHO, 2018).

In Ethiopia 17,357 persons were killed by traffic accident from 2015 to 2019 E.C. from this, 12.9% were in Addis-Ababa ( (Addis-Ababa Police Commission, 2020). To reduce the effect of speeding on fatal traffic accident, controlling the speed of the vehicle (setting posted speed limit) is a best mechanism ( (WHO, 2018). Even if there is posted speed limit in Addis-Ababa urban road, drivers are speed up to yet since speed limit enforcement in Addis-Ababa is manual and rear especially during free flow traffic condition. 43% of Addis Ababa city drivers exceeded posted speed limit in two round observational studies conducted by (Hopkins university, 2016).

The gap of the study was most of 85<sup>th</sup> speed model did not account parking density and pedestrian volume rather account parking facility and pedestrian facility, and all of 85<sup>th</sup> speed prediction model was done considering local driver driving behavior but driving condition is affected by culture, society and environment. Therefore, 85<sup>th</sup> speed prediction model which is done in particular urban area should not be used for other urban area. Therefore, the objective of the study was, modeling

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85<sup>th</sup> speed in urban road of Addis-Ababa which is used to estimate posted speed limit and evaluating the existing urban road by considering parking density and pedestrian volume in addition to road geometry that are useful for traffic management policy and strategy.

## **Chapter three: Methodology**

### **3.1. Introduction**

The main objective of this study was evaluating the effect of posted speed limit and roadway geometry on 85<sup>th</sup> percentile operating speed of driver in straight tangent section of urban road of Addis-Ababa. The effect of number of lane, land use, road side parking and object density, hourly traffic volume and posted speed limit were evaluated. In addition to general objective, assessing driver speeding attitudinal survey was also conducted to know the main cause of driver speeding. The study was conducted on a straight tangent section which had posted speed limit of 40 KPH and 50 KPH.

### **3.2 Description of Study Area**

Addis Ababa is the capital city of the Federal Democratic Republic of Ethiopia. The city is located at the center of the country on an elevation of 2,300 meters and latitude and longitude of 9°1'48"N 38°44'24"E respectively. The area of the city has been expanded to over 540 square kilometers (km<sup>2</sup>) and is divided into 10 administrative Sub cities and further divided into 116 Woredas. Among the 10 sub- cities, the study routes are located in Arada, yeka, and bole sub cities.

#### **3.2.1. Selection procedure of study routes**

This study has done on both divided and undivided urban roads of Addis-Ababa which have well defined road geometry and well displayed posted speed limit. Five routes were selected after preliminary field visit using stratified random sampling method .Firstly; the study population was categorized in to two parts based on posted speed limit (40km/hr. and 50 km/hr.).Both posted speed limit category have almost equal chance of selection (50% for each). Then after, a total of 23 study sections were selected from five different routes (i.e.11 and 12 sections which have posted speed limit of 50km/hr. and 40 km/hr. respectively) which meet the listed selection criteria. The study section was selected based on consideration of different type of roadway geometry from five different routes of urban roads which meet the following selection criteria.

##### **3.2.1.1. Selection criteria of the study section**

The following conditions will be considered during the selection of study sections:

- ✓ Divided and undivided roads were chosen for the study which has well defined roadway geometry and posted speed limit;

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- ✓ Mid-block and Straight segments of tangent section will be selected to minimize the effect of controlling point such as curve section, signal and intersections.

Based on the researcher's preliminary field survey, the following 23 section from five routes of urban road were selected by stratified-random wise based on the above criteria.

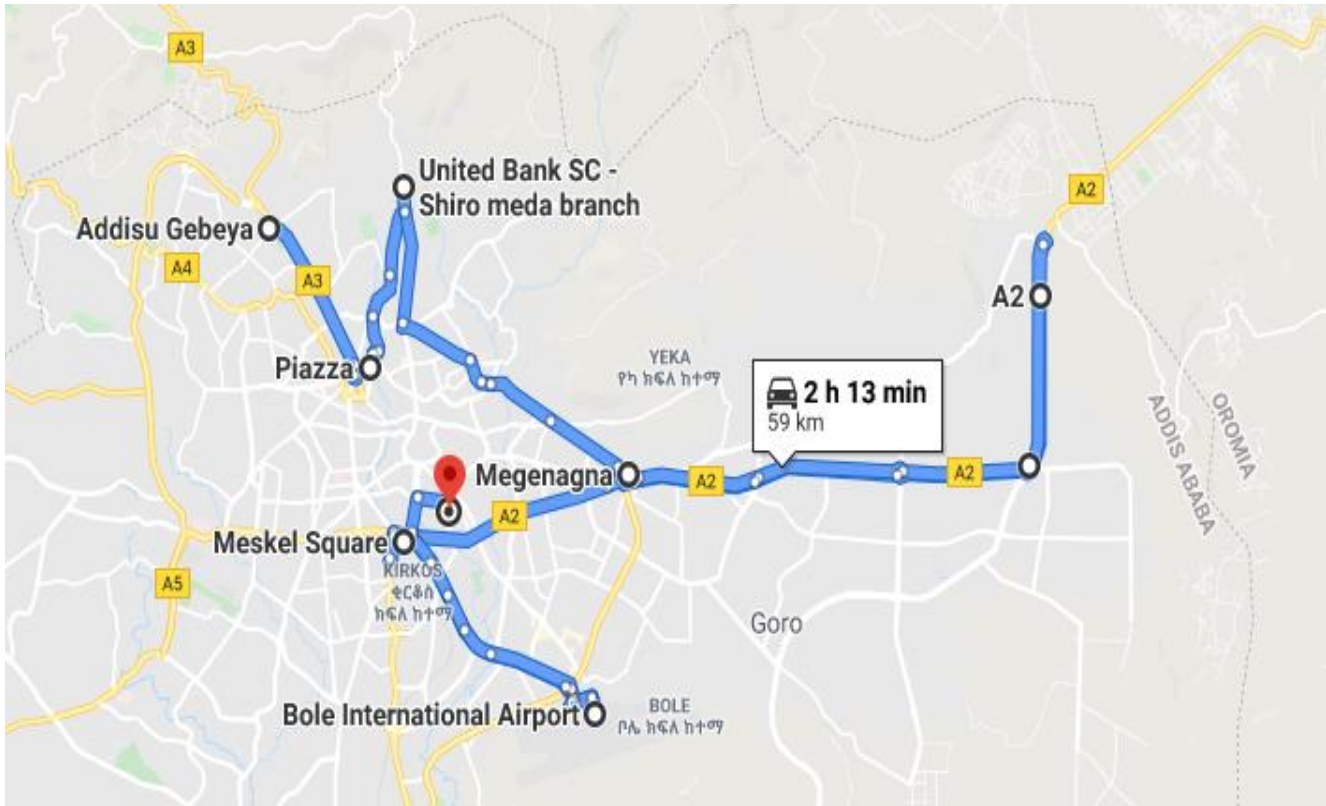


Figure 1: Selected urban routes in Addis –Ababa for this study

Based on the above selected route, the following number of section was selected by systematic random method at each route as follows on the table below.

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**Table 1: Selected and number of section**

N	Location	PSL	Number of Section	No.of lane per direction	Lane width	Median height (m)	Median Width (m)
1	From Adisu-gebya to Piazza	40 kmh.	4	3	3.5	0.6	1
2	From shiromeda to sidest-kilo	50 kmh. 40 kmh.	2 2	2	3.5	0	0
3	Megenagna to Sidst kilo	50 Kmh.	3	4	3.5	0.6	2
4	CMC to Ayat	40 KPH	6	4	3.5	2	0.5
5	Meskel-Square to Bole	50 KPH	6	4	3.5	2	2

### 3.3. Study Design

In this section, dependent and independent variable description, the data collection and analysis method were described. To meet each specific objective, both multiple linear regression models and factor analysis were employed. Multiple linear regression models was used to predict the effect of road way geometry, hourly traffic volume and posted speed limit on 85<sup>th</sup> percentile speed of drivers. In this model 85<sup>th</sup> percentile operating speed was the only dependent variable and the following (number of lane , Midian type; pedestrian hourly volume, land use: side parking density, longitudinal grade, hourly traffic volume, roadside object, average road side object offset distance and posted speed limit) are independent variables. Factor analysis was also employed to identify few dimensional factors that are the main cause of speeding. Logistic regression was also used to evaluate the effect of driver and vehicle demographic characteristics on drivers past two year accident and speeding involvement history.

#### 3.3.1. Dependent Variable for 85 percentile speed

The operating speed of the drivers was the only parameter which was obtained by manual calculation from videography survey data which extracted using VLC media player and 85<sup>th</sup> percentile operating speed was the only dependent variable which was obtained by simple manipulation of cumulative frequency distribution graph.

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### **3.3.2. Independent (Explanatory) variable for 85 percentile speed**

The following parameters were independent variable used for this study as input data. Number of lane; pedestrian hourly volume; pedestrian width; vehicle hourly volume, roadside object density, average offset distance of road side object, side parking density: land use (commercial, residential. and institutional): median type (divided or undivided), median height and width and posted speed limit (40 km/hr. and 50 km/hr.) were the explanatory variables for 85<sup>th</sup> percentile speed of drivers.

### **3.3.3. Dependent and independent variables for driver attitudinal survey**

Driver and vehicle demographic characteristics were the quantitative data which were obtained by questionnaires' to know the effect's on driver's accident and speeding involvement. This quantitative data used to asses drivers past two year accident and speeding involvement history in Addis-Ababa and used to identify the main factors from the main cause of original speeding reason. The independent variable for driver traffic accident and speeding frequency involvement included driver demographic characteristics (gender, age, marital status, education, experience and ownership) and vehicle characteristics (Type of vehicle.).The speeding frequency (ordinal logistic regression) and accident (binary logistic regression) history in past two years were the only categorical dependent variable. Speeding history was rating from nothing receiving speeding ticket(0), less than five speeding ticket(1) and greater than or equal five speeding ticket in past two years(2).The accident involvement in past two years was also rating by binary response (yes or no) regardless of the number of crash and severity.

## **3.4. Data sampling technique**

The free flow vehicles used for this study were selected from video-graph which was traversing the selected stretch section of road on that occasion of time until the minimum numbers of vehicles were achieved. All type of free flow vehicles were selected from recorded video. Each vehicle has equal chance of selection if they are free flow on that duration of recording video. The sections of the road were selected by systematic-random method after the routes were selected by stratified random sampling method. Driver speeding attitudinal survey questionnaire was also distributed by simple random-lottery method to drivers in Addis-Ababa city after pilot survey.

### **3.4.1. Determination of sample size of spot speed (vehicle) per section**

The amount and type of selected sample should be the representative of the population at a given confidence level and allowed precision. The sample size should be between 50 and 100 vehicles for study of spot speed on free flow traffic condition (Ewing, 1999). The sample sizes of speed study

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depend on either standard deviation of maximum speed attained by the vehicle or speed range of the vehicle (ITE., 1999) .Therefore, the sample requirement for speed study varies with vehicle type (Li, et al., 2002). For estimation of population mean from sample mean, the sample size should have met the following formula (Li, et al., 2002) .

$$\text{sample size}(N) = \left[ \frac{z \cdot \sigma}{e} \right]^2$$

Where: e=tolerance,  $\pm$ mph

Z (normal standard) =1.96 for 95% confidence interval

Based on (Dr. A. K. Mauryaa & P.S.Bokareb, 2013) the standard deviation of speed for each vehicle type is 2.78 and 5 for truck and car respectively and the error is 1.0 mph.

Therefore, the sample size (N):

$$\text{sample size of speed of car (N)} = \left[ \frac{1.96 \cdot 5 \text{mph}}{1.0 \text{ mph}} \right]^2 = 96.04 = 97 \text{ vehicle speed}$$

$$\text{sample size of speed of truck (N)} = \left[ \frac{1.96 \cdot 3 \text{mph}}{1.0 \text{ mph}} \right]^2 = 34.6 = 35 \text{ vehicle speed}$$

### 3.4.2. Determination of sample size to driver speeding attitudinal survey

In this study, the driver's accident and speeding involvement as function of driver and vehicle characteristics had been assessed based on speeding and accident history of driver which was reported by themselves in past two years. This data was collected through close-ended well-structured questioner. The sample size required for questioner should be always greater than direct field data because the reliability and accuracy is lower than observational and field measurement data. Therefore, another method which is called Cochran's formula for calculating sample size for infinite population was used. (Cochran, 1963) developed a formula to calculate a representative sample for proportions as:

$$n = (z^2 p \cdot q) / (e^2)$$

Where, n is the sample size,

z is the standard value of corresponding confidence level

p is the succeeded proportion of the population,

q=1-p=un-succeeded proportion and e is level of precision

To get maximum sample size assuming the maximum variability which was equal to 50% (p =0.5) and taking 95% confidence level with  $\pm$ 5% precision.

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$$p = q = 0.5, z = 1.96 \text{ and } e = 0.05$$

$$n = (1.96^2 * 0.5 * 0.5) / 0.05^2 = 384.16 = 385 \text{ minimum number of driver.}$$

A total of 470 driver speeding attitudinal survey with distributed pilot survey questionnaire was distributed in Addis-Ababa.

### 3.4.3. Determination of number of road section

The numbers of road sections selected for this study are depending on variability of road features, budget and time. Most of previous studies considered all this three factors especially budget and time as the main constraint. Previous studies road section selections are summarized as follows in table.

**Table 2: Previous 85<sup>th</sup> percentile speed studies with number of road section**

Researchers	Research Topic	Number of road section
(Rohaizan & Mashros,, 2016)	Effect of posted speed limit on drivers speed choice during off-peak	3
(Zhang , 2015)	Relation between speed limit and operating speed	9
(Poe. & Mason, 1996)	Effect of road geometry of urban collector road on operating speed	27
Ali et al. (2007)	Effect of road geometry of urban road on operating speed	35
(Fitzpatrick, et al., 2001)	Influence of road geometry and speed limit on operating speed	25

By taking in to account, road feature variability, budget and time and previous study sample size , 23 number of road section were selected by systematic-random method. Firstly; the study population was categorized in to two parts based on posted speed limit (40km/hr. and 50 km/hr.).Both posted speed limit category have almost equal chance of selection (50% for each). Then after, a total of 23 study sections were selected from five different routes (i.e.11 and 12 sections which have posted speed limit of 50km/hr. and 40 km/hr. respectively).Based on researcher’s field survey, the variability of road features in Addis-Ababa is little. The variability of

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roads in Addis-Ababa in terms of lane (one, two and three lanes) and median (divided, no divided)

Based on the above criteria, selected road segment had the following detail road geometry.

**Table 3: Detail geometric parameters of selected road section**

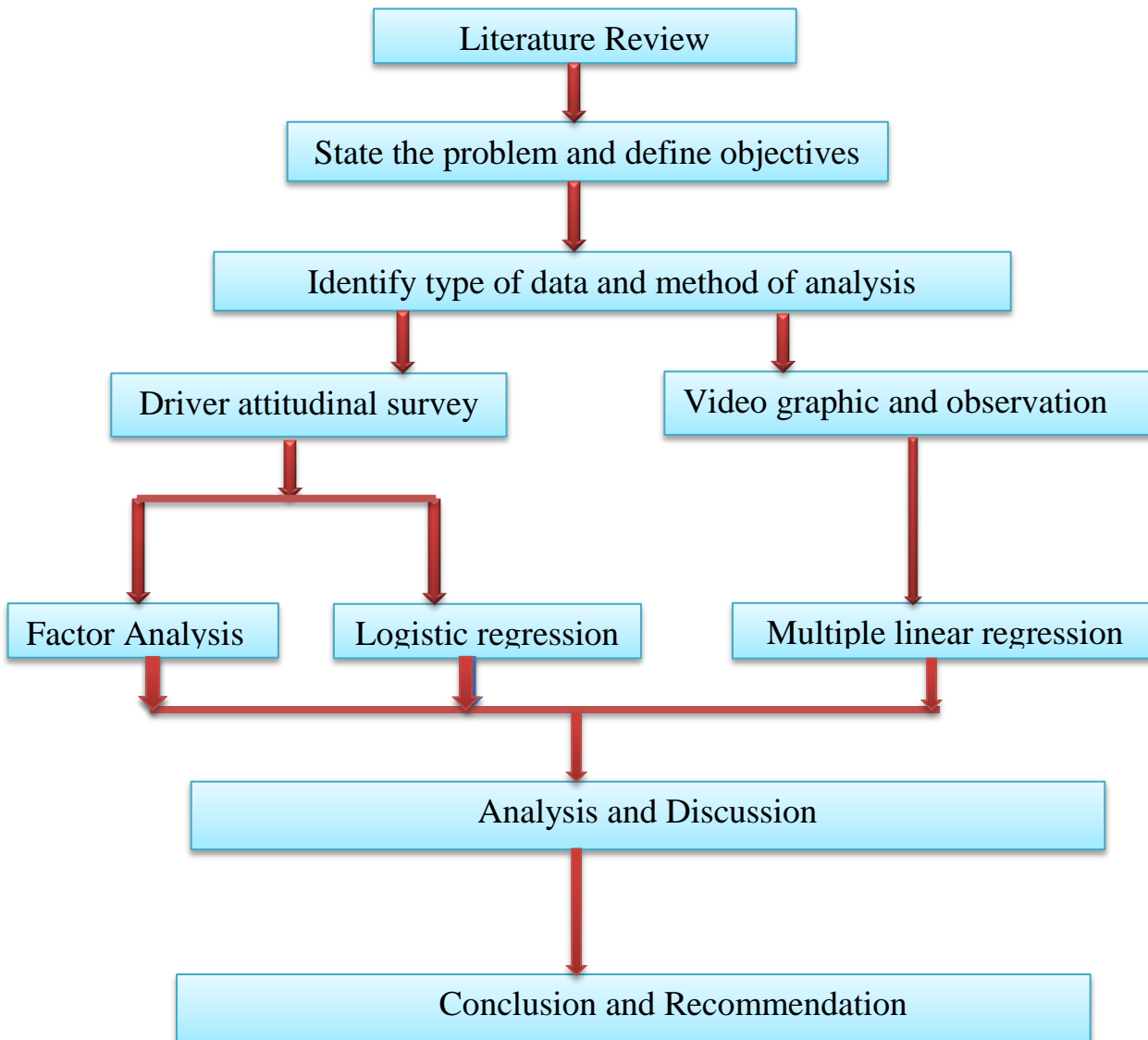
Geometric parameters of selected road segment										
Road segment ID	NO.of lane/dir.	Median divided	median width	median height	pedestrian walk width	Gradient of the road	No. of road side object	Average offset distance of object	Land use	Speed limits (km/hr.)
CAR1	4	Yes	0.5	2	4	Up grade	11	0.6	Institutional	40
CAR3	4	Yes	0.5	2	4	Down grade	12	0.6	institutional	40
CAR2	4	Yes	0.5	2	3.6	Up grade	2	0.5	Commercial	50
SR1	2	No	0	0	4	Down grade	7	0.6	institutional	40
SR2	2	No	0	0	5.5	Up grade	4	0.4	institutional	50
SR4	2	No	0	0	4.2	Down grade	9	0.8	institutional	40
SR3	2	No	0	0	9	Down grade	13	4.8	institutional	40
MR1	4	Yes	2	0.7	3	Down grade	5	0.45	Commercial	50
MR2	4	Yes	2	0.7	3	Down grade	7	0.4	institutional	50
MR3	4	Yes	2	0.7	4	Up grade	5	0.6	Commercial	50
BR1	4	Yes	2	1.5	3.6	Up grade	17	0.8	Commercial	50
BR2	4	Yes	2	1.5	3.5	Up grade	22	0.4	Commercial	50
BR3	4	Yes	2	1.5	3.5	Up grade	13	0.5	Commercial	50
BR4	4	Yes	2	1.5	3.6	Up grade	13	0.6	Commercial	50
BR5	4	Yes	2	1.5	4	Up grade	16	0.5	Commercial	50
BR6	4	Yes	2	1.5	3.8	Down grade	8	0.55	Commercial	50

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ADR1	3	Yes	1	0.6	3	Downgrade	6	0.5	Commercial	40
ADR2	3	Yes	1	0.6	3	Downgrade	6	0.4	Commercial	40
ADR3	3	Yes	1	0.6	3.6	Up grade	8	0.6	institutional	40
ADR4	3	Yes	1	0.6	3	Up grade	12	0.6	institutional	40
CAR4	4	Yes	0.5	2	4	Upgrade	11	0.6	institutional	40
CAR5	4	Yes	0.5	2	4	Downgrade	7	0.6	institutional	40
CAR6	4	Yes	0.5	2	4	Up grade	12	0.6	institutional	40

### 3.5. Research method

The general procedure of this research was structured after reviewed several literatures. The overall flow chart is presented as follows:



### 3.6. Research Materials

For data collection, different instruments were employed to obtain different type of data. Linear tape was used to measure stretch length, carriageway width, pedestrian walk and average object distance. A video camera was used to recording vehicle movement when traversing the selected stretch length. VLC video player was used for extracting type of vehicle, time duration of traversing section and lane position. The driver attitudinal survey (questioners) was randomly distributed for selected drivers in Addis-Ababa after pilot survey. For analysis of data STATA-16 and Application software's were also used for documentation.

### **3.7. Data collection and Extraction method**

#### 3.7.1. Data Collection for 85<sup>th</sup> percentile speed determination and road geometry

To meet the objective of this study, primary source of data was used for all type of dependent and independent parameters. Primary data were obtained directly from the field in the form of observation, field linear measurement, video survey, pedestrian counting and questionnaire. So as to collect all necessary field data for Multiple linear regression model, first 23 urban road straight tangent section with different posted speed limit and roadway feature would be randomly selected using primarily field survey which meet the above criteria and at each selected urban road tangent section, the following road geometry; number of lanes, lane width, median type, pedestrian volume, pedestrian width, and posted speed limit were obtained ;and the land use data include commercial and Institutional center were also obtained using observational survey by considering the function of the building next to the road. The operating speed of driver was obtained at off-peak period (Sunday, other morning day) when the head way between successive vehicles were greater than 5 second so as to reduce the influence of front vehicle on rear vehicle (Poe. & Mason, 1996), (Fitzpatrick, et al., 2001).The method of data collection used for this study had been described as followed:

##### a). Field linear measurement

Carriageway width, Stretch length, pedestrian walk, average road side object offset distance and median width data were obtained using field linear measurement on selected road segment using linear tape.

##### b). Observational survey

Posted speed limit, number of lane, land use, roadside object density and median type were obtained by observational survey during site visit. The number of side parked vehicle and the pedestrian volume during video record of vehicle movement were counted manually for the same duration of video survey simultaneously.

##### c). Video survey

Video survey was employed for data collection by recording the movement of vehicle on selected stretch road section for (spot speed study) on half hour during off peak hour when headway

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between two successive vehicle are greater than five seconds .The video recording were carried out using two Samsung tablets where one tablet record the entry vehicle in to the section and the second tablet record the exit vehicle out of the section for extraction of time took to traversing the section and headway to identify free flow condition. After field video survey were conducted, the filmed video (one section- two video ) would be played at the same time using VLC media player so as to extract: type of vehicle; lane position of vehicle; entry time of vehicle; exit time of vehicle; head way; number of pedestrian on that occasion of time and number of side parked vehicle. The matching of entry and exit vehicle was by observation from filmed video by opening two video at the same time.

### 3.7.1.1. Stop watch method supported by videography survey for determination of spot study

Stop watch method is quick and inexpensive method to determining spot speed from video recorded film. The 85<sup>th</sup> operating speed of vehicle were determined by spot speed study on selected section of road segment (Robertson & H. D., 1994). Based on the researcher, spot speed study used to determine 85<sup>th</sup> percentile speed of vehicle which was used for evaluating the existing roadway and posted speed limit condition. The following procedures were followed to determine 85<sup>th</sup> percentile speed.

- I. Select proper location and layout and obtain appropriate study length
- II. Record observations using video camera and record time in Stop watch method format using VLC media player.
- III. Calculate vehicle speeds.
- IV. Generate frequency distribution table and determine 85<sup>th</sup> speed percentiles

Study length of road section is very important because it is used to determine speed of vehicle. It is most of the time recommended by based on average speed of traffic stream for reliable observer reaction time.

Table 4: Recommended spot speed study length based on previous studies ( (Duane & J, 2002)

Traffic stream average speed	Recommended study length
Less than 40km/hr.	30 m
40km/hr-65km/hr.	60 m
Above 65 km/hr.	90 m

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The study length of road section was decided by assuming the average speed of vehicle traffic is equal to posted speed limit of road section. Therefore for speed limit of both 40 km/hr. and 50 km/hr. the study length of all road section taken were greater than 60m. Based on the above ideology, type of vehicle, lane position, time duration, head way and spot speed were manipulated in excel spread sheet.

### 3.7.2. Data Extraction and manipulation for 85<sup>th</sup> percentile speed determination

After all data were collected for each study segment, relevant data required for the study were extracted from recorded video. Vehicle class (passenger car, light commercial vehicles, bus and truck) and, starting and ending point time of individual vehicle were manually extracted from recorded video. The vehicle classes for this study were grouped in to three classes: passenger car (passenger car); Light commercial vehicles (mini-bus, pickup, land cruiser and taxi) and large vehicle (Bus and Trucks). Travel time of each vehicle was obtained as the difference between the ending and starting point time of individual vehicles. Then after operating speed of each vehicle were calculated by dividing length of segment to travel time. Finally 85<sup>th</sup> percentile operating speed were determined using speed frequency distribution graph.

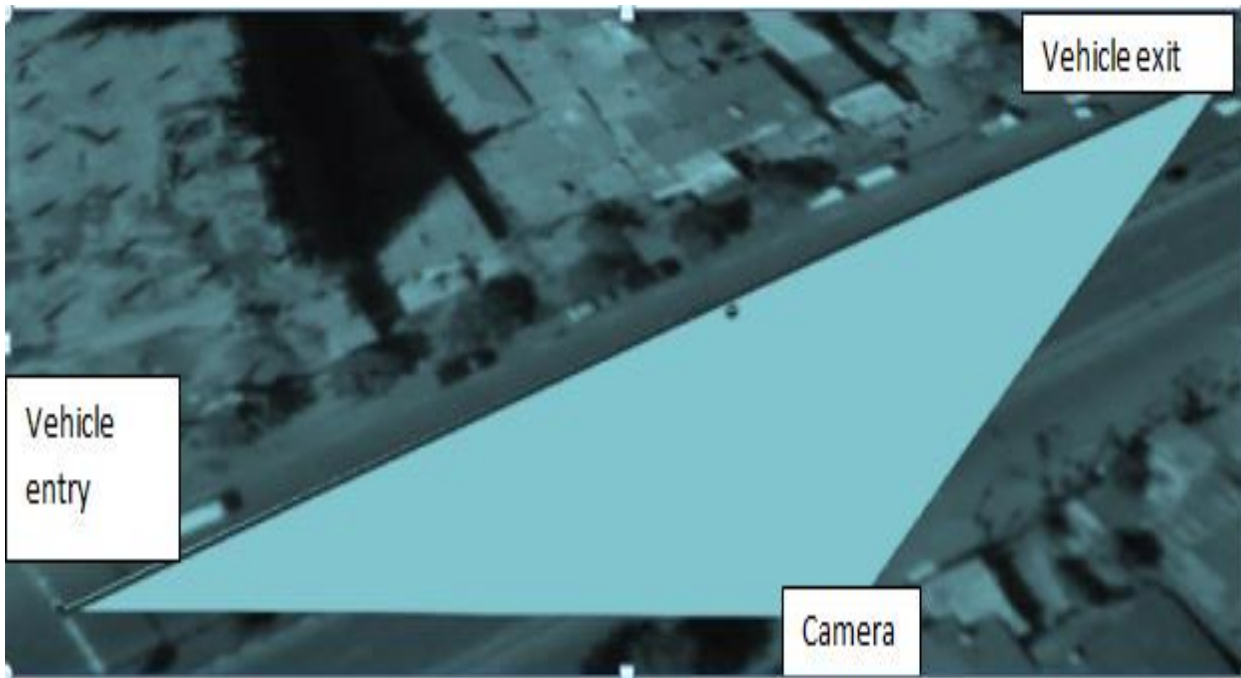


Figure 2: Video recording lay out

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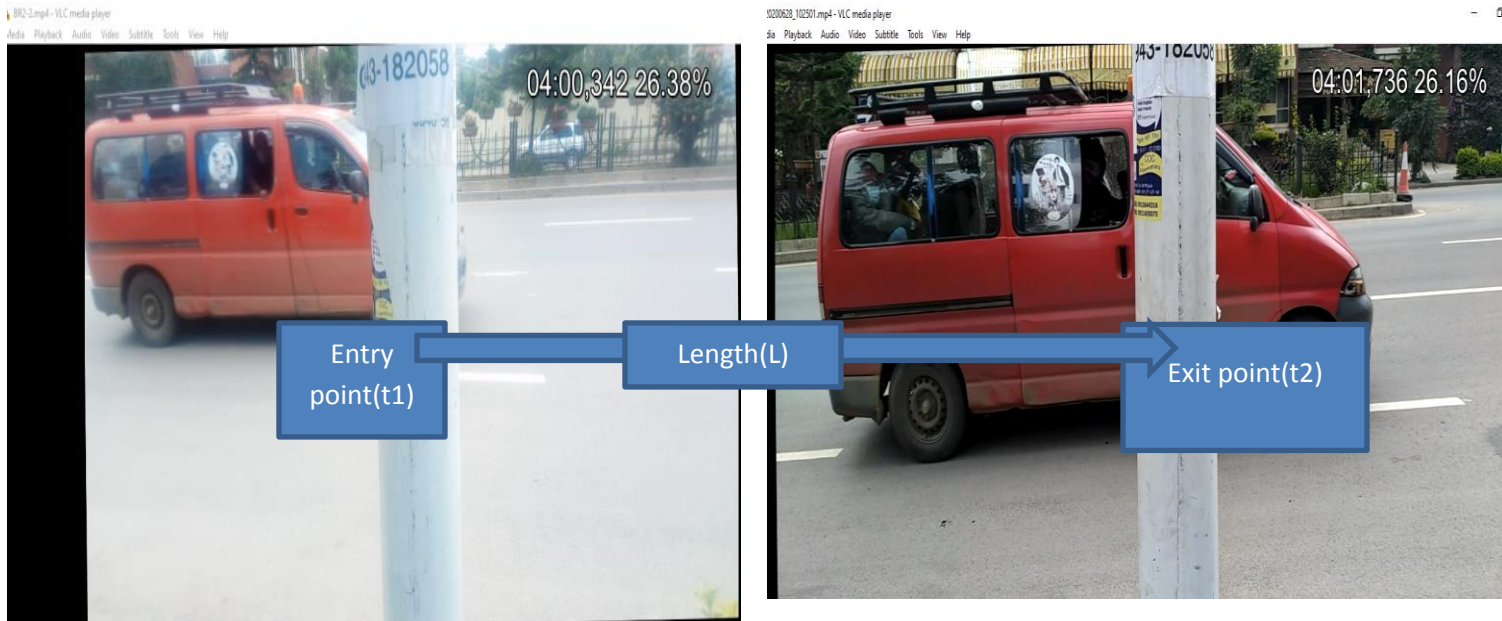


Figure 3: Entry Time and Exit Time layout

Most of the field data were directly taken for analysis but some data were needed manual manipulation such as head way, operating speed, pedestrian volume and traffic hourly volume accordingly, the following data were manipulated as follows:

a) Traffic hourly volume(PCE/hr/lane): 
$$HV \left( \frac{PCE}{hr} \right) = (3600 \frac{SEC}{Average\ Headway(sec)})$$

b) Operating speed: the observed speed of individual vehicle to traversing a stretch section of the road on specific period of time. It is determined by dividing stretch length of road to the time difference between entry and exit time.

$$spot\ speed(v)(kph) = \left[ \frac{[Stretch\ length\ (m)]}{[time(t2 - t1)(sec)]} \right] * 3.6$$

c) Pedestrian volume: the number of pedestrian traversing pedestrian walk parallel to on both direction of vehicle movement per hour. It is determined by counting the number of pedestrian who enter and exit from the section for the same duration of video camera and convert to pedestrian volume per hour (ped./hr.).

d) Side parking density: the number of vehicle parked on the side of stretch study section stretch per 100m for the same duration of video recorded.

e) Road side object density: the number of road side object with in selected stretch road section per 100m.

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### 3.7.2.1. Spot speed data extraction detail

After field observation and video data recorded, the filmed video was played using VLC video player which count by (hour, minute, second and millisecond) so as to obtained all necessary data to calculate operating speed of each vehicle: (time entry and exit); average headway, and vehicle composition. All section data are extracted and manipulated in the following format and all results of manipulated data are presented in Appendix's part in the form of Speed frequency distribution graph.

Table 5: Sample summery format of extracted data collection detail

<b>Street</b>		Bole to Meskel Square (BR1)								
stretch length		60 meter		Legend:						
Median		Yes		M.bus= mini-bus						
land use		Commercial		L.Cruiser=land cruiser						
road side object		17		P.up=pickup						
average offset distance		0.8 meter		Pc=passenger car						
pedestrian walk		3.6m		Lane position:1=inner lane						
Longitudinal grade		Upgrade		Lane position:2=second inner lane						
parking density		0		Lane position:3=second inner lane						
Number of Lane/direction		4		Manipulated data						
Vehicle type	Lane position	Start Time		End Time		start time (sec)	end time (sec)	Head way	duration	Speed (km/hr.)
		Sec.	mili-Sec.	Sec.	Mili					
m.bus	1	3	209	6	926	3.21	6.93		3.72	58.11
m.bus	2	4	922	7	153	4.92	7.15		2.23	96.82
pc	3	10	199	12	159	10.20	12.16		2.96	91.32
pc	2	27	181	29	419	27.18	29.42	22.27	2.24	96.51
pc	3	28	931	31	938	28.93	31.94	19.78	3.01	71.83
truck	1	31	188	34	655	31.19	34.66	27.98	3.47	62.30

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### 3.7.3. Procedure of 85<sup>th</sup> percentile operating speed determination

The 85<sup>th</sup> percentile operating speed of vehicle were determined by spot speed study on selected section of road segment (Robertson & H. D., 1994). Based on the research, spot speed study used to determine the 50<sup>th</sup> and 85<sup>th</sup> percentile speed of vehicle which is used for evaluating the existing roadway and posted speed limit condition. Posted speed limits are provided by considering 85<sup>th</sup> percentile speed which is assuming to be 85% of the drivers are traveling at safe speed (Loutzenheiser, et al., 1996). Cumulative frequency distribution table is a convenient way to determine 85<sup>th</sup> percentile operating speed. For this study, minimum of 120 vehicles per section of road segment were used.

#### 3.7.3.1. Detail of 85<sup>th</sup> percentile operating speed determination

85<sup>th</sup> percentile speed is the speed at which 85 percentile of the driver is not exceeded. It is obtained by direct manipulation of frequency distribution graph at 85 percentages. All selected section of road segment would be analyzed in the following ways in order to get 85<sup>th</sup> percentile speed of each speed.

Table 6: Sample summery format of 85<sup>th</sup> percentile speed determination for BR1

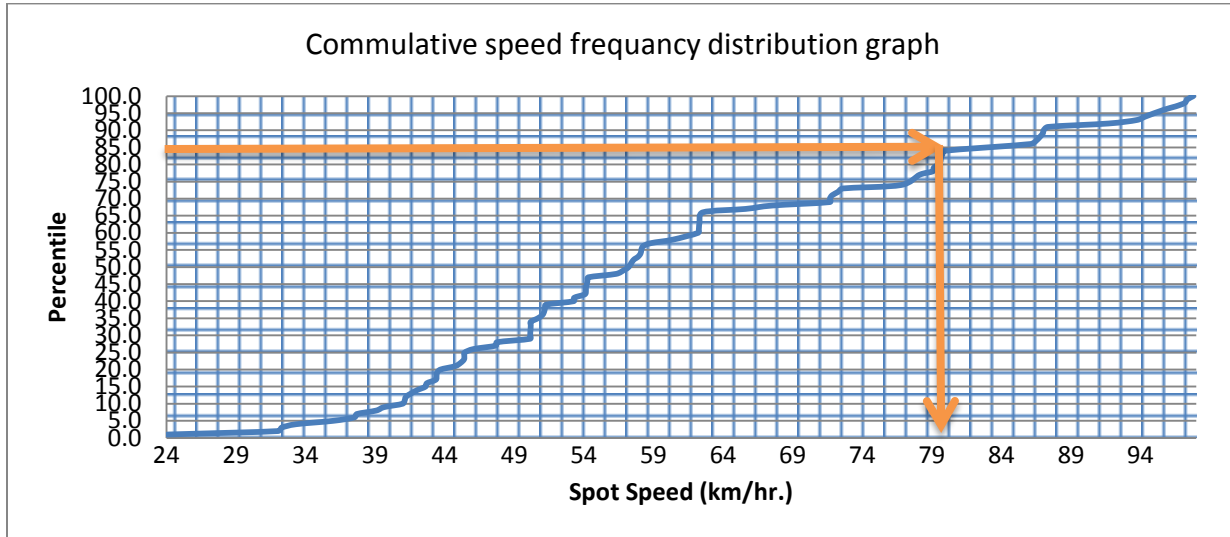
Speed (km/hr.)	Frequenc y	cum. frequenc y	Percentag e	Speed (km/hr.)	frequenc y	cum.frequan cy	percentag e
24.05	1	1	1.00	54.24	1	46	46.00
32.00	1	2	2.00	54.31	1	47	47.00
32.25	1	3	3.00	56.31	1	48	48.00
33.29	1	4	4.00	56.83	1	49	49.00
35.97	1	5	5.00	57.20	1	50	50.00
37.49	1	6	6.00	57.54	2	52	52.00
37.68	1	7	7.00	57.88	1	53	53.00
39.06	1	8	8.00	58.06	1	54	54.00
39.63	1	9	9.00	58.22	2	56	56.00
40.96	1	10	10.00	58.82	1	57	57.00
41.11	1	11	11.00	60.37	1	58	58.00

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41.20	1	12	12.00	62.19	2	60	60.00
41.56	1	13	13.00	62.25	1	61	61.00
42.02	1	14	14.00	62.27	1	62	62.00
42.60	1	15	15.00	62.30	1	63	63.00
42.70	1	16	16.00	62.54	3	66	66.00
43.34	1	17	17.00	65.59	1	67	67.00
43.40	1	18	18.00	67.54	1	68	68.00
43.43	1	19	19.00	71.67	1	69	69.00
43.68	1	20	20.00	71.67	1	70	70.00
44.74	1	21	21.00	71.83	1	71	71.00
45.14	1	22	22.00	72.26	1	72	72.00
45.38	1	23	23.00	72.61	1	73	73.00
45.40	1	24	24.00	76.79	1	74	74.00
45.43	1	25	25.00	78.12	3	77	77.00
46.06	1	26	26.00	79.06	1	78	78.00
47.66	1	27	27.00	79.12	1	79	79.00
47.75	1	28	28.00	79.47	1	80	80.00
50.12	1	29	29.00	79.62	1	81	81.00
50.13	1	30	30.00	79.65	1	82	82.00
50.14	1	31	31.00	79.76	1	83	83.00
50.16	1	32	32.00	79.85	1	84	85.00
50.17	1	33	33.00	86.09	2	86	86.00
50.18	1	34	34.00	86.50	1	87	87.00
50.68	1	35	35.00	86.96	2	89	89.00
51.02	1	36	36.00	87.03	1	90	90.00
51.14	1	37	37.00	87.34	1	91	91.00
51.20	1	38	38.00	91.68	1	92	92.00
51.27	1	39	39.00	93.71	1	93	93.00
53.25	1	40	40.00	94.32	1	94	94.00
53.28	1	41	41.00	95.66	2	96	96.00

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54.05	1	42	42.00	96.51	1	97	97.00
54.14	1	43	43.00	97.17	1	98	98.00
54.14	1	44	44.00	97.34	1	99	99.00
54.20	1	45	45.00	97.78	1	100	100.00



**Figure 4:** Sample of Speed frequency distribution graph for BR1

### 3.7.4. Data Collection detail for Driver Speeding Attitudinal Survey (Questionnaire)

Questionnaire based driver perception survey was conducted on randomly selected driver in Addis-Ababa. Driver speeding reason analysis was based on the data reported by the driver themselves through structured questioners which contain four parts. The parts are about driver and vehicle demographic characteristics; driver’s accident and speeding history in past two years based on the report of themselves, driver belief and attitude about speeding and what were the possible reasons of speeding. The driver attitude and belief for speed limit questions were answered by using 5 point Likert scale (4 Likert questions were answered by scales from “strongly agree to strongly disagree”, which is rating from 1 to 5 respectively) while the possible frequent cause of speeding were answered by using Likert scales from “always reason to never reason” which is rating from 1 to 5 respectively).

The close-ended questionnaire was distributed to randomly selected drivers. The minimum number of sample required for questionnaires’ was 385 but the totals of 470 samples with pilot survey were

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distributed for driver so as to obtain reliable data. From all distributed questioners, 441 questioners were well- responded. The vehicle and driver demographic characteristics include (Gender, Age, and education level, experience of driver, family status, and vehicle type): driver opinion about speeding in Addis-Ababa urban road (what they believe about lowering the speed limit, the believe about why police target speeding vehicle), driver accident and speeding involvement history in past two years) and why did drivers were speeding? A questionnaire with close-ended items was originally prepared by researchers. It was initially developed in English and then translated into Amharic to collect information from drivers.

### 3.8. Data Analysis

This section describes the overall data analysis methodology of the research. For this study multiple linear regressions, logistic regression and factor analysis would be employed for two different cases. Multiple linear regressions have been developed after stepwise selection of each significant independent variable which significantly affect 85<sup>th</sup> percentile operating speed. The effect of driver and vehicle demographic characteristics on drivers past two year accident and speeding history was also assessed by using binary logistic regression and ordinal logistic regression respectively. Factor analysis was also employed to identify factors which affect driver speed.

#### 3.8.1. Multiple linear regressions

Multiple linear regressions is a method of data analysis used to predict or estimate the relation between continuous 85<sup>th</sup> percentile speed and independent or explanatory variables which have linear relationship with  $V_{85}$ . In linear regression model, the unknown model parameters can be estimated from linear function which is developed based observed data (Asha Weinstein, et al., 2012). Multiple linear regressions are formulated in the form of:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \dots + \beta_nX_n$$

**Where:** Y=dependent/response variable

$\beta_0 = \text{constant coefficient}$

$\beta_1, \beta_2 \dots \beta_n = \text{slopes of explanatory variables}$

Multiple linear regression coefficients are estimated by either ordinary least square and maximum likelihood method ((Simon P, et al., 2003). Before regression analysis is done, the following five assumptions of multiple linear regressions were checked.

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- I. The relation between response and explanatory variable should be linear. This linearity can be checked by scatter plot of dependent variables versus independent variable.
- II. There should not be strong linear relationship between independent variables (multicollinearity). It can be evaluated by either correlation coefficient or variance inflation factors. To avoid strong relationship between independent variable, the correlation coefficient and variance inflation factor should be less than 0.4 and 10 respectively.
- III. Residuals should have constant variance along predicted value (homoscedasticity). It can be checked by plotting predicted and residual value on scatter plot.
- IV. Outlier data should be excluded from the analysis because it is different from the value estimated by the regression model.
- V. The dependent variable should have continuous normally distributed variable. The normal distribution of independent variable can be observed by plotting histogram and normal residual P-P plot.

There for in this paper, speed will be modeled as follows using multiple linear regressions.

$$V_{85} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_n X_n \quad (1)$$

Where;  $V_{85}$ = 85<sup>th</sup> operating speed of driver

$X_{i-n}$ = explanatory variables depending on their significant value;

$\beta_{1-n}$ = are estimated parameters;

$\beta_0$ = constant

### 3.8.2. Logistic regression

Logistic regression is non-linear analysis for estimating categorical dependent variable. The independent variable was both drivers frequency of speeding and accident history in past two years. The frequency of speeding was ordinal categorical dependent variable rating from Never receiving speeding ticket (speeding ticket=0), Sometime receiving speeding ticket (speeding ticket<5) and most time receiving speeding ticket (speeding ticket>=5) in past two years. Therefore ordinal logistic regression had been employed to know the detail effect of driver and vehicle demographic characteristics on past two year speeding history. Accident involvement history in past two years was also binary dependent variable in which the response was “yes” or “no”. Therefore binary logistic regression was employed. Logistic regression uses maximum likelihood estimation and it is

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better since it does not consider assumption of linear regression except multi-collinearity. The independent categorical variables were (Gender, Age, Education level, Experience of driver, family status(marriage), and vehicle type).

The model had been developed as follows:

For binary logistic regression (accident involvement):

$$\begin{aligned} \text{Log (p(YES)//P(NO.))} &= a + a_1 * X_1 + a_2 * X_2 + a_3 * X_3 \\ &+ a_4 * X_4 + a_5 * X_5 + a_6 * X_6 \end{aligned}$$

For ordinal logistic regression (frequency of speeding)

$$\begin{aligned} \ln(\text{speeding ticket} \geq 5) &= b + b_1 * X_1 + b_2 * X_2 + b_3 * X_3 \\ &+ b_4 * X_4 + b_5 * X_5 + b_6 * X_6 \end{aligned}$$

$$\begin{aligned} \ln(1 \leq \text{speeding ticket} < 5) &= c + c_1 * X_1 + c_2 * X_2 + c_3 * X_3 \\ &+ c_4 * X_4 + c_5 * X_5 + c_6 * X_6 \end{aligned}$$

Where:

- YES and NO are categorical dependent variable for accident involvement in past two years,
- Never receiving (speeding=0), seldom receiving (speeding<5) and most time receiving (speeding>=5) speeding ticket in past two years were ordered dependent variable.
- a, a<sub>1</sub>, a<sub>2</sub>....a<sub>n</sub>, b, b<sub>1</sub>, b<sub>2</sub>....b<sub>n</sub> , c,c<sub>1</sub>,c<sub>2</sub>,....c<sub>n</sub> ,d, d<sub>1</sub>,d<sub>2</sub>,d<sub>3</sub>...d<sub>n</sub> , are coefficients of independent categorical variables
- X<sub>1</sub>, X<sub>2</sub>, X<sub>3</sub>, X<sub>4</sub>, X<sub>5</sub> and X<sub>6</sub> are independent categorical variables.

### 4.8.3. Factor analysis

Factor analysis is data reduction method used to re-express multi-variate data with fewer dimension (Kim & Mueller, 1978). The goal of this analysis was used to summarize fewer factors from original speeding reason that capture maximum possible information from 15 original cause of speeding which was listed in questionnaire. This method of analysis had been accomplished through factor rotation followed by factor extraction.

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Factor extraction is nothing but making choice few number of factors from more factors. This few factors were based on trade-off between simplicity and completeness. It was determined using Kaiser Criterion based on the Eigen value of greater than 1 (Kaiser, 1974). Factor rotation is done to making simple structure for grouping each variable and understandable (Ford, et al., 1986) and (Thurstone , 1947). The rotation of extracted factor was done using orthogonal rotation which used to make factors uncorrelated to each other and easy to understand (Ford, et al., 1986).

### 3.9. Descriptive statistics of collected data

Table 7: Variable description and statistics for field data

V85 (km/hr.)	Minimum spot speed (km/hr.)	Maximum spot speed (km/hr.)	pedestrian volume (vol/hr)	parking density	average headway	Traffic hourly volume (pcu./hr./lane)	longitudinal grade	road side object density	Pave-ment surface	Sec ID.
68	20	89.6	440	5	8.5	424	up grade	11	wet	CAR1
57.1	20	90	350	8	6.4	563	downgrade	12	wet	CAR2
67.4	24.2	92.3	156	2	4.5	735	up grade	2	wet	CAR3
66.6	25	80.4	176	0	8.87	406	downgrade	7	Dry	SR1
62	10	80	196	0	7.8	462	up grade	4	Dry	SR2
58.9	25	95	216	3	6.2	581	downgrade	9	Dry	SR4
53	20	95	196	5	5.6	643	downgrade	13	Dry	SR3
48.4	20	90	220	9	5.33	675	downgrade	5	Dry	MR1
53	30	90	276	10	5.7	632	downgrade	7	Dry	MR2
55	25	85	192	8	5.9	610	up grade	5	Dry	MR3
79.8	25	97	220	0	13.62	264	up grade	17	Dry	BR1
73.5	36	88	228	4	12.55	287	up grade	22	Dry	BR2
75.2	38	90	248	2	11.091	325	up grade	13	Dry	BR3
77.2	22	98	248	3	15.72	229	up grade	13	Dry	BR4
72.1	30.4	96.5	384	2	14.43	249	up grade	16	Dry	BR5
56.9	30	83	592	10	10.765	334	downgrade	8	Dry	BR6
46.8	25	60	544	14	6.5	554	downgrade	6	wet	ADR1
53.4	22	76	492	11	6.8	529	downgrade	6	wet	ADR2
55.8	35	65	472	9	7.2	500	up grade	8	wet	ADR3
61.7	30	90	348	6	9.3	387	up grade	12	Dry	ADR4
57.4	30.17	88.9	438	5	8.2	429	up grade	11	wet	CAR4
68.7	33.75	96.53	356	8	5.9	589	downgrade	7	wet	CAR5
63.4	20	90	154	2	4.7	800	up grade	12	wet	CAR6

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**Table 8: Categorical data description and statistics for driver attitudinal survey**

Variables	Category description	Frequency	Percent
Gender	Male=1	392	88.9
	Female=0	49	11.1
Age	18-30 year	98	22.2
	30-40 year	243	55.1
	41-50 year	44	10.0
	>50 year	56	12.7
Marriage	Yes=1	272	61.7
	No=0	169	38.3
Education level	8-12 grade	250	56.7
	Diploma	55	12.5
	Degree & above	159	33.8
Ownership of vehicle	Owner =0	271	61.5
	Employee =1	170	38.5
Experience of drivers	<5 years	144	32.7
	5-10 years	240	54.4
	>10 years	57	12.9
Driving frequency	Always	162	36.7
	Most time	152	34.5
	Sometime	100	22.7
	seldom	27	6.1
Have you been involved as driver in any road accident in the two past years?	Yes=1	109	26.3
	No=0	325	73.7

**Table 9: General believe and opinion of driver about speeding.**

Questions	Possible values	Percent	Mean	Standard Deviation
Would you believe lowering the speed limit would reduce injury severity?	1. Strongly believe to be false,	1.4	3.44	1.06
	2. Believe to be false,	15.4		
	3. I don't know,	27.9		
	4. Believe to be true	30.6		
	5. Strongly believe to be true	18.8		
The main reason police target speeding vehicle is to make money	1. Strongly believe to be false,	38.5	2.41	1.28
	2. Believe to be false,	11.1		

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for government	3. I don't know, 4. Believe to be true 5. Strongly believe to be true	22.9 25.4 2.0		
Lowering speed limit would create more pleasant environment for you and your environment	1. Strongly believe to be false, 2. Believe to be false, 3. I don't know, 4. Believe to be true 5. Strongly believe to be true	1.8 3.4 49.9 11.1 37.2	3.84	0.96
How often did you stopped by police when you travel above posted speed limit in this year?	Never =1 seldom =2 Most time =3	44.9 47.2 7.90		
Why did you speeding?		Percent	Mean	Stad.dev
R1: There is no traffic police around the road.	Always reason =1 Most time reason = 2 Sometime reason =3 Rarely reason =4 Never reason =5	5.7 22.7 56.0 10.4 5.2	2.9	0.77
R2: I enjoy driving fast.	Always reason =1 Most time reason = 2 Sometime reason =3 Rarely reason =4 Never reason =5	3.9 2.0 24.9 34.7 34.7	4.0	0.84
R3: I can drive safely over posted speed limit.	Always reason =1 Most time reason = 2 Sometime reason =3 Rarely reason =4 Never reason =5	62.8 29.5 2.9 15.2 4.8	1.4	0.53
R4: There is no too much road side object.	Always reason =1 Most time reason = 2 Sometime reason =3 Rarely reason =4 Never reason =5	2.7 2.3 4.5 27.0 40.8	4.7	0.46
R5: I do not consider speed limit.	Always reason =1 Most time reason = 2 Sometime reason =3 Rarely reason =4 Never reason =5	0.7 58.5 31.7 6.3 4.5	2.3	0.48
R6: I am hurry when running late.	Always reason =1 Most time reason = 2 Sometime reason =3 Rarely reason =4 Never reason =5	28.1 34.7 29.3 13.4 6.6	2.1	0.86

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R7: I am not sure what speed limit is?	Always reason =1	2.5	4.0	0.89
	Most time reason = 2	3.6		
	Sometime reason =3	29.5		
	Rarely reason =4	27.2		
	Never reason =5	34.9		
R8: Speed limit is too low.	Always reason =1	7.3	3.0	0.93
	Most time reason = 2	23.6		
	Sometime reason =3	34.9		
	Rarely reason =4	32.4		
	Never reason =5	1.8		
R9: Most speed signs are not attracting attention.	Always reason =1	12.7	2.4	0.71
	Most time reason = 2	27.4		
	Sometime reason =3	52.4		
	Rarely reason =4	0.9		
	Never reason =5	6.8		
R10: I am distracting by external and internal things.	Always reason =1	1.6	3.3	0.53
	Most time reason = 2	28.1		
	Sometime reason =3	55.8		
	Rarely reason =4	9.3		
	Never reason =5	5.2		
R11: There is no more traffic volume on the road.	Always reason =1	2.5	2.9	0.79
	Most time reason = 2	12.0		
	Sometime reason =3	51.7		
	Rarely reason =4	31.3		
	Never reason =5	2.5		
R12: Speed limit is not visible	Always reason =1	0.9	3.2	0.68
	Most time reason = 2	28.3		
	Sometime reason =3	56.0		
	Rarely reason =4	9.5		
	Never reason =5	5.2		
R13: The carriage way is wide and comfortable.	Always reason =1	0.7	2.9	0.77
	Most time reason = 2	31.8		
	Sometime reason =3	56.0		
	Rarely reason =4	9.8		
	Never reason =5	11.8		
R14: there is no side parking vehicle on the road.	Always reason =1	7.50	2.9	0.78
	Most time reason = 2	21.29		
	Sometime reason =3	42.74		
	Rarely reason =4	9.48		
	Never reason =5	18.82		
R15: There is no more pedestrian around the road	Always reason =1	0.5	3.0	0.82
	Most time reason = 2	27.7		
	Sometime reason =3	53.5		
	Rarely reason =4	11.8		
	Never reason =5	6.6		

## Chapter Four: Results and Discussion

### 4.1. Introduction

In this part, the analysis and discussion of multiple linear regression models, driver degree of compliance for speed limit and driver speeding attitudinal survey analysis were conducted in their order of specific objective. The analysis and discussion was presented in terms of statistical modeling and descriptive graph.

### 4.2. Multiple linear regression model

Before conducting multiple linear regression model development, the basic assumptions of multiple linear regressions were checked primarily.

**Table 10: Description of statistics for multiple linear regression models**

Variable	Symbol	Description
85 <sup>th</sup> percentile speed	V85	V85(km/hr.), mean=62.2,median=61.7 Minimum 46.8= and maximum=79.8 and stand.dev=9.2
Posted Speed limit	PSl.	Speed limit :40km/h (no.=12) and 50 km/h(no.=11)
Land use	Land	Commercial="1", ( no.=11) and institutional="0", ( no.=12)
Median divided	Med	Yes=1,( No.=19) no=0, (No.=4)
Number of lane per direction.	Lan.num.	Two and three lane(no.=8) Four lane(no.= 15)
Side parking density	Parking density	Parking density, maximum=14 vehicle and minimum= 0 vehicle
Pedestrian volume	Hourly Pedestrian volume	Pedestrian hourly volume, mean= 310 and stad. Dev=129
Road side objects density.	Object density	Road side object density: mean= 9 and stad.dev.=4
Hourly traffic volume per lane	Hourly volume	Traffic volume per hour per lane way which traversing the stretch length: mean = 486 veh./hr./lane And stad.dev. =157

## Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

Average head way	Headway	Average head of successive vehicle at the beginning of stretch section (sec): mean= 6 and stad.dev =1.2
Weather	Weather	Weather :sunny=1: no.=14 and otherwise=0 :no.=9
Pavement surface	Pavement surface	wet=0 :no.=9 dry =1:no.=14
Longitudinal grade	Grade	Up-grade"1"(no.=12) Down grade"0"(no.=11)
Pedestrian walk(meter)	Pedestrian walk	Width of pedestrian mean= 3.2 meter and stad.dev.= 1.23m
Road side object offset distance (meter).	Off-set distance	road side object offset distance , mean= 0.56 meter and stad.dev.= 0.25 meter

### 4.2.1. Checking assumption of multiple linear regression

The five assumption of linear regression were checked as follows:

**Assumption 1:** The relation between response and explanatory variable should be linear. It could be checked by scatter plot of dependent and each independent variable's. Based on the figure below, the 85<sup>th</sup> percentile speed was almost linear with side parking density, number of roadside object, number of lane and hourly volume.

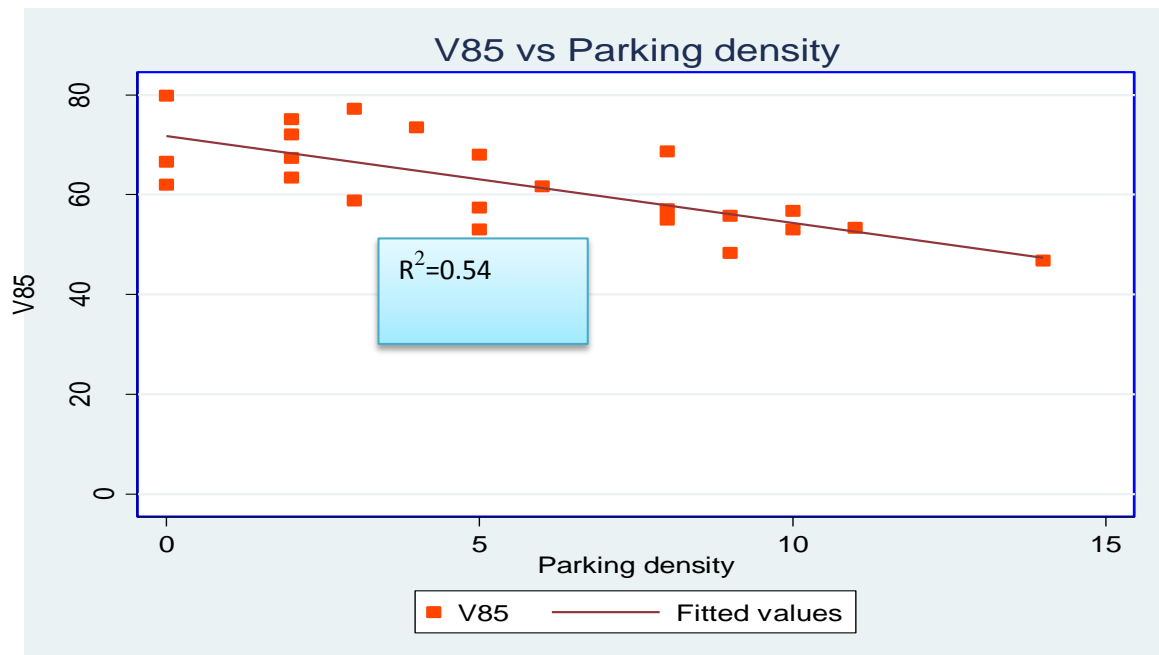


Figure 5: parking density vs V85<sup>th</sup> percentile speed

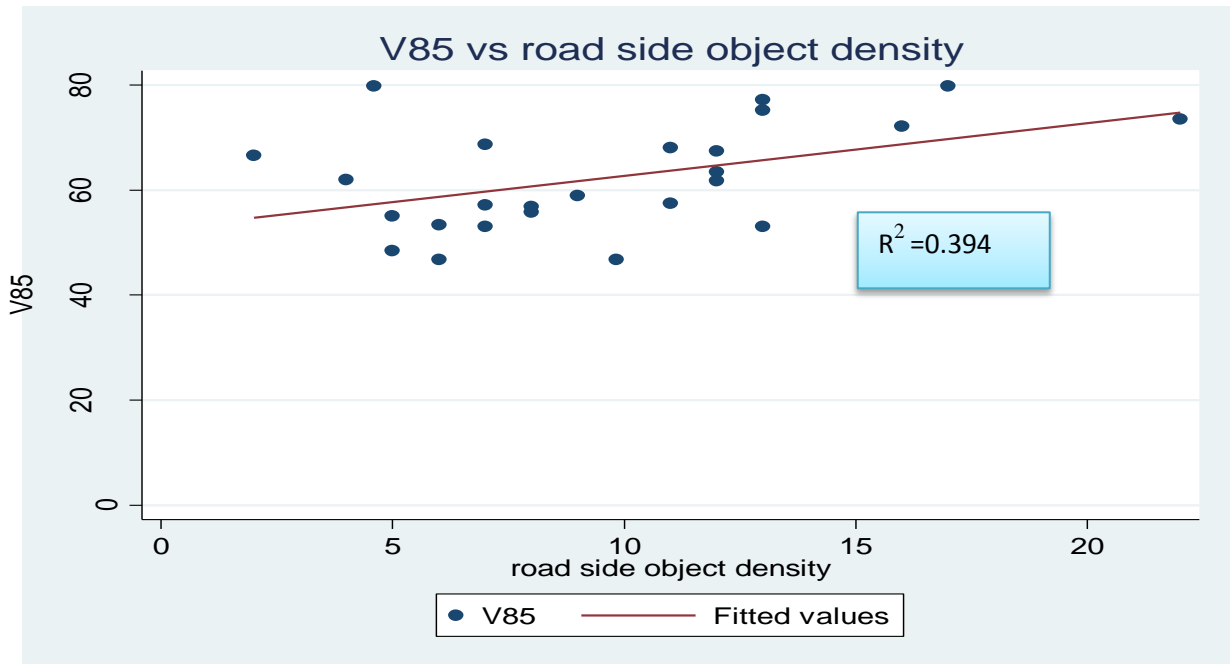


Figure 6: Road side object density vs 85<sup>th</sup> percentile speed

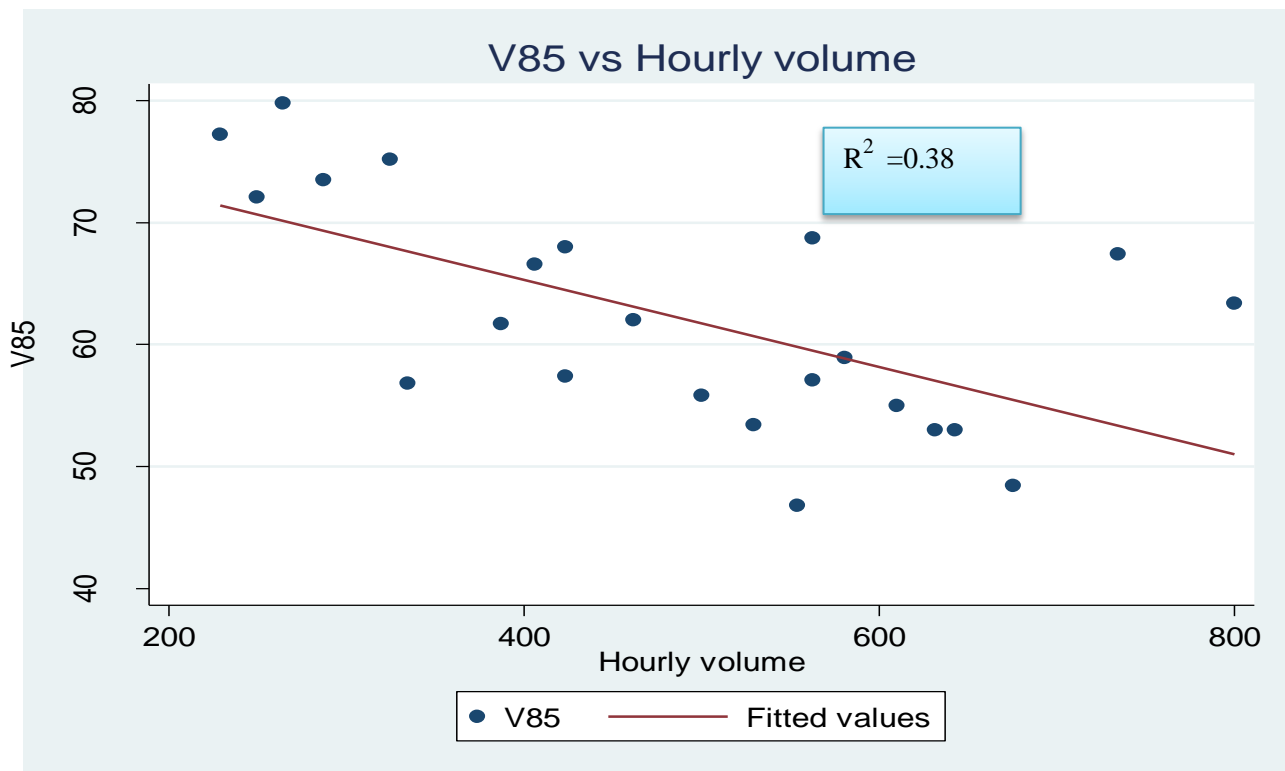


Figure 7: Traffic hourly volume vs 85<sup>th</sup> percentile speed

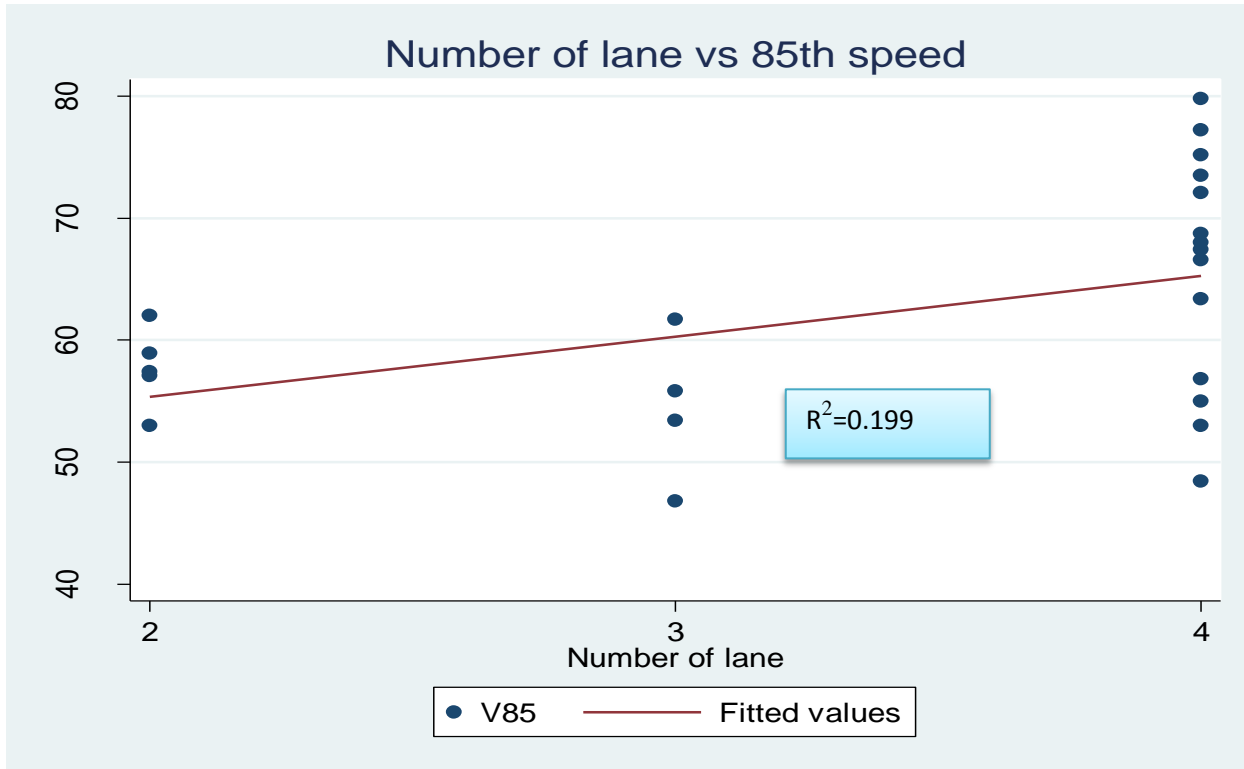


Figure 8: V85 vs number of lane

**Assumption 2:** There should not be strong linear relationship between independent variables (multicollinearity). It could be evaluated by either Pearson correlation coefficient, tolerance or variance inflation factors. Tolerance measures the influence of one independent variable on all other independent variables. The tolerance is calculated with an initial linear regression analysis. Tolerance is defined as  $T = 1 - R^2$  for these first step regression analysis. To avoid multicollinearity between independent variable, tolerance should be greater than ( $T > 0.1$ ) and the correlation coefficient and variance inflation factor should be less than 0.6 and 10 respectively. As shown in table below, most independent variables have significantly correlated with each other. Therefore, these correlated variables should be rejected so as to know the influence of each independent variable on 85<sup>th</sup> percentile speed

## Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

**Table 11: Pearson correlation coefficient**

Variables	V85	number of lane	Median	width of pedestrian walk	pedestrian vol/hr	parking density/100m	road side object density
V85	1.000	.446	.181	-.089	-.328	-.736	.628
number of lane	.646	1.000	.657	-.469	-.127	-.073	.202
Median	.181	.657	1.000	-.733	.324	.282	.098
width of pedestrian walk	-.089	-.469	-.733	1.000	-.286	-.264	.098
Pedestrian volume (vol/hr.)	-.328	-.127	.324	-.286	1.000	.667	-.146
parking density/100m	-.736	-.073	.282	-.264	.667	1.000	-.397
road side object density/100m	.628	.202	.098	.098	-.146	-.397	1.000
offset distance	-.182	-.374	-.560	.896	-.201	-.059	.170
land use	.194	.498	.371	-.352	.083	.062	.093
hourly volume	-.617	-.172	-.187	.194	-.260	.290	-.437
Grade	.573	.205	.181	-.078	-.213	-.528	.538
Psl	.335	.498	.112	-.171	-.297	-.277	.074
Weather	-.446	-.274	-.483	.246	-.349	.016	-.454
pavement surface	.215	.165	-.311	.146	-.423	-.340	.163
Median width	0.211	0.486	0.498	-0.503	0.104	0.485	-0.029
Median height	0.422	0.353	0.588	-0.255	0.164	-0.065	0.411
Variables	offset distance	land use	hourly volume	Grade	Psl	weather	pavement surface

**Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads**

V85	-.182	.194	-.617	.573	.335	-.446	.215
number of lane	-.374	.498	-.172	.205	.498	-.274	.165
Median	-.560	.371	-.187	.181	.112	-.483	-.311
width of pedestrian walk	.896	-.352	.194	-.078	-.171	.246	.146
Pedestrian volume (vol/hr.)	-.201	.083	-.260	-.213	-.297	-.349	-.423
parking density/100m	-.059	.062	.290	-.528	-.277	.016	-.340
road side object density	.170	.093	-.437	.538	.074	-.454	.163
offset distance	1.000	-.233	.209	-.222	-.243	.255	.159
land use	-.233	1.000	-.487	-.038	.652	-.233	.411
hourly volume	.209	-.487	1.000	-.346	-.482	.296	-.406
Grade	-.222	-.038	-.346	1.000	.137	-.195	.016
Psl.	-.243	.652	-.482	.137	1.000	.124	.768
Weather	.255	-.233	.296	-.195	.124	1.000	.460
pavement surface	.159	.411	-.406	.016	.768	.460	1.000
Median width	0.310	0.475	-0.037	0.024	0.475	0.134	0.288
Median height	-0.296	-0.111	-0.075	0.347	-0.175	-0.0804	-0.506

Based on Pearson correlation coefficient, side parking density, road side object density, and hourly volume and number of lane have correlation coefficient greater than 0.6 which influence 85<sup>th</sup> speed significantly. Even if, weather condition, grade and median height have correlation coefficient less than 0.6, they also affect 85<sup>th</sup> percentile operating speed but correlated with most significant variables. Using these highly correlated independent variable on dependent variable; variance inflation factor was calculated using initial regression.

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Table 12: Variance inflation factor for correlated variable with 85<sup>th</sup> speed

Independent variables	VIF	1/VIF
Median width	4.14	0.242
Weather condition	4.01	0.249
Long.grade	2.03	0.493
Road side object density	1.89	0.529
Parking density	1.61	0.620
Hourly volume	1.50	0.666
Number of lane	1.18	0.846
mean VIF	2.34	

All above selected variables have variance inflation factor less than 10 which fulfilled necessary requirement of multiple linear regression. But median height, weather condition and longitudinal grade were significantly correlated with highly significant independent variables than others.

**Assumption3:** Residuals should have constant variance along predicted value (homoscedasticity). It can be checked by plotting predicted and residual value on scatter plot. As show below on the graph, the standardized residual were concentrated around zero.

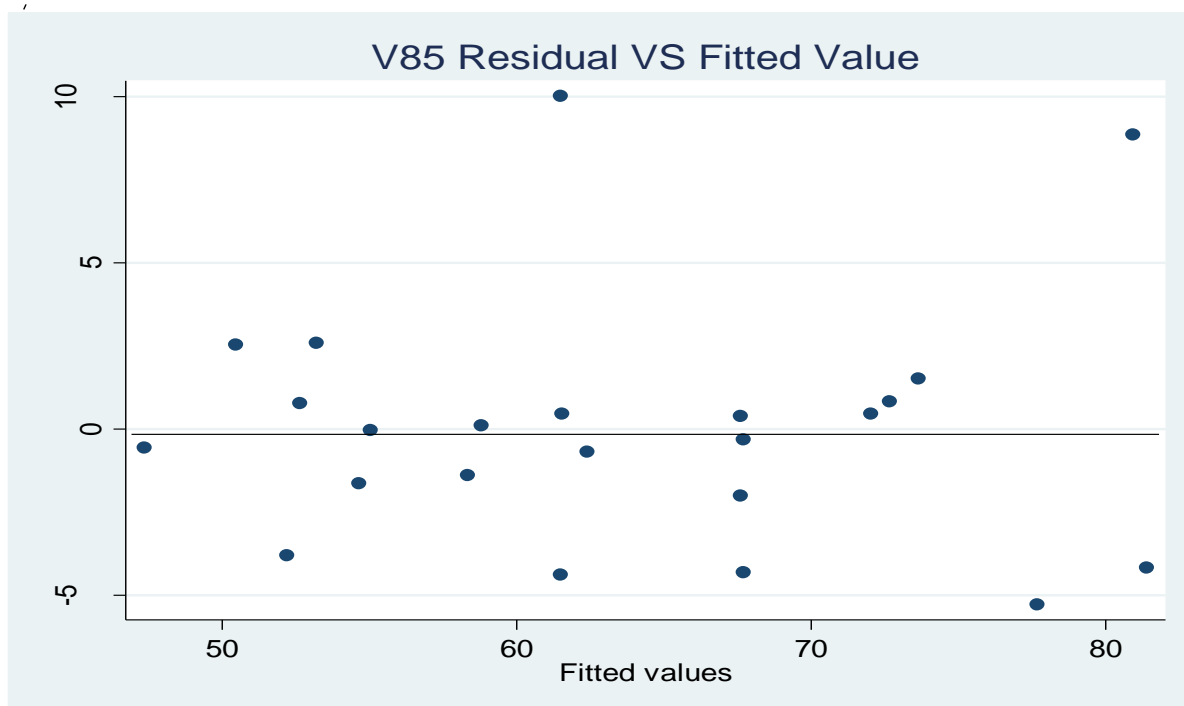


Figure 9: Homoscedasticity test

## Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

**Assumption4:** The dependent variable should be continuous and normally distributed. The normal distribution of independent variable can be observed by plotting histogram and normal residual P-P plot and using kurtosis and skewness. As shown in bell-shaped normal distribution graph below, it was almost normally distributed which has almost equal mean and median.

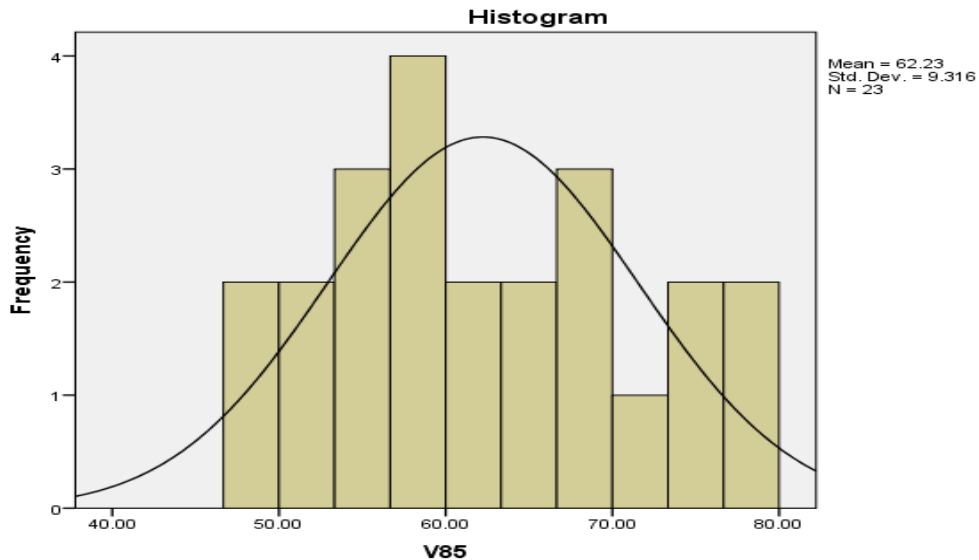


Figure 10: Normal distribution graph

Based on the P-P plot, as we have seen in the graph below, the observed cumulative probability follows the expected predicted cumulative probability continuously.

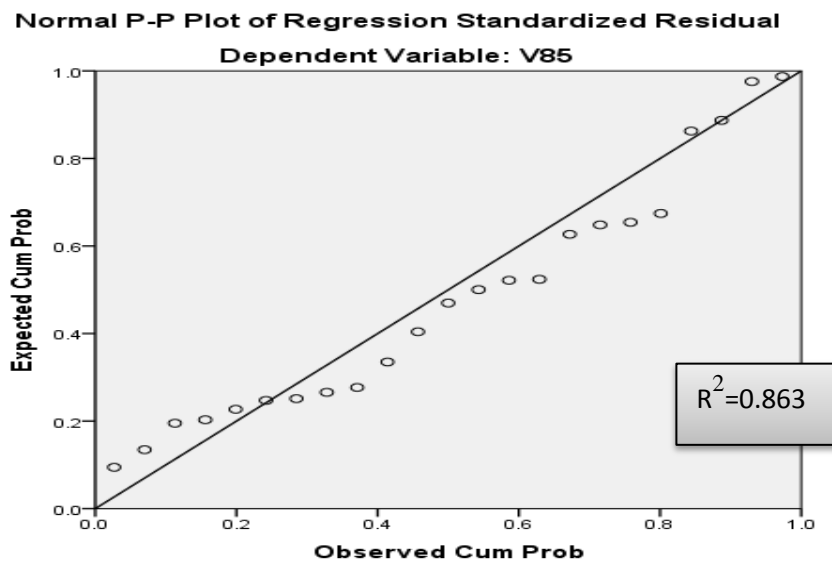


Figure 11: Normal p-p plot

## Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

**Table 13:** Descriptive Statistics for normality test using kurtosis and Skewness

Dependent variable	Range	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
V85	43.00	46.80	79.80	62.4143	2.20100	9.3
Skewness			Kurtosis			
Statistic	Std. Error	Z	Statistic	Std. Error	Z	
.547	.481	1.137	.111	.935	0.118579	

Kurtosis and skewness are descriptive Statistics used to evaluate the normality of continuous dependent variable depend on the number of sample. For sample size less than 50, Z value of skewness and kurtosis used to identify normal distribution in which it has to lie between -1.96 and 1.96. Therefore, for both cases Z value were  $-1.96 < 0.12$  and  $1.137 < 1.96$ .

The normal distribution of 85<sup>th</sup> percentile speed was also examined using Kolmogorov-Smirnov and Shapiro-Wilk normality test.

Ho: 85<sup>th</sup> percentile speed is far from significant for normal distribution.

**Table 14:** Test of normality by Kolmogorov-Smirnov and Shapiro-Wilk

Tests of Normality						
	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
V85	.116	23	.200*	.963	23	.516
a. Lilliefors Significance Correction						

The null hypothesis was rejected because it is not significant ( $0.200 > 0.05$ ) at 95 % confidence level. Therefore 85<sup>th</sup> percentile speed of these data was normally distributed continuous variable.

**Assumption5:** Outlier data should be excluded from the analysis because it is different from the value estimated by the regression model. Therefor (Simon P, et al., 2003) box-plot assured that, there was no outlier 85<sup>th</sup> percentile speed data.

## Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

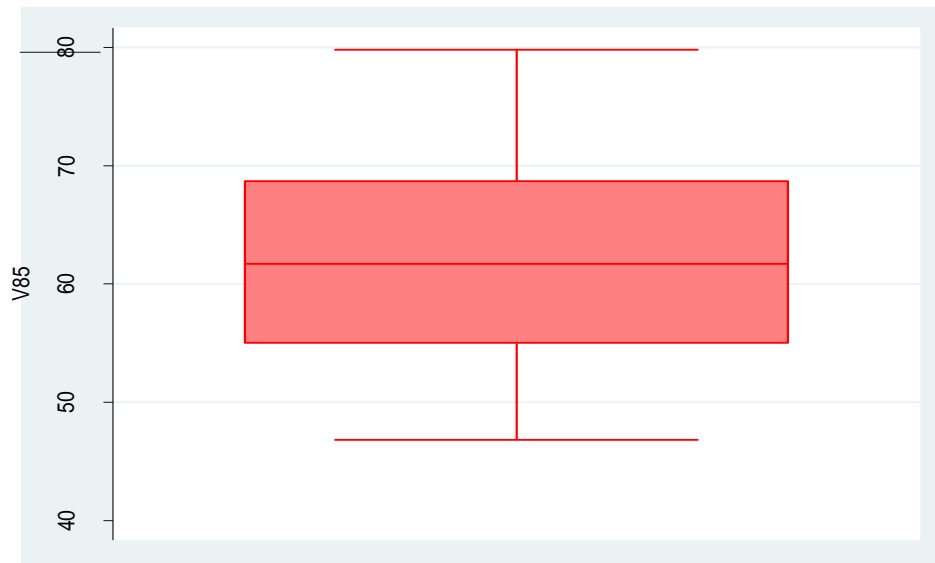


Figure 12: Box plot to identify outlier data

### 4.2.2. Regression model

After all linear regression assumption are satisfied , a linear regression model was developed using stepwise selection of the most significant variables so as to know the effect of each independent variables on 85<sup>th</sup> percentile speed of drivers.

### 4.2.3. Developing Model

The multiple linear regression models were developed with step wise selection of most significant and non-correlated variables. A variable which were correlated with dependent variable but correlated with most independent variable has been rejected from model.

Table 15: Stepwise regression model

Model	Variables	Coefficient	stad.Err	T	p> t	R <sup>2</sup>	Adjusted R <sup>2</sup>	RME
V85(1)	side parking density	-1.741	0.349	-4.99	0.000(**)	0.5424	0.5206	6.45
	constant	71.76	2.33	30.7	0.000(**)			
V85(2)	side parking density	-1.673	0.291	-5.73	0.000(**)	0.697	0.667	5.378

**Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads**

	number of lane	4.379	1.371	3.2	0.005(**)			
	constant	56.54	5.15	10.98	0.000(**)			
V85(3)	side parking density	-1.374	0.274	-5.1	0.000(**)	0.7848	0.7508	4.651
	number of lane	3.74	1.21	3.1	0.006(**)			
	road side object density	0.65	0.234	2.78	0.012(**)			
	constant	50.66	4.93	10.29	0.000(**)			
V85(4)	side parking density	-1.271	0.228	-5.58	0.000(**)	0.862	0.8312	3.82
	number of lane	3.43	0.998	3.44	0.003(**)			
	road side object density	0.425	0.205	2.07	0.05(**)			
	Hourly volume	-0.018	0.0057	-3.17	0.005(**)			
	constant	62.18	5.44	11.42	0.000(**)			

Based on the above stepwise regression analysis, model 4(V85) has selected based on degree of determination (adjusted R-squared) and root mean square error (RME). Because V85 (4) had better degree of determination with adjusted R-squared(R-squared=0.832) and lowest root mean square error (RME=3.82).Median height, longitudinal grade, and weather condition are not included in the model due to correlation diagnostics. The detail regression model with analysis of variance was presented as follow in table below.

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**Table 16: ANOVA for Selected regression model**

ANOVA	Source	SS	Df	MS	No. of observation=	23	
	Model	1645.6	4	411.39	F(4, 18)=	28.09	
	Residual	263.663	18	14.65	Prob.>F=	0.0000	
	Total	1909.25	22	86.78	R-squared=	0.862	
						Adjusted R-squared=	0.8312
					root MSE=	3.82	
Model	Variable	Coefficient	stad.Err	T	p> t	95%Confidence interval	
V85	side parking density	-1.271	0.228	-5.58	0.000	-1.75	-0.9468
	number of lane	3.43	0.998	3.44	0.003	1.34	8.9818
	road side object density	0.425	0.205	2.07	0.05	-0.062	0.856
	Hourly volume (veh/hr/lane).	-0.018	0.0057	-3.17	0.005	-0.031	-0.0061
	Constant	62.18	5.44	11.42	0.000	50.744	73.61

Based on the above developed model, parking density, number of lane, road side object density and hourly volume are significant at 95% confidence level with better degree of determination.

### 4.2.4. The effect of road geometry on 85<sup>th</sup> operating speed

Based on the result of analysis, side parking density, number of lane, road side object density and traffic hourly volume are the most significant independent variable at 95% confidence level. Therefore increasing the side parked vehicle by one unit per 100 meter are decrease the 85<sup>th</sup> percentile speed by 1.271 km/hr. by keeping other variable constant which argue with the study done by (Wang.et.al., 2006.). Number of lane has greatest contribution for the increment of 85<sup>th</sup> percentile speed. Adding one lane to the urban road has increased the 85<sup>th</sup> percentile speed by 3.43 km/hr. by keeping other variables constant. Number of lane in this study has similar effect on 85<sup>th</sup> operating speed with (Wang.et.al., 2006.). Road side object density and hourly volume on urban road are also significantly affected 85<sup>th</sup> percentile speed at 95% confidence level. Increasing the

## **Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads**

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road side object by one unit per 100m where ever offset distance is, the 85<sup>th</sup> percentile operating speed have increased by 0.425 km/hr. by keeping constant other independent variables. The effect of road side object on 85<sup>th</sup> percentile speed is contradicting the result of other similar studies, (Martens, et al., 1997) . (horst & ridder, 2007) and (Wang.et.al., 2006.).This may be due to aggressive behavior of drivers and lack of knowledge about road side object which is the cause of most traffic accident in the world. Hourly volume of traffic is also another significant variable which affect speed of all vehicle. Even if hourly volume is significant at 95% confidence level, it has no much effect on 85<sup>th</sup> operating speed like number of lane and road side object. This indicates that, the traffic flow condition is almost free flow condition since the traffic and speed data was collected on off-peak hour. But all of these (posted speed limit, width of pedestrian, pedestrian volume, offset distance and land use) were not significant for 85<sup>th</sup> percentile speed.

### **4.2.5. The effect of posted speed limit on 85<sup>th</sup> speed.**

$$V_{85} = 34.84 + 0.37psl \dots (p(t) = p(1.63) = 0.118 \text{ and Adjusted } R^2 = 0.0702)$$

Based on the result of analysis, posted speed limit is not significant variable for 85 percentile speed which indicates that recklessness and bad behavior of drivers. The result of this study is similar with other studies (Ahmed M. Semeida, 2012), (Wang.et.al., 2006.) and in some extent (Fitzpatrick, et al., 2001), but contradicting the result of study of (Poe. & Mason, 1996).

Therefore, there is no universal agreement on the effect of posted speed limit on operating speed of most driver because drivers have dynamic behavior depending on environment, culture and awareness level of traffic rules. Based on the result of analysis, 85<sup>th</sup> percentile speed of all road section are greater than the provided posted speed limit. Even if this study is conducted on and during non-speed limit enforcement section and time, the speed choice of most driver are affected by the method of speed enforcement based on previous studies.

Manual speed limit enforcement can reduce 31% fatal crash due to speeding whereas speed camera had reduced 15 to 20% of fatal crash due to excessive speed (OECD/ECMT, 2006). This indicates that the speed of most drivers are not exceeded posted speed limit if there is traffic police or speed camera means that posted speed limit has negative effect on the speed of 85 percent of the driver if there is significant speed limit enforcement.

Based on the studies conducted by (Fitzpatrick.k, et al., 2003), the posted speed limits are decided by 85<sup>th</sup> percentile speed but should consider accident history. In general the speed limit should be seat 5mph to 10mph deviation from the 85<sup>th</sup> percentile speed ( (Institute of transport Engineer(ITE),

## **Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads**

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2007). If we think Addis-Ababa urban roads experienced worst traffic experience, the speed limit should be set 16km/hr. deviation from 85<sup>th</sup> percentile speed.

## **Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads**

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### **4.3.0. Driver degree of compliance for posted speed limit**

In this section, driver degree of compliance as per vehicle class and posted speed limit was described in bar-graph and tabular form. Drivers whose spot speed is greater than speed limit were considered as compliance unless violence. All necessary data used for study were extracted from recorded video using VLC media player and then transferred to excel spread sheet to determine spot speed distribution of each vehicle for both speed limit( 40 and 50km/hr.).

#### **4.3.1. Sample size and vehicle composition**

A total of 3779 vehicles spot speed data were obtained from manipulated excel spread sheet. The vehicle composition and speed limit were summarized as follows in table below.

Table 17: Vehicle composition and degree of compliance as per vehicle class

Urban road	Name Of	PSL (Km/hr.)	No.of Vehicle (Total)	Composition of vehicle			Degree of compliance (%)	Degree of violation (%)
	Route			Passenger car	LCV	Bus and Truck		
Median divided	BR	50	1227	844	309	74	28.68	71.32
	CAR	40	1172	679	430	63	33.6	66.4
	MR	50	379	177	135	67	60.2	39.8
	ADR	40	535	309	190	36	39.06	60.94
Non-median divided	SR	50	255	123	74	14	46.47	53.53
	SR	40	211	129	95	31	31.65	68.35
	Total		3779	2261	1233	285	39.61	60.39

**4.3.2. Driver degree of compliance for speed limit as per total number of vehicle**

From spot speed of each vehicle category, bar charts were developed to indicate driver degree of compliance and violated for each category of vehicle. For each section of road bar charts were developed in addition to total degree of compliance as shown in table below:

Table 18: Descriptive statistics on degree of compliance of speed limit as per total number of vehicle.

PSL	Num.lane	Mean degree of compliance	N
40	2	31.65	2
	3	39.08	4
	4	33.94	6
	Average degree of compliance	34.89	12
50	2	46.47	2
	4	44.44	9
	Average degree of compliance	45.96	11
Total average degree of compliance		39.61	23

Based on the above descriptive table, the average degree of compliance for speed limit of 50 and 40 km/hr. were 44.44 % and 35.01 % respectively on median divided urban road of Addis-Ababa during free flow traffic condition. There for, increase the speed limit would increase compliance of driver for speed limit but dangerous for safety.

The average degree of compliance for speed limit of 50 and 40 km/hr. were 46.47 % and 31.65 % respectively on non-median divided urban road of Addis-Ababa during free flow traffic condition. When we compare median and non-median divided roads, they have 44.44 % and 46.47% degree of compliance for 50 km/hr. speed limit respectively but the reverse is true for speed limit 40 km/hr. This is due to factors like parking density which affect speed of most drivers which was high on three lane road on recorded data. Median divided roads has lower degree of compliance than non-median divided roads because median is associated with three or more number of lanes per direction on selected section in this study which was found to be the main factor of increasing 85<sup>th</sup>

## Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

speed in multiple linear regression models. This implies median reduce the influence of opposite coming vehicle which influence the speed of upcoming vehicle on study stretch.

### 4.3.3. Total degree of compliance on median divided road based on vehicle category

Table 19: Compliance for speed limit of 50km/hr. as vehicle category

Vehicle category	Total	% compliance	% violated
Passenger car	1021	49.9	50.1
LCV	444	52.05	47.95
Bus and Truck	144	71.85	28.15

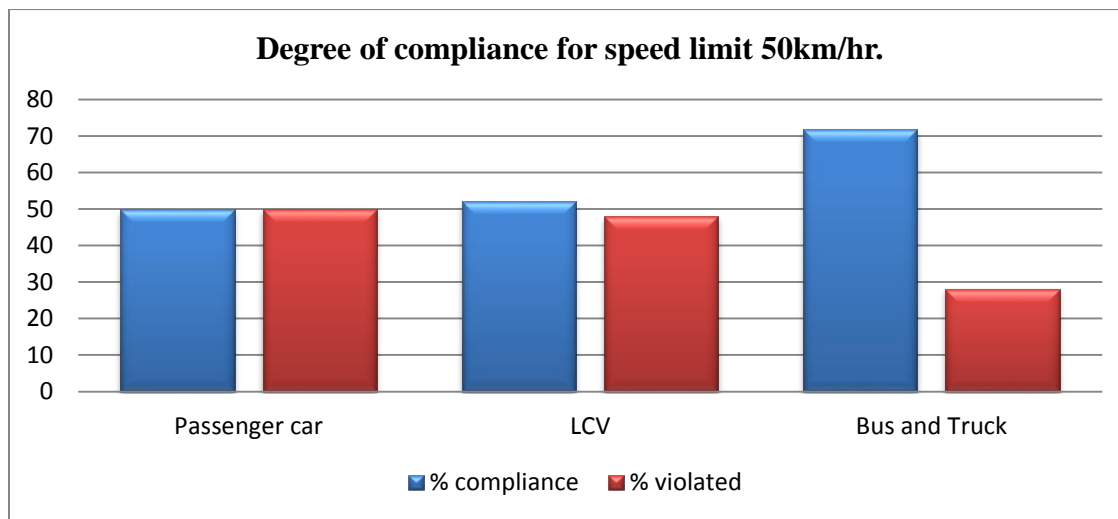


Figure 13: Total degree of compliance as per vehicle class for speed of 50 km/hr.

## Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

Table 20: Total degree of compliance as per vehicle class for speed limit of 40km/hr.

vehicle class	Total	% compliance	% violated
Passenger car	988	31.84	68.16
LCV	620	29.02	70.98
Bus and Truck	99	50.99	49.01

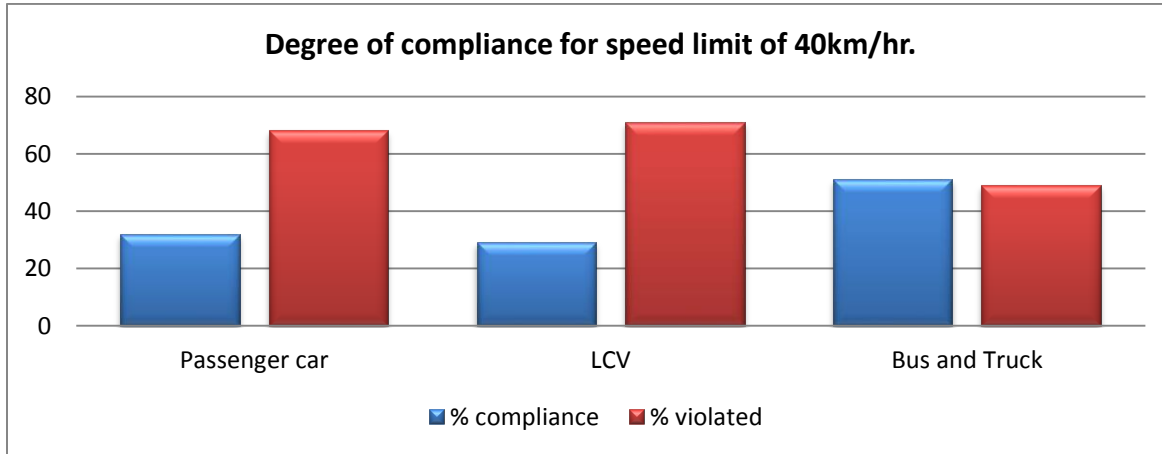
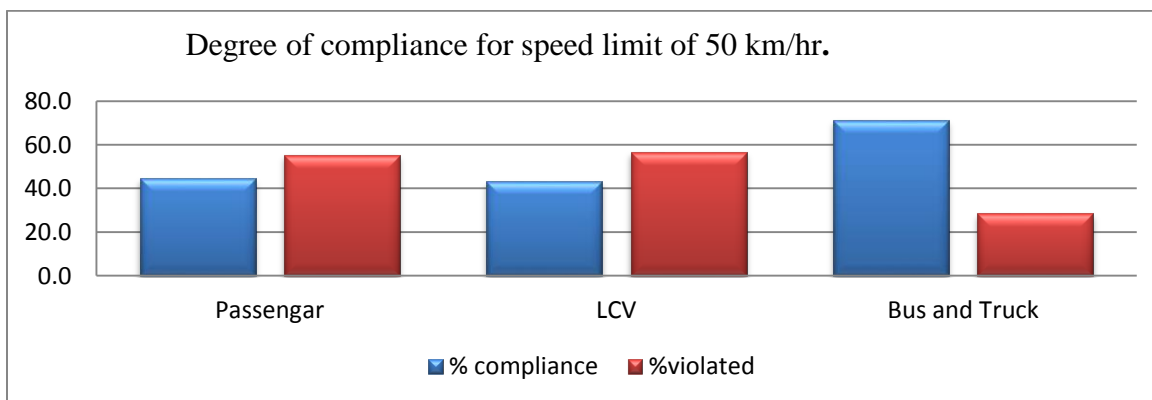


Figure 14: Total degree of compliance as per vehicle class for speed limit of 40km/hr.

### 4.3.4. Degree of compliance on non-median divided road as per vehicle category

Table 21: Total degree of compliance as per vehicle class for speed limit of 50km/hr.

Vehicle class	Total	% compliance	% violated
Passenger car	123	44.7	55.3
LCV	74	43.2	56.8
Bus and Truck	14	71.4	28.6



## Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

Figure 15: Total degree of compliance as per vehicle class for speed limit of 50km/hr.

Table 22: Total degree of compliance as per vehicle class for speed limit of 40 km/hr.

Vehicle class	Total	%Compliance	%Violated
Passenger car	129	34.1	65.9
LCV	95	35.8	64.2
Bus and Truck	31	77.4	22.6

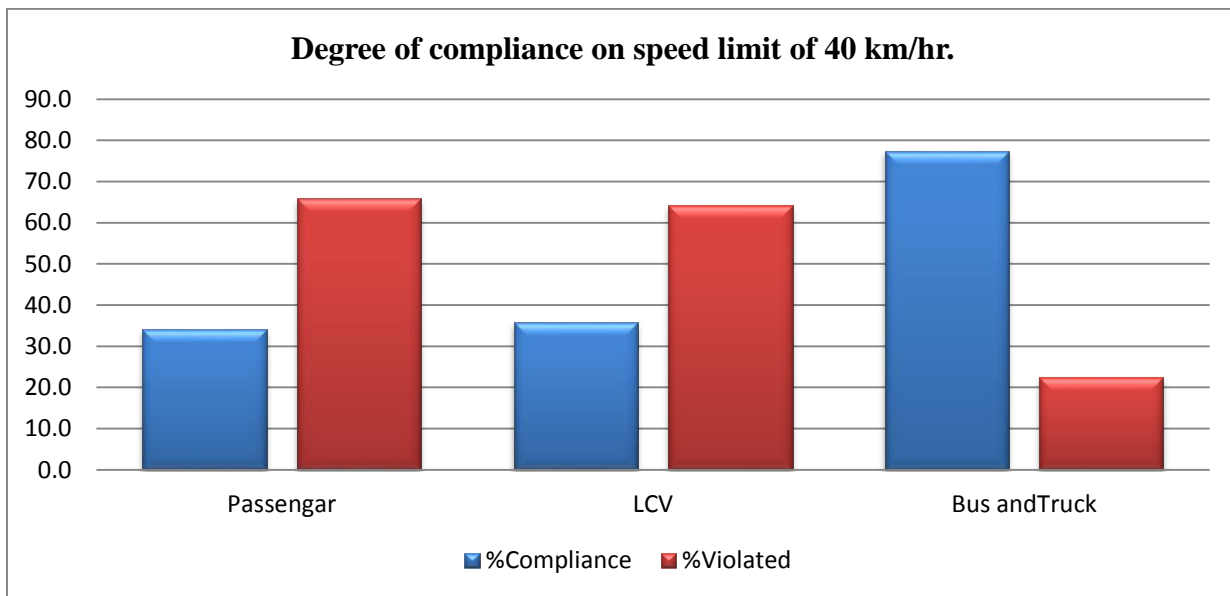


Figure 16: Total degree of compliance as per vehicle class for speed limit of 40km/hr.

Therefore, based on the result of analysis, degree of compliance of driver increase with speed limit for both median divided and non-median divided urban road. Based on vehicle category, degree of compliance of bus and truck is highest than other vehicle category for both median divided and non-median divided urban road and for both speed limit. Passenger car has better degree of compliance of speed limit than light commercial vehicle in some extent, but there is no definite difference. The result of this study is contradict the study done by (Rohaizan & Mashros,, 2016) which was concluded that driver speed compliance decrease with increase of posted speed limit. Howe ever, degree of compliance of large vehicle (Bus and Truck) is better than other vehicles which have argued with the research done by (Zhang , 2015). In this study, it is also found that large percentage of vehicle (60.36%) exceeded posted speed limit which is very high as compared to the study done by (Hopkins university, 2016) in Addis-Ababa city which was 43%.

#### 4.4. Driver Speeding Attitudinal survey Analysis

In this part, factor analysis, binary logistic regression, and ordinal logistic regression analysis were conducted using driver attitudinal survey data by following descriptive statistics.

##### 4.4.1. Descriptive Statistics

Demographic characteristics of driver who participated in speeding altitudinal survey were presented as follow in table below.

As we have seen below in table, male drivers participated in altitudinal survey was contributed 88.9 percent and mostly participated age group were from ( 30 to 40 year) which was contributed 55.1%.

**Table 23: Frequency and Percentage of gender**

Gender	Frequency	Percent
Male	392	88.9
Female	49	11.1

**Table 24: Frequency and Percentage of age category**

Age (year)	Frequency	percent
<=30	98	22.2
30-40	243	55.1
40-50	44	10.0
>50	56	12.7

**Table 25: Frequency and percentage of Education category**

Education level	frequency	percent
8-12 grade	250	56.7
Diploma	55	12.5
Degree and above	149	33.8

**Table 26: Frequency and percentage of experience of driver**

Experience of driver(year)	Frequency	percent
<=5	144	32.7
5-10	240	54.4
> 10	57	12.9

**Table 27: Frequency and percentage of marital status of driver**

Marital Status	Frequency	Percent
married	272	61.7
single	169	38.3

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### 4.4.2. Drivers traffic accident and speeding history

As shown in table 28 and 29, only 24.7 % of drivers faced accident irrespective of its severity and 7.9 % percent of driver were received speeding ticket greater than or equal five times per past two years while 47.2 percent of drivers were received speeding ticket than less five times in past two years. This indicates that almost half of the drivers received speeding ticket less than five times in past two years based on the report of them.

Table 28: drivers past two-year traffic accident history

Have you faced traffic accident in past two year?	frequency	Percent
No	332	75.3
Yes	109	24.7

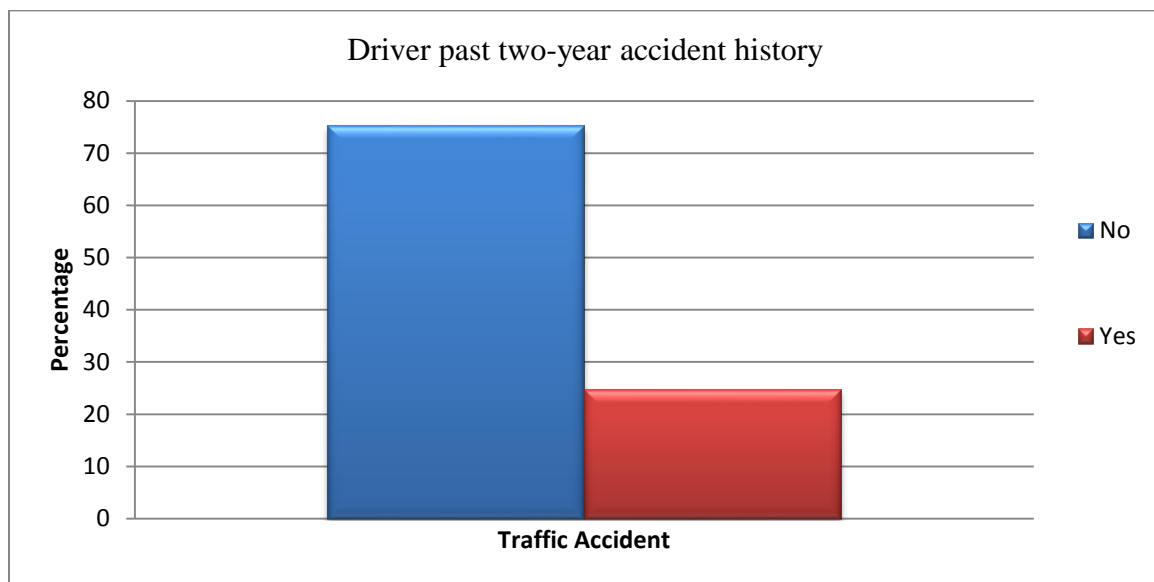


Figure 17 :percent of driver faced traffic accident in past two years

Table 29: Speeding frequency in past two year

How often have you been caught by traffic police when you were traveling above posted speed limit in past two year?	Frequency	percent
Most time ( $\geq 5$ speeding ticket)=2	35	7.9

## Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

Seldom (<5 speeding ticket)=1	208	47.2
Nothing=0	198	44.9

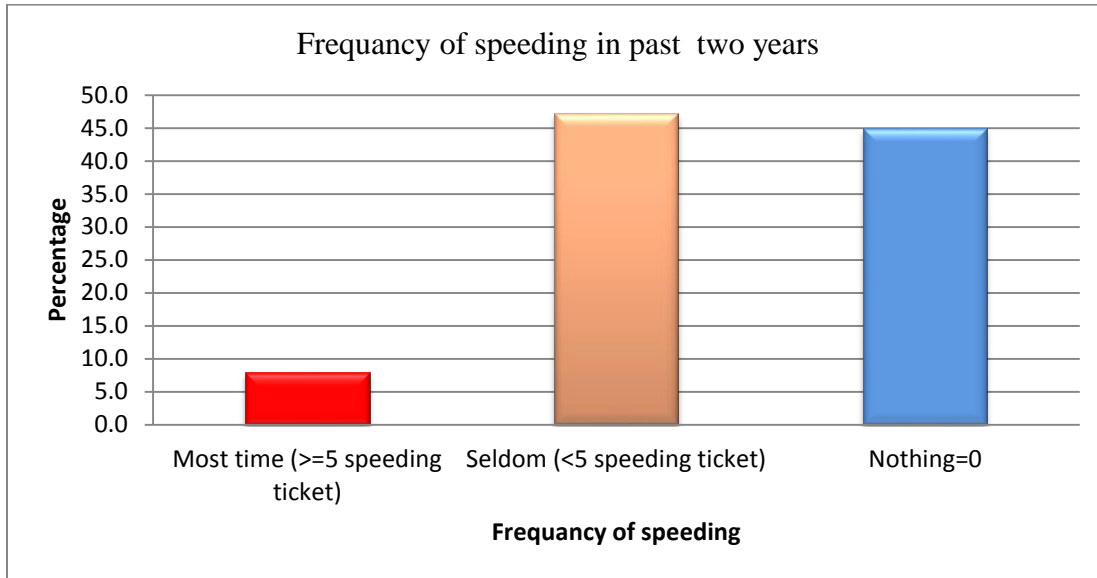


Figure 18: Speeding frequency in past two years

### 4.4.3. Frequent Reason for speeding over speed limit

The frequent of possible reason of speeding was used 5 point Likert scale (always reason=1, most time=2, sometime=3, rarely=4 and never reason=5). Individual drivers had their own over speeding reason that can be driver behavior, vehicle characteristics and road way condition. The percent mean and standard deviation for each cause of speeding presented in table as follows.

Table 30: Descriptive statistics of possible speeding reason

Why did you speeding?		Percent	Mean	Stad.dev.
R1: There is no traffic police around the road.	Always reason =1	4.83	2.95	0.86
	Most time reason = 2	27.67		
	Sometime reason =3	52.33		
	Rarely reason =4	10.50		
	Never reason =5	4.67		
R2: I enjoy driving fast.	Always reason =1	2.33	4.03	0.84
	Most time reason = 2	21.17		
	Sometime reason =3	30.00		
	Rarely reason =4	28.50		
	Never reason =5	28.50		
R3: I can drive safely over posted	Always reason =1	4.67	1.35	0.54

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speed limit.	Most time reason = 2	8.50		
	Sometime reason =3	15.17		
	Rarely reason =4	45.83		
	Never reason =5	25.83		
R4: There is no too much road side object.	Always reason =1	4.67	4.68	0.47
	Most time reason = 2	7.83		
	Sometime reason =3	10.33		
	Rarely reason =4	24.83		
	Never reason =5	52.33		
R5:I do not consider speed limit.	Always reason =1	14.00	2.45	0.48
	Most time reason = 2	34.67		
	Sometime reason =3	30.17		
	Rarely reason =4	9.17		
	Never reason =5	12.00		
R6: I am hurry when running late.	Always reason =1	25.17	4.0	0.56
	Most time reason = 2	34.67		
	Sometime reason =3	34.67		
	Rarely reason =4	5.50		
	Never reason =5	0.00		
R7: I am not sure what speed limit is.	Always reason =1	7.00	2.96	0.89
	Most time reason = 2	9.67		
	Sometime reason =3	28.33		
	Rarely reason =4	25.83		
	Never reason =5	29.17		
R8: Speed limit is too low.	Always reason =1	11.67	2.42	0.93
	Most time reason = 2	33.17		
	Sometime reason =3	19.83		
	Rarely reason =4	5.00		
	Never reason =5	30.33		
R9: Most speed signs are not attracting attention.	Always reason =1	4.33	3.27	0.71
	Most time reason = 2	8.00		
	Sometime reason =3	15.67		
	Rarely reason =4	27.50		
	Never reason =5	44.50		
R10: I am distracting by external and internal things.	Always reason =1	11.67	2.87	0.53
	Most time reason = 2	33.00		
	Sometime reason =3	20.00		
	Rarely reason =4	4.67		
	Never reason =5	30.67		
R11: There is no more traffic volume on the road.	Always reason =1	2.33	3.2	0.84
	Most time reason = 2	1.50		
	Sometime reason =3	11.00		
	Rarely reason =4	44.00		
	Never reason =5	41.17		
R12: Speed limit is not visible	Always reason =1	5.67	2.91	0.67

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	Most time reason = 2	9.33		
	Sometime reason =3	12.33		
	Rarely reason =4	28.67		
	Never reason =5	44.00		
R13: The carriage way is wide and comfortable.	Always reason =1	15.67	2.62	0.77
	Most time reason = 2	28.29		
	Sometime reason =3	40.91		
	Rarely reason =4	9.48		
	Never reason =5	5.82		
R14: there is no side parking vehicle on the road.	Always reason =1	7.50	2.92	0.87
	Most time reason = 2	21.29		
	Sometime reason =3	42.74		
	Rarely reason =4	9.48		
	Never reason =5	18.82		
R15: There is no more pedestrian around the road	Always reason =1	0.33	2.96	0.82
	Most time reason = 2	55.41		
	Sometime reason =3	53.91		
	Rarely reason =4	10.98		
	Never reason =5	6.82		

Based on the result of the above descriptive analysis (R13, R3, R8, R14 and R15) were the most important frequent reason of most drivers based on rating of mean (Lower mean indicate most frequent reason).

#### 4.4.4. Factor analysis

Factor analysis is data reduction method used to re-express multi-variate data with fewer dimension (Kim & Mueller, 1978). The goal of this analysis was used to summarize fewer factors from original speeding reason that capture maximum possible information from 15 original cause of speeding which was listed in questionnaire. This method of analysis had been accomplished through factor rotation followed by factor extraction.

##### 4.4.4.1. Factor Extraction

The first step for factor analysis was checking sample adequacy and correlation between speeding reasons. The adequacy of the sample size is based on the ratio of 10 responses per reason. Kaiser-Mayer –Olkin can measure the adequacy of data’s for the application of factor analysis in which it should be above 0.8 (Kaiser, 1974). For this particular study, it is possible to apply factor analysis, because KMO value were greater than 0.8. Bartlett’s’ test of sphericity was used to check the correlation between items (Bartlett, 1950) and the result below shows the presence of at least one significant correlation between speeding reason.

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**Table 31:KMO and Bartlett's Test**

<b>KMO and Bartlett's Test</b>		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.862
Bartlett's Test of Sphericity	Approx. Chi-Square	6239.031
	df	105
	Sig.	.000

After assured the adequacy of the sample and the correlation between speeding reason, factorial extraction was conducted. The factor analysis was conducted on 15 main causes of speeding of the driver. As shown in table below, the variance of each speeding reason explaining the variance of all factors which is commonly called communality were presented. Communality is the proportion of variance jointly explained one variable and it is indicator of reliability. Communality calculated by summing up factor loadings for all variables. Based on the result of analysis, R15, R14, R13 and R11 have measured large percent of variance for all speeding reasons.

**Table 32: Speeding reason communalities**

Cause of speeding	Initial	Extraction
R1	1.000	.952
R2	1.000	.778
R3	1.000	.681
R4	1.000	.864
R5	1.000	.867
R6	1.000	.830
R7	1.000	.686
R8	1.000	.648
R9	1.000	.512
R10	1.000	.465
R11	1.000	.905
R12	1.000	.613
R13	1.000	.938
R14	1.000	.945
R15	1.000	.881
Extraction Method: Principal Component Analysis.		

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Eigen value represents the amount of variance of variable explained by factors. It is the sum of all squared loading of principal factors across all variables. Based on the result of the analysis, four components were extracted which have Eigen value greater than 1 which explained cumulative variance of 77.1 percent as shown in the table below.

Table 33: Factor extraction based on Eigen value

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.211	41.404	41.404	6.211	41.404	41.404
2	2.560	17.067	58.471	2.560	17.067	58.471
3	1.666	11.106	69.577	1.666	11.106	69.577
4	1.127	7.514	77.091	1.127	7.514	77.091
5	.958	6.385	83.476			
6	.631	4.208	87.684			
7	.574	3.829	91.513			
8	.446	2.971	94.484			
9	.210	1.402	95.886			
10	.171	1.137	97.023			
11	.142	.947	97.970			
12	.125	.830	98.800			
13	.082	.545	99.345			
14	.053	.355	99.700			
15	.045	.300	100.000			

The scree plot suggests that four components can explain 77.1 % variance of 15 original components.

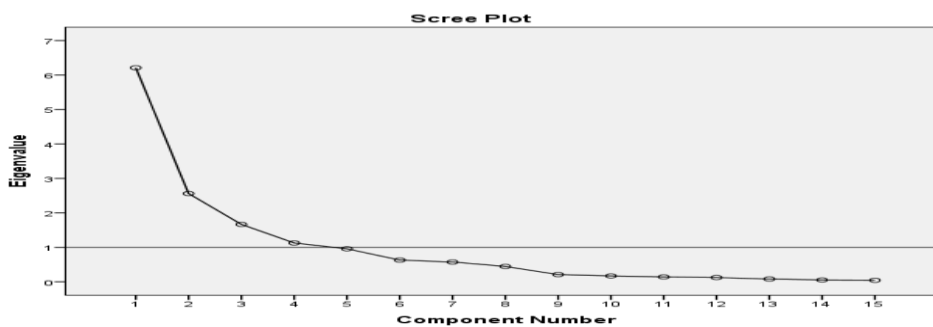


Figure 19: Screen plot of principal component

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### 4.4.4.2. Factor rotation

Factor rotation is done to make simple structure for grouping each variable and understandable (Ford, et al., 1986) and (Thurstone , 1947). The rotation of extracted factor was done using orthogonal rotation which is used to make factors uncorrelated to each other and easy to understand (Ford, et al., 1986). In this study Varimax rotation were used in the rotation step. After factors were extracted, representative name for the extracted factor was given based on the group of correlated variables.

Table 34: Rotated Component Matrix

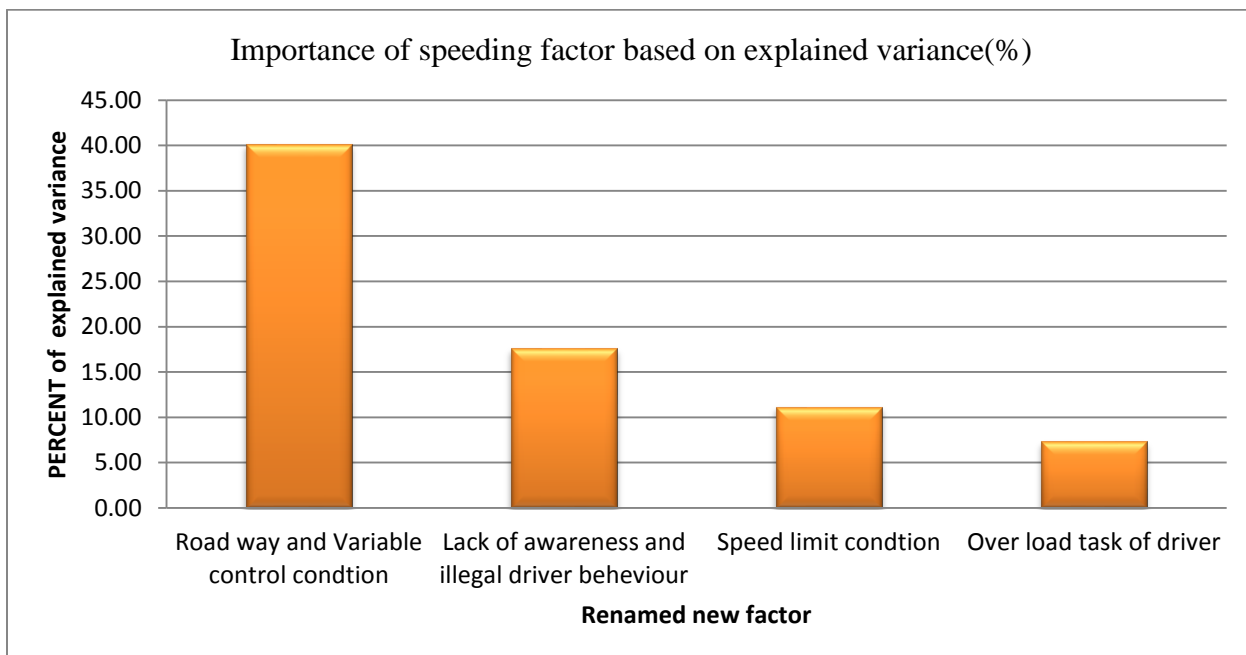
Reason	Component			
	1	2	3	4
R14	.932			
R13	.931			
R1	.930			
R11	.929			
R15	.918			
R6		.865		
R5		-.823		
R7		-.801		
R4		.784		
R3		.673		
R8			.795	
R12			.755	
R9			.674	
R10				.674
R2		-.571		.642
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				

After factors are extracted and rotated, the next step was naming of new factors which captured most information of original correlated variables. The name of new factor is dependent on the variable mostly explain the retained factors. The renamed reason was presented as follow in table below.

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**Table 35: Renamed new factor**

Factor	Most correlated reason	New factor name	% explained variance
1	R1: Absence of traffic police R11: There is low traffic volume R13: Conformable and wider carriage way. R14: There is no side parking vehicle R15: There is low pedestrian volume	Roadway and variable control condition	41.40
2	R6: I am not sure what speed limit is? R5: I do not consider speed limit R7: I am hurry when running late R3: I can drive safely over posted speed limit R4: Road side object density	Lack of awareness and illegal driver behavior.	17.07
3	R8: Speed limit is too low R12: Speed limit is not visible R9: speed limit signs are not attracting attention.	Speed limit condition	11.11
4	R10: thinking away while I am driving R2: I enjoy driving fast	Over-load task of driver	7.51



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Figure 20: Explained variance of new factor

Based on the result of the analysis, road way and variable control condition, lack of awareness and illegal driver behavior, Speed limit condition and over load task of the driver were the cause of speeding for most drivers which contributed to explained 77.1 % of variance. The roadway and variable control condition found to be the primer ranked factor for speeding included (wide carriage way, absence of traffic police, low traffic volume, absence of side parked vehicle and low pedestrian volume) which was contributed to 41.4 % all speeding variance. This group of reason had most possible frequent of reason than others which was affected speeding of most drivers.

The second ranked speeding factor was lack of awareness and illegal driver behavior. This new factor includes (I am not sure what speed limit is? I enjoy driving fast, I am hurry when running late, I can drive safely over posted speed limit and Road side objects density). Based on the result of the analysis, some drivers thought that speeding is ability and considered it as enjoyment and some drivers had not enough awareness about speed limit. They did not considered speed as the cause of accident and death. They did not know road side object is the cause of traffic accident when the may be run-out. Speed limit condition was the third new factor which explained the variance of 11.11%. This factor includes:(visibility and intentionality of speed limit, speed limit is too low as compared to road way condition) which were the most variables which were grouped under this category.

Over load task of the driver was another most important reason for speeding in which drivers did not pay full attention to their driving task rather they were distracted by other external and internal distraction factors. Generally, traffic management office, road safety agency, transport planner and road designer of Addis-Ababa should consider this four grouped factor to create safe and sustainable urban road transport system.

### 4.4.5. Logistic regression model by self-reported traffic accident data of driver

The first step of logistic regression model was coding of categorical dependent and independent variable. The dependent variable was accident involvement in past two year or not. The independent data were driver and vehicle demographic characteristics and driving frequency of driver in Addis-Ababa urban roads. The coding of variable was presented as follows:

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Table 36: Coding of vehicle and driver categorical variable

Variable	Variables used in the model	Category	Given code	Remark
Gender	Gender	Male	1	Independent variable
		Female	0	
Age	AGE	18-30 year	1	Independent variable
		31-40 year	2	
		41-50 year	3	
		>> 50 year	4	
Marital status	Married	Married	1	Independent variable
		Single	0	
Ownership of vehicle	Ownership	Employee	0	Independent variable
		Owner	1	
Experience of driver	Experience	<<5 year	1	Independent variable
		5- 10 year	2	
		>>10 year	3	
Education level	Education	8-12 grade	1	Independent variable
		Diploma	2	
		Degree and above	3	
Type of vehicle	Vehicle	Passenger car	1	Independent variable
		LCV	2	
		Mini-bus	3	
		Bus	4	
		Truck	5	
Driving frequency	Driving frequency	Always	3	Independent variable
		Most time	2	
		Some time	1	
Traffic accident in past two years	accident	Yes	1	Dependent variable
		No	0	
Speeding frequency	Speeding frequency	Most time( $\geq 5$ )	2	Dependent variable
		Some time ( $< 5$ )	1	
		Never(0)	0	

Then after, multicollinearity between independent variable was checked in order to avoid redundant independent variable which contains the same information on the dependent variable. As we have seen in table below, there is no multicollinearity problem.

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Table 37: Correlation coefficient for categorical variable

Correlation Coefficient									
Variables	Accident	speeding frequency	AGE	Education	Marriage	Experience	Vehicle class	ownership	Speeding
accident	1	.293**	-.21**	-.100*	-.26**	-0.08	0.058	.166**	.294**
speeding frequency	.29**	1	-.13**	-0.042	-0.081	0.028	.169**	-.137**	.969**
AGE	-.21**	-.127**	1	.319**	.394**	.387**	-0.076	0.074	-.120*
Education	-.100*	-0.042	.319**	1	.120*	.111*	-.27**	0.039	-0.078
Marriage	-.26**	-0.081	.394**	.120*	1	.209**	.120*	-.327**	-.097*
Experience	-0.08	0.028	.387**	.111*	.209**	1	.165**	-.251**	0.056
Vehicle Type	0.058	.169**	-0.076	-.271**	.120*	.165**	1	-.402**	.178**
ownership	.17**	-.137**	0.074	0.039	-.33**	-.251**	-	1	-.119*
Speeding	.29**	.969**	-.120*	-0.078	-.097*	0.056	.178**	-.119*	1
** Correlation is significant at the 0.01 level (2-tailed).									
* Correlation is significant at the 0.05 level (2-tailed).									

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### 4.4.5.1. Binary logistic regression model for traffic accident involvement

After checking the assumption of binary logistic regression model and coding of variable, the next step was developing model.

**Table 38: Accident involvement binary logistic regression model**

Logistic regression	Number of obs =	441					
LR chi2(8) =	84.07						
Prob. > chi2 =	0.000						
Log likelihood = -212.1	Pseudo R2 =	0.1654					
Accident	Odds Ratio	stad.Err	Z	p> z	[95% Conf. interval]		Remark
Speeding	4.5	1.186	5.73	0.000	2.69	7.55	sg(**)
Employed	2.76	0.808	3.47	0.000	1.56	4.89	sg(**)
Married	0.57	0.166	-1.94	0.05	0.319	1.01	sg(**)
Age	0.684	0.111	-2.36	0.019	0.499	0.938	sg(**)
Vehicle type	1.22	0.132	1.87	0.061	0.991	1.511	
OR							
Truck	1.7	0.432	2.08	0.038	1.032	2.795	sg(**)
Constant	0.175	0.78	-3.92	0.000	0.0732	0.419	sg(**)
Sg(*)=significant at 90%							
sg(**) =significant at 95 %							

Based on the result of above binary logistic traffic accident regression model, Mc faddens Pseudo R Square told that full model containing the significant predictors represents 16.54% improvement in fit relative to null model. There for the model is acceptable because the predictors improved 16.54% in fit from null model. Based on the result of analysis speeding, ownership, married, age and truck (vehicle type) are found to be significant variable at 95% confidence level. The interpretation of each significant independent variable had presented as follow:

Speeding increase the traffic accident involvement by odd ratio of 4.5 by keeping other predictor constant. These argue that speeding is the main cause of world traffic accident (WHO., 2018) and (National Highway Traffic Safety Administration, , 2002). Married drivers are playing a great role

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in reducing traffic accident involvement. Married drivers are decrease traffic accident involvement by log odds of 0.57 times than single drivers. Based on vehicle type, large vehicle had greatest probability of traffic accident risk than small vehicle which increase by log odds of 1.22 times. Especially, trucks have higher traffic accident involvement than other vehicle category which increases by odd ratio of 1.7 times than other vehicle type. Young drivers are also found to be having greater traffic accident involvement than other drivers. Generally speeding, ownership married drivers, truck and age of driver which are found to be significant categorical variable and argued with similar studies done by (K.Kanitpong.et.al., 2013) but gender is not significant in this study which contradict the study of (K.Kanitpong.et.al., 2013).This may be due to the number of female participate in questionnaire's was small as compared to male drivers.

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### 4.4.5.2. Speeding frequency using ordinal logistic regression

Ordinal logistic regression is simply the extension of binary logistic regression with naturally ordered dependent variable. For speeding frequency, ordinal logistic regression was employed because the response was ordered from never receiving speeding ticket to seldom to most time receiving speeding ticket by traffic police in past two years. This model indicates the most categorical class for each variable which have high influence on speeding involvement frequently than other categorical class.

Table 39: Speeding frequency ordinal logistic regression

Ordinal logistic regression	Number of obs.	441							
LR chi2(6) =	38.54								
Prob. > chi2 =	0.000								
Log likelihood = -144.73	Pseudo R2 =	0.057							
Parameter Estimates									
Speeding frequency		Estimate	Odd ratio	Std. Error	Wald	Df	Sig.	95% Confidence Interval	
								L.B.	U.B.
Cut point	[speeding frequency = 0]	.896	2.449	.275	10.63	1	.001	.357	1.434
	[speeding frequency = 1]	5.176		.456	128.6	1	.000	4.281	6.070
variable	[owner=0]	.348	1.416	.245	2.012	1	.156	-.132	.828
	[owner=1]	0 <sup>a</sup>							
	[Education=1]	.452	1.572	.225	4.05	1	.044	.012	.893
	[Education=2]	.243	1.275	.353	.473	1	.492	-.449	.935
	[Education=3]	0 <sup>a</sup>							
	[married=0]	.515	1.674	.221	5.441	1	.020	.082	.948
	[married=1]	0 <sup>a</sup>							
	[Vehicle1=1]	.612	1.844	.289	4.490	1	.034	.046	1.178
	[Vehicle1=2]	.794	2.212	.320	6.167	1	.013	.167	1.421
	[Vehicle1=3]	1.181	3.257	.358	10.89	1	.001	.480	1.882
	[Vehicle1=4]	0 <sup>a</sup>							
	[expriance1=1]	-.510	.600	.224	5.206	1	.023	-.948	-.072
	[expriance1=2]	-.033	.967	.309	.012	1	.914	-.639	.572
[expriance1=3]	0 <sup>a</sup>								

## Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

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Link function: Logit.

In this model, likelihood ratio chi square test was used to identify the significant improvement in fit of full model relative to null model. Based on, models have showed significant improvement in fit of full model over null model with  $X^2(6) = 38.54$ , prob.  $\leq 0.00$ . Both cut points (intercept) for frequency of speeding category are significant which have positive effect on each category of speeding frequency.

Based on the result of analysis, drivers with lower education class ( $\leq 12$  grade), single driver, and vehicles class (passenger car, light commercial vehicle and minibus) are found to be the most significant independent category which initiate drivers for speeding up frequently. Drivers which have lower education level (8 to 12 grade) have increased the involvement of speeding frequently by the log odds of 0.452 times by keeping other variables as it is then other higher education class.

Married drivers play great role in reducing speeding involvement than single drivers. Single drivers increase speeding involvement by odd ratio of 1.67 times than married drivers. From vehicle category, (passenger car, LCV and minibus) are found to be significant variable which increase the probability of speeding frequency by odd ratio of 1.84, 2.21 and 3.26 times by keeping other significant variable constant.

However, the experience of driver shows negative effect on frequency of speeding. Drivers which have lower driving experience reduce involvement of speeding which contradicts the study done by (K.Kanitpong.et.al., 2013) , (Al-Omari.et.al., 2013 and 2015) and world health organization report (WHO., 2018). But age of the driver, frequency of trip and owner ship of vehicle is not significant variable in this model.

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### 4.4.6. Comparing multiple linear regression and driver speeding reason factor analysis result

In multiple linear regression models, number of lane, side parking density, road side object density and traffic hourly volume are the most significant independent variable. Their mean effect is presented in bar graph below.

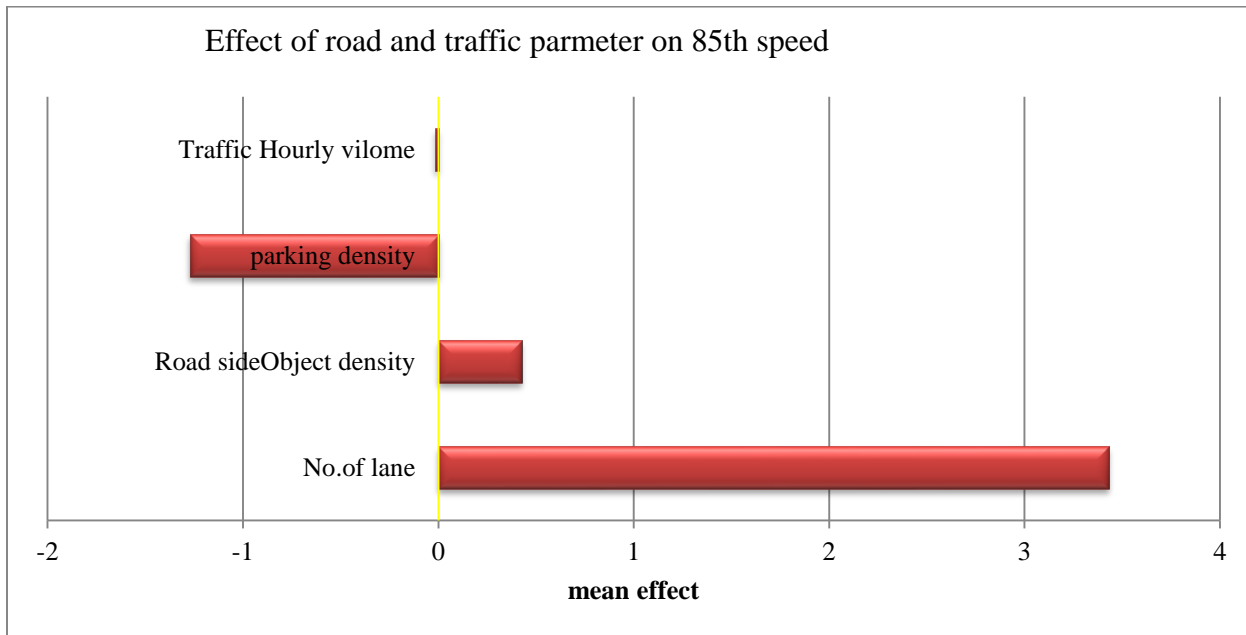


Figure 21: Mean effect of dependent variable on 85<sup>th</sup> speed

In driver attitude survey analysis the following are the most important frequent reason of speeding in addition to illegal driver behavior.

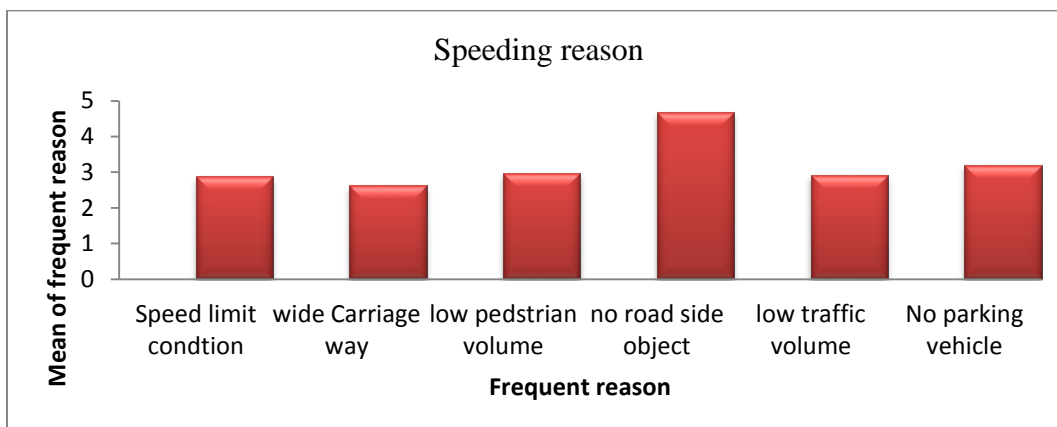


Figure 22: Frequent reason mean effect on speeding

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Based on the above two bar charts, carriage way (number of lane) is the most frequent reason for speeding for most drivers which could validate the effect of number of lane on 85<sup>th</sup> percentile speed which was increase 85<sup>th</sup> percentile speed by 3.43 km/hr. by keeping constant other variable from multiple linear regression model. No Side parking vehicle and low traffic volume are also another frequent possible reason of most drivers for speeding and it has positive effect on operating speed of most drivers which is the same result from output of multiple linear regression models. However road side object density is not frequent possible reason of speeding for most drivers since it has mean frequency of 4.62 which is nearly never reason. But in case of multiple linear regression analysis, it is found to be initiate drivers for speeding which contradict previous studies. This may be due to lack of awareness of driver about road side object which is the main cause of traffic accident especially property damage and due to bad behavior of drivers. Posted speed limit conditions are also another frequent possible reason of speeding which includes too low speed limit, visibility and intentionality problem of speed limit. These all reason makes posted speed limit non-significant for 85<sup>th</sup> percentile speed of most drivers which could approve multiple linear regression output.

## **Chapter five: Conclusion and Recommendation**

### **5.1. Conclusion**

This study has achieved by finding the effect of roadway geometry and posted speed limit on 85<sup>th</sup> speed of straight section of urban road. This study has been done by collecting all necessary road geometry data and traffic volume with detail driver attitudinal survey which is used to indirect validation of multiple linear regression models. The study was done by using multiple linear regressions to know the effect of roadway condition and traffic volume supported by detail driver speeding reason factor analysis. Based on the result of analysis,

- Numbers of lane and road side object density have increased the 85<sup>th</sup> percentile speed whereas parking density and hourly traffic volume are found to be calming tools for speed of most drivers. Since the number of lane increase the flexibility of the driver for maneuvering from one lane to another lane at free flow condition. However the effect of road side object density contradicts the result of previous studies. This is due to the factor of lack of knowledge about the effect of road side object on traffic accident and bad behavior of drivers which is found to be the main possible factor of most drivers from result of factor analysis. Side parking density and hourly traffic volume are also significant factors of 85<sup>th</sup> speed which used for calming vehicle speed of most drivers. Even if traffic hourly volume is significant, it had no much effect on 85<sup>th</sup> speed since the data was collected during free flow traffic condition.
- Degree of compliance of driver is increasing with posted speed limit for both divided and un-divided median road irrespective of number of lane. As per vehicle category, large vehicle (Bus and Truck) has better degree of compliance than other vehicle. However, there is no significance difference between passenger vehicle and light commercial vehicle.
- Road way and variable control condition, lack of awareness and illegal driver behavior, Speed limit condition and over load task of the driver are the four main factor of speeding which contributed to explain 77.1 % of variance. From these four main factors, roadway and variable control condition found to be the primer ranked factor for speeding which included (wide carriage way, absence of traffic police, low traffic volume, absence of side parked vehicle and low pedestrian volume) which was contributed to 41.4 % all speeding reason.

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- In addition to factor analysis for driver attitudinal survey, both binary and ordinal logistic regression for past two year accident history and speeding frequency involvement were conducted respectively. Based on the result of binary logistic analysis, speeding, larger vehicle and younger driver are increasing the probability of accident involvement whereas married and owner of vehicle are found to be significant driver characteristics which reduce traffic accident involvement.

### **5.2. Recommendation**

This study has found the effect of road way geometry and posted speed limit on 85<sup>th</sup> speed of urban road in Addis-Ababa city. This study can be used as initial guide lines for transport planner and traffic management agency so as to set traffic rules. Based on this study, the following recommendations are provided:

- ✓ On roads having greater than two number of lane, side parking should be encouraged so as to increase compliance of driver for speed limit during free flow condition.
- ✓ The speed limit condition (intentionality and visibility of speed limit sign) should be given great consideration. It is better to place digital speed limit sign than catalog.
- ✓ Knowledge and behavior of driver also another issue which needs great emphasize at a center of driver training institute.

For future study, the integrative effect of all component of urban road transport system on operating speed of driver in different class of urban road is recommended to be studied because different class of urban road has different design and evaluation standard.

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### Appendix

Table 40: Sample of spot speed calculation for BR1 road section

Street		Bole to Meskel Square (BR1)								
stretch length		60		m.bus=mini-bus pc=passenger car l.Cruiser=land cruiser P.UP=pickup						
Median		yes								
land use		commercial								
road side object		17								
average offset distance		0.8								
Posted Speed Limit		50								
width of pedestrian walk		3.6								
Longitudinal grade		upgrade								
parking density		0								
Number of Lane/direction		4								
Vehicle type	Lane position	Start Time		End Time		start time (sec)	end time (sec)	Head way	duration	Speed (km/hr.)
		second	mili-Second	Second	Mili-Second					
m.bus	1	3	209	6	926	3.21	6.93		3.717	58.11
m.bus	2	4	922	7	153	4.92	7.15		2.231	96.82
pc	3	10	199	12	159	10.20	12.16		1.96	110.20
pc	2	27	181	29	419	27.18	29.42	22.27	2.238	96.51
pc	3	28	931	31	938	28.93	31.94	19.78	3.007	71.83
truck	1	31	188	34	655	31.19	34.66	27.98	3.467	62.30
l.cruiser	2	32	943	34	668	32.94	34.67	5.25	1.725	125.22
pc	1	36	411	39	400	36.41	39.40	5.22	2.989	72.26
taxie	2	37	402	39	185	37.40	39.19	4.52	1.783	121.14
pc	3	37	402	37	656	37.40	47.89	5.72	10.488	20.59
pc	1	48	201	50	156	48.20	50.16	11.79	1.955	110.49
pc	1	52	936	55	950	52.94	55.95	4.74	3.014	71.67
m.bus	2	79	653	81	678	79.65	81.68	42.49	2.025	106.67
m.bus	3	89	195	92	927	89.20	92.93	55.27	3.732	57.88
pc	3	105	656	107	946	105.6	107.95	15.02	2.29	94.32
pc	2	106	654	111	171	106.65	111.17	29.49	4.517	47.82
m.bus	3	110	681	114	905	110.68	114.91	6.96	4.224	51.14
m.bus	1	112	666	115	431	112.67	115.43	59.73	2.765	78.12

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p.up	1	115	407	118	408	115.41	118.41	2.74	3.001	71.98
m.bus	2	124	691	126	420	124.69	126.42	15.25	1.729	124.93
pc	1	126	182	128	691	126.18	128.69	10.78	2.509	86.09
m.bus	3	133	927	136	657	133.93	136.66	21.75	2.73	79.12
pc	3	136	653	139	187	136.65	139.19	2.53	2.534	85.24
pc	3	139	906	142	900	139.91	142.90	3.71	2.994	72.14
pc	2	144	439	148	193	144.44	148.19	21.77	3.754	57.54
m.bus	1	150	409	155	194	150.41	155.19	24.23	4.785	45.14
pc	1	165	453	169	687	165.45	169.69	15.04	4.234	51.02
pc	1	175	916	179	717	175.92	179.72	10.46	3.801	56.83
pc	1	193	951	198	170	193.95	198.17	18.04	4.219	51.20
pc	2	194	929	199	906	194.93	199.91	51.71	4.977	43.40
pc	1	196	420	199	158	196.42	199.16	2.47	2.738	78.89
pc	2	197	928	203	933	197.93	203.93	4.03	6.005	35.97
truck	1	202	688	206	157	202.69	206.16	6.27	3.469	62.27
pc	1	208	448	212	438	208.45	212.44	5.76	3.99	54.14
p.up	2	208	448	212	438	208.45	212.44	8.51	3.99	54.14
m.bus	1	209	448	213	186	209.45	213.19	1.00	3.738	57.78
pc	2	214	158	219	216	214.16	219.22	6.78	5.058	42.70
pc	1	215	459	220	217	215.46	220.22	6.01	4.758	45.40
pc	1	220	206	223	220	220.21	223.22	4.75	3.014	71.67
pc	1	227	705	232	229	227.71	232.23	7.50	4.524	47.75
pc	1	236	183	240	237	236.18	240.24	8.48	4.054	53.28
m.bus	2	238	170	243	240	238.17	243.24	24.02	5.07	42.60
motor	1	239	941	243	240	239.94	243.24	3.76	3.299	65.47
pc	2	241	191	245	242	241.19	245.24	2.00	4.051	53.32
pc	2	248	943	251	248	248.94	251.25	6.01	2.305	93.71
pc	1	253	198	257	254	253.20	257.25	13.26	4.056	53.25
pc	1	275	428	280	256	275.43	280.26	22.23	4.828	44.74
pc	1	280	462	283	275	280.46	283.28	5.03	2.813	76.79
pc	1	281	714	284	281	281.71	284.28	1.25	2.567	84.14
pc	2	283	926	286	282	283.93	286.28	35.03	2.356	91.68
pc	2	285	424	288	284	285.42	288.28	2.00	2.86	75.52
pc	2	292	450	296	286	292.45	296.29	8.00	3.836	56.31
pc	1	314	716	318	294	314.72	318.29	33.00	3.578	60.37
pc	1	331	175	336	316	331.18	336.32	16.46	5.141	42.02
pc	1	331	727	335	923	331.73	335.92	0.55	4.196	51.48
m.bus	3	335	709	339	934	335.71	339.93	197.03	4.225	51.12
pc	3	337	423	340	442	337.42	340.44	0.51	3.019	71.55

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pc	3	345	170	350	931	345.17	350.93	10.49	5.761	37.49
m.bus	1	355	733	359	405	355.73	359.41	24.01	3.672	58.82
pc	2	366	701	369	419	366.70	369.42	73.13	2.718	79.47
pc	1	368	960	372	680	368.96	372.68	13.23	3.72	58.06
l.cruiser	2	369	946	373	656	369.95	373.66	4.24	3.71	58.22
pc	1	371	675	375	404	371.68	375.40	2.72	3.729	57.92
pc	2	379	933	382	156	379.93	382.16	8.50	2.223	97.17
pc	1	383	214	388	947	383.21	388.95	11.54	5.733	37.68
m.bus	2	383	707	386	439	383.71	386.44	4.28	2.732	79.06
pc	1	386	200	389	441	386.20	389.44	2.99	3.241	66.65
m.bus	2	391	456	394	431	391.46	394.43	7.99	2.975	72.61
taxie	1	401	676	406	436	401.68	406.44	15.48	4.76	45.38
pc	2	428	953	432	935	428.95	432.94	38.50	3.982	54.24
p.up	2	440	175	443	951	440.18	443.95	11.02	3.776	57.20
pc	2	447	442	451	934	447.44	451.93	7.98	4.492	48.09
p.up	2	450	425	454	465	450.43	454.47	2.53	4.04	53.47
m.bus	2	452	678	456	433	452.68	456.43	1.97	3.755	57.52
taxie	2	452	172	456	434	452.17	456.43	0.00	4.262	50.68
taxie	2	454	191	458	180	454.19	458.18	1.75	3.989	54.15
l.cruiser	2	455	682	460	635	455.68	460.64	2.45	4.953	43.61
m.bus	2	458	712	461	184	458.71	461.18	0.55	2.472	87.38
pc	2	461	190	465	156	461.19	465.16	3.97	3.966	54.46
m.bus	1	462	174	466	436	462.17	466.44	60.50	4.262	50.68
p.up	2	462	706	469	403	462.71	469.40	4.25	6.697	32.25
pc	2	465	453	469	175	465.45	469.18	-0.23	3.722	58.03
pc	1	467	678	472	932	467.68	472.93	5.50	5.254	41.11
pc	1	473	683	476	180	473.68	476.18	6.01	2.497	86.50
m.bus	2	475	454	477	196	475.45	477.20	8.02	1.742	124.00
taxie	1	482	708	485	420	482.71	485.42	9.03	2.712	79.65
m.bus	1	499	921	503	906	499.92	503.91	17.21	3.985	54.20
m.bus	2	511	450	514	904	511.45	514.90	37.71	3.454	62.54
pc	2	517	923	520	181	517.92	520.18	5.28	2.258	95.66
m.bus	2	519	175	523	687	519.18	523.69	3.51	4.512	47.87
pc	1	528	456	533	653	528.46	533.65	28.54	5.197	41.56
m.bus	2	530	957	533	441	530.96	533.44	9.75	2.484	86.96
pc	1	531	224	535	915	531.22	535.92	2.77	4.691	46.05
pc	1	533	214	537	656	533.21	537.66	1.99	4.442	48.63
p.up	2	533	925	536	668	533.93	536.67	3.23	2.743	78.75
pc	1	536	200	540	0	536.20	540.00	2.99	3.8	56.84

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pc	1	541	177	545	932	541.18	545.93	4.98	4.755	45.43
truck	1	542	954	545	427	542.95	545.43	1.78	2.473	87.34
pc	1	544	445	548	933	544.45	548.93	1.49	4.488	48.13
pc	2	553	444	557	440	553.44	557.44	20.77	3.996	54.05
pc	1	561	938	564	157	561.94	564.16	17.49	2.219	97.34
p.up	2	571	455	576	906	571.46	576.91	19.47	5.451	39.63
pc	1	573	172	578	445	573.17	578.45	11.23	5.273	40.96
m.bus	2	583	959	588	904	583.96	588.90	12.00	4.945	43.68
pc	2	585	444	589	680	585.44	589.68	0.78	4.236	50.99
pc	2	592	180	597	154	592.18	597.15	7.47	4.974	43.43
pc	2	593	203	595	408	593.20	595.41	-1.75	2.205	97.96
pc	2	594	211	597	431	594.21	597.43	2.02	3.22	67.08
pc	2	597	928	600	920	597.93	600.92	3.49	2.992	72.19
pc	1	604	480	606	175	604.48	606.18	31.31	1.695	127.43
p.up	1	610	189	614	402	610.19	614.40	5.71	4.213	51.27
pc	1	611	457	615	433	611.46	615.43	1.27	3.976	54.33
p.up	1	614	922	616	433	614.92	616.43	3.47	1.511	142.95
pc	2	624	968	627	681	624.97	627.68	26.76	2.713	79.62
truck	3	625	423	628	716	625.42	628.72	8.45	3.293	65.59
pc	1	629	925	633	902	629.93	633.90	15.00	3.977	54.31
p.up	1	631	453	634	904	631.45	634.90	1.53	3.451	62.59
m.bus	2	633	701	636	406	633.70	636.41	8.72	2.705	79.85
pc	2	640	702	642	154	640.70	642.15	5.75	1.452	148.76
pc	2	667	175	671	707	667.18	671.71	29.55	4.532	47.66
taxie	2	682	686	686	156	682.69	686.16	14.45	3.47	62.25
m.bus	2	684	445	688	186	684.45	688.19	2.03	3.741	57.74
taxie	2	696	187	701	430	696.19	701.43	13.24	5.243	41.20
truck	1	701	454	704	652	701.45	704.65	70.00	3.198	67.54
pc	2	707	171	712	155	707.17	712.16	10.73	4.984	43.34
pc	1	720	962	723	171	720.96	723.17	19.51	2.209	97.78
m.bus	1	722	204	727	186	722.20	727.19	1.24	4.982	43.36
taxie	2	722	448	725	156	722.45	725.16	13.00	2.708	79.76
pc	2	725	428	750	428	725.43	750.43	25.27	25	8.64
p.up	2	744	426	758	200	744.43	758.20	7.77	13.774	15.68
taxie	2	753	698	764	600	753.70	764.60	6.40	10.902	19.81
m.bus	1	760	691	765	172	760.69	765.17	38.49	4.481	48.20
taxie	2	761	175	773	667	761.18	773.67	9.07	12.492	17.29
pc	1	770	441	779	964	770.44	779.96	9.75	9.523	22.68
pc	2	773	945	792	167	773.95	792.17	18.50	18.222	11.85

## Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

taxie	2	783	972	796	954	783.97	796.95	4.79	12.982	16.64	
m.bus	1	791	672	805	666	791.67	805.67	21.23	13.994	15.44	
truck	2	800	462	811	180	800.46	811.18	14.23	10.718	20.15	
taxie	2	807	965	811	435	807.97	811.44	0.25	3.47	62.25	
motor	2	809	950	818	931	809.95	818.93	7.50	8.981	24.05	
pc	1	812	952	819	441	812.95	819.44	21.28	6.489	33.29	
pc	2	815	970	820	671	815.97	820.67	1.74	4.701	45.95	
pc	1	817	705	822	173	817.71	822.17	4.75	4.468	48.34	
pc	1	819	955	824	954	819.96	824.95	2.25	4.999	43.21	
pc	1	820	204	826	672	820.20	826.67	0.25	6.468	33.40	
pc	1	824	957	829	458	824.96	829.46	4.75	4.501	47.99	
p.up	2	827	956	829	673	827.96	829.67	9.00	1.717	125.80	
truck	1	838	456	840	938	838.46	840.94	13.50	2.482	87.03	
pc	2	849	946	852	419	849.95	852.42	22.75	2.473	87.34	
m.bus	2	874	925	879	423	874.93	879.42	27.00	4.498	48.02	
pc	1	876	457	883	208	876.46	883.21	38.00	6.751	32.00	
l.cruiser	2	876	800	880	940	876.80	880.94	1.52	4.14	52.17	
p.up	1	879	954	884	947	879.95	884.95	3.50	4.993	43.26	
p.up	2	879	673	885	203	879.67	885.20	4.26	5.53	39.06	
pc	2	880	212	885	214	880.21	885.21	0.01	5.002	43.18	
pc	2	882	472	886	174	882.47	886.17	0.96	3.702	58.35	
pc	1	883	979	888	669	883.98	888.67	4.03	4.69	46.06	
pc	2	886	736	890	209	886.74	890.21	4.03	3.473	62.19	
								<b>A.head way</b>	13.62	Average	61.72
								<b>H.Volume</b>	264	Median	56.57

Appendix 1: Speed frequency distribution graph  
Figure 23:BR1-Speed frequency distribution graph

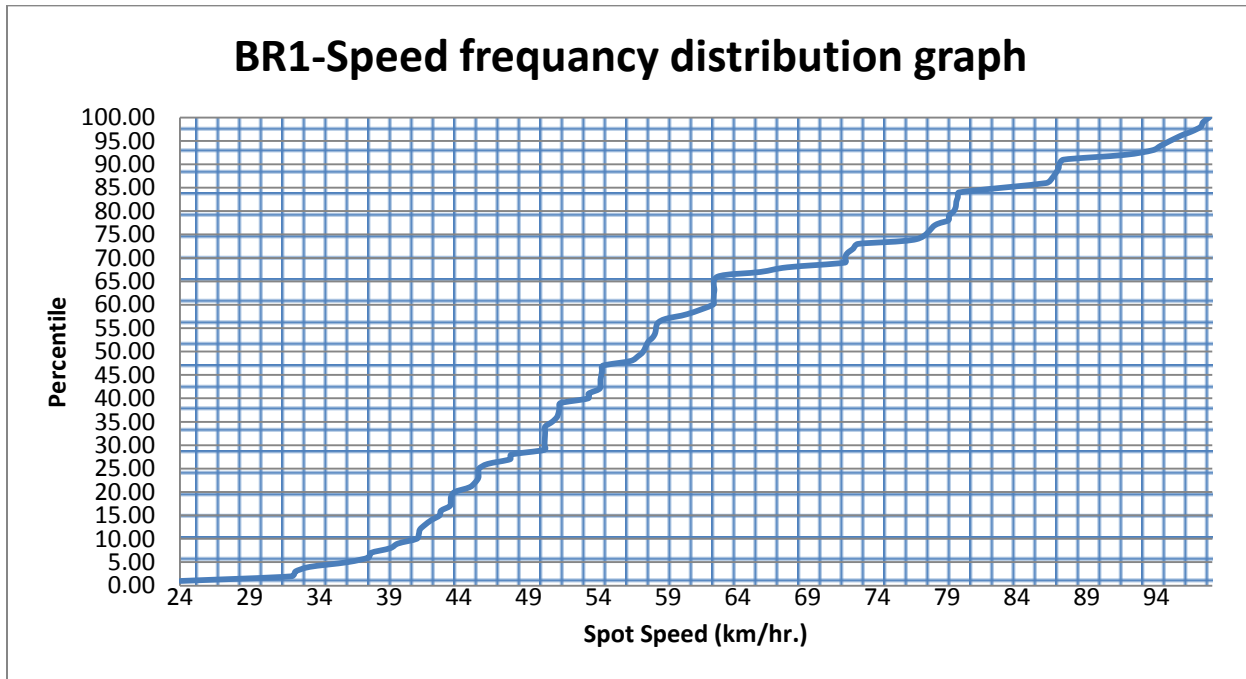
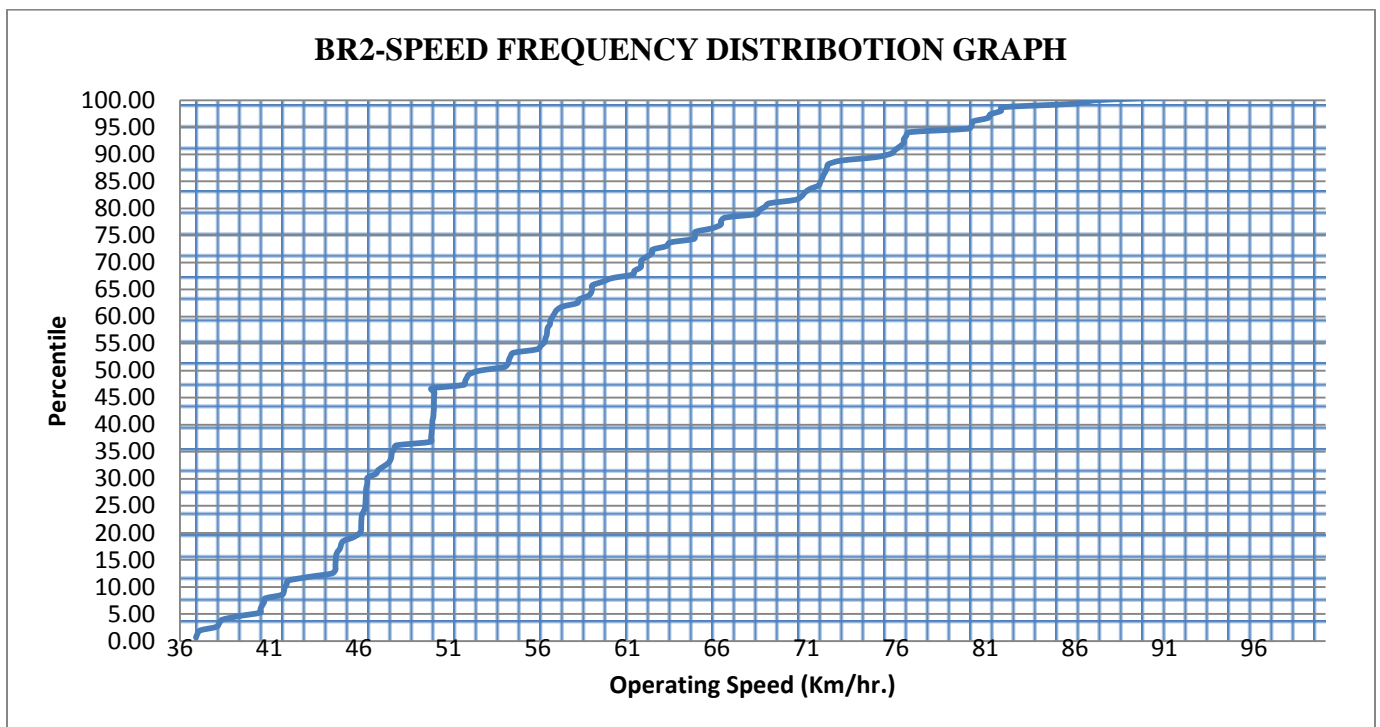


Figure 24:BR2-Speed frequency distribution graph



# Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

Figure 25:BR3-Speed frequency distribution graph

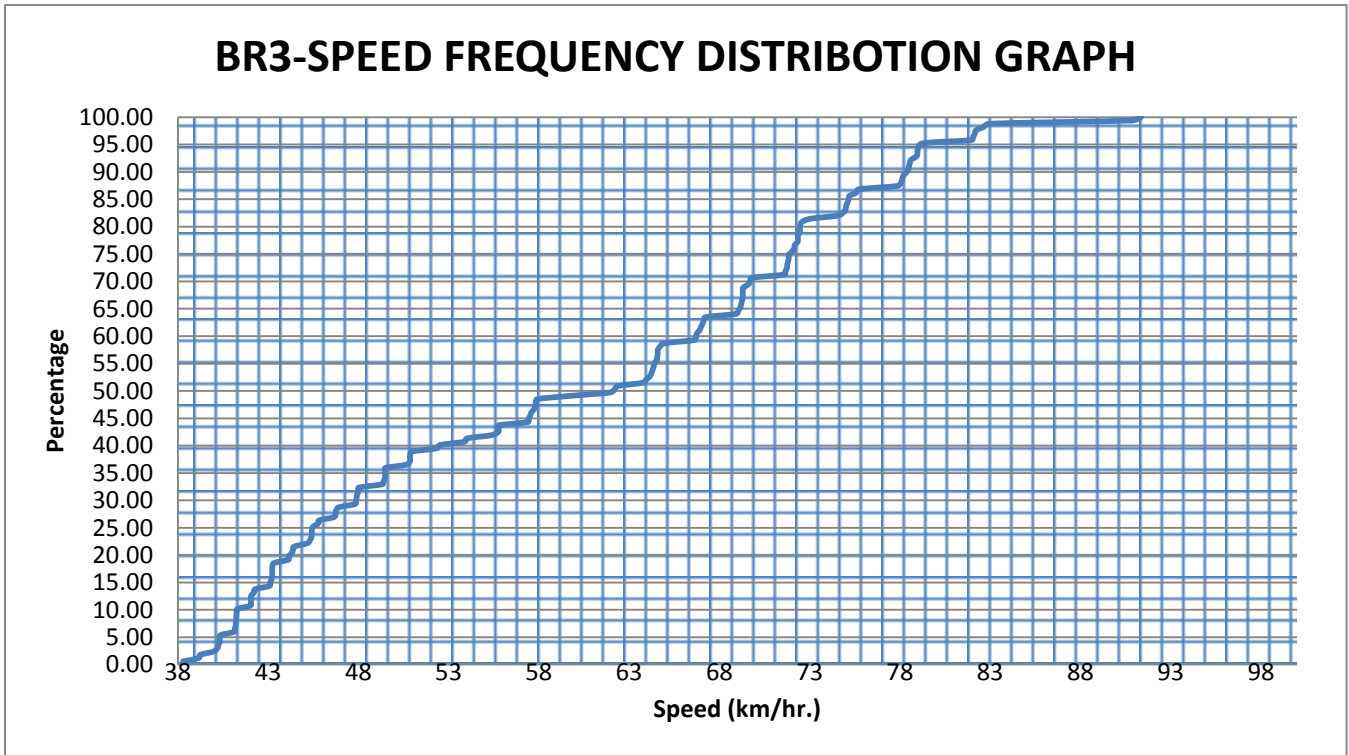


Figure 26:BR3-Speed frequency distribution graph

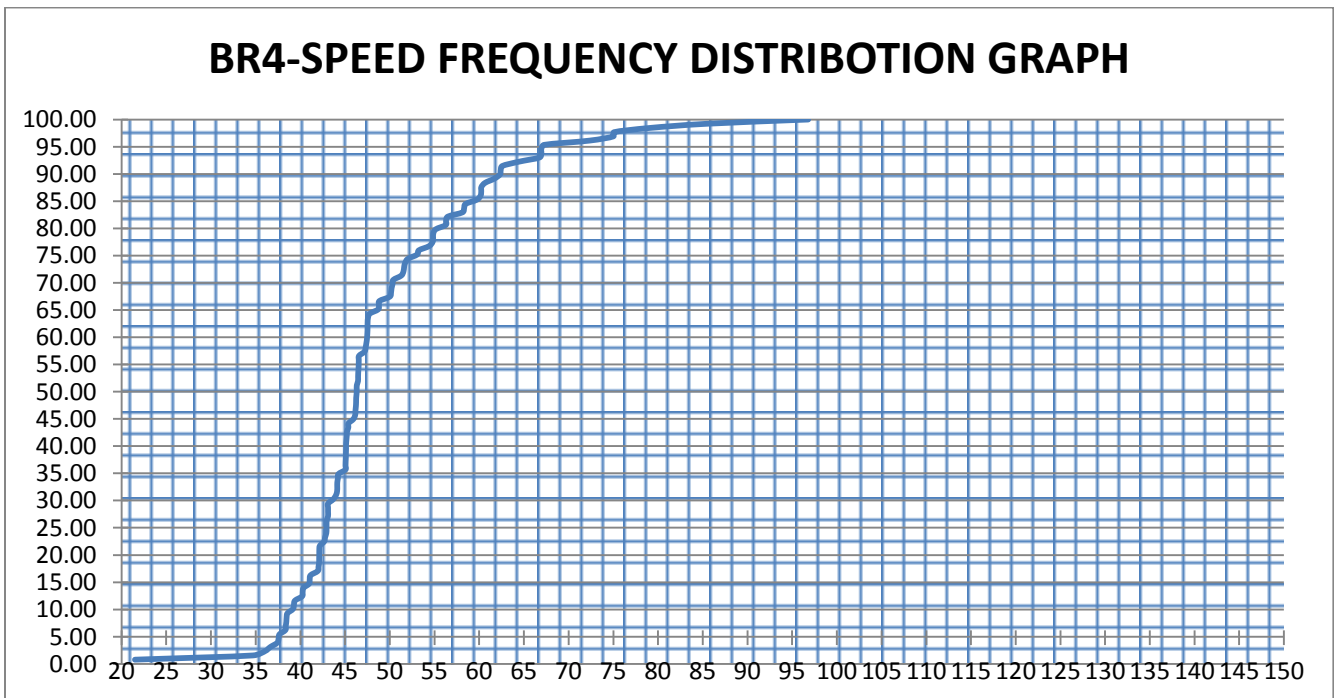


Figure 27:BR5-Speed frequency distribution graph

# Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

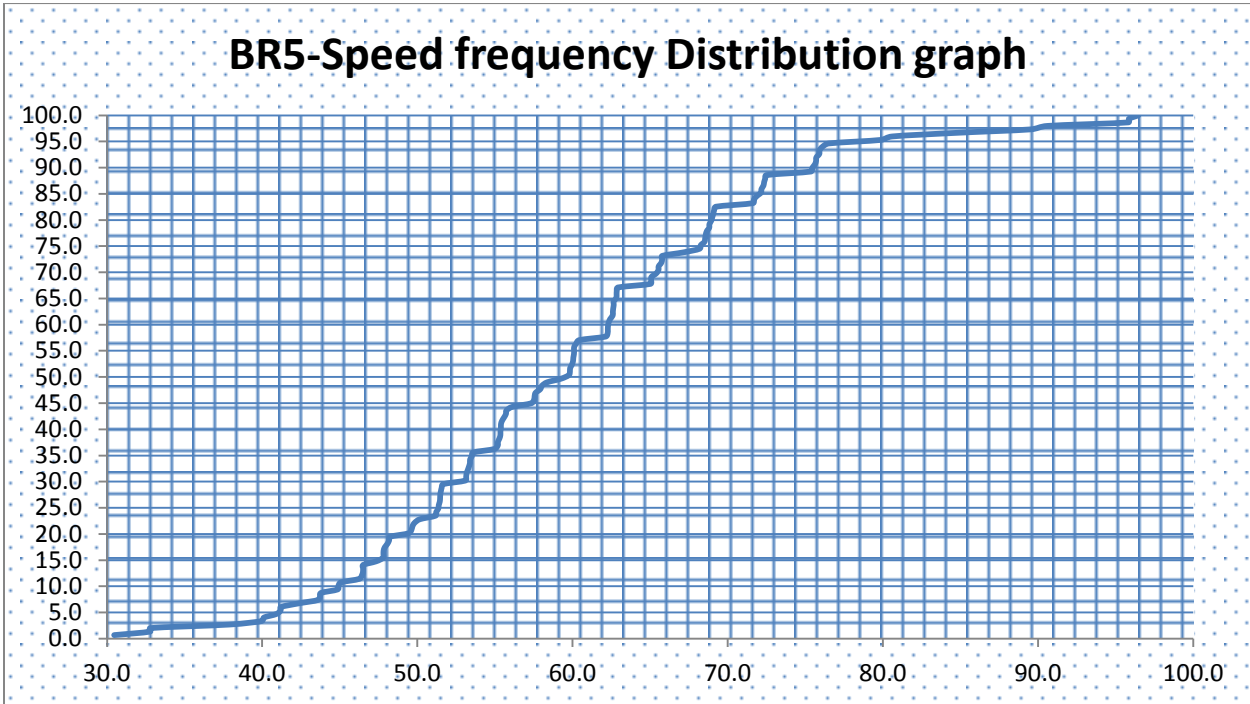


Figure 28:BR6-Speed frequency distribution graph

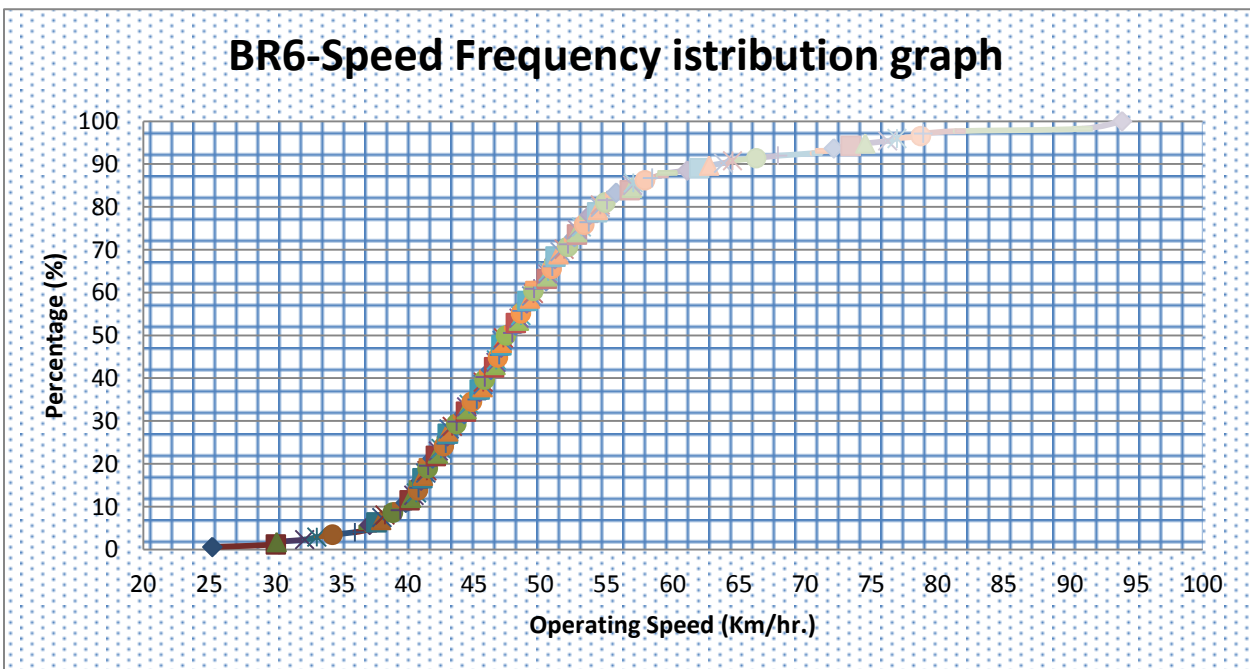


Figure 29:SR4-Speed frequency distribution graph

Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

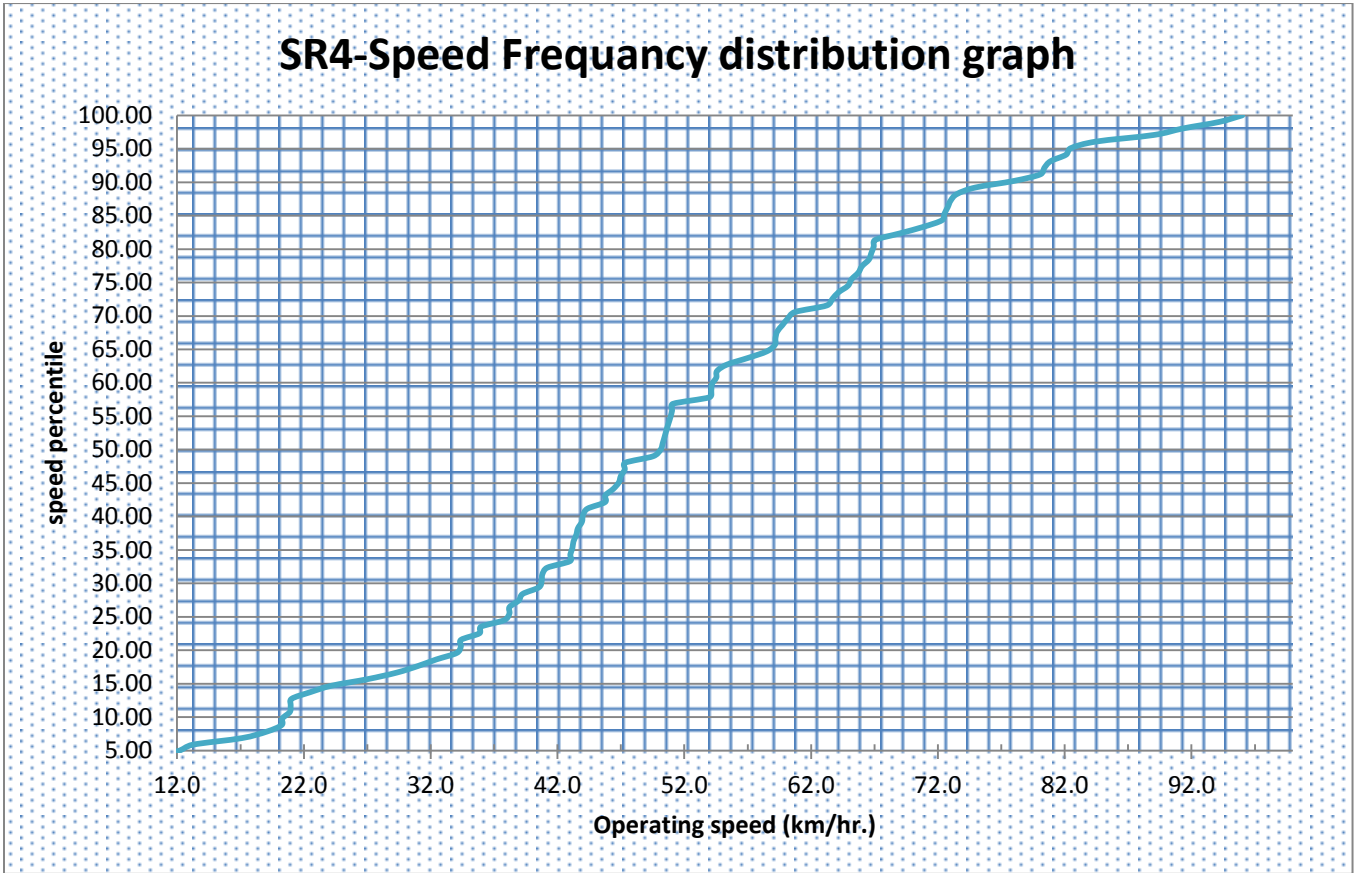


Figure 30:SR2-Speed frequency distribution graph

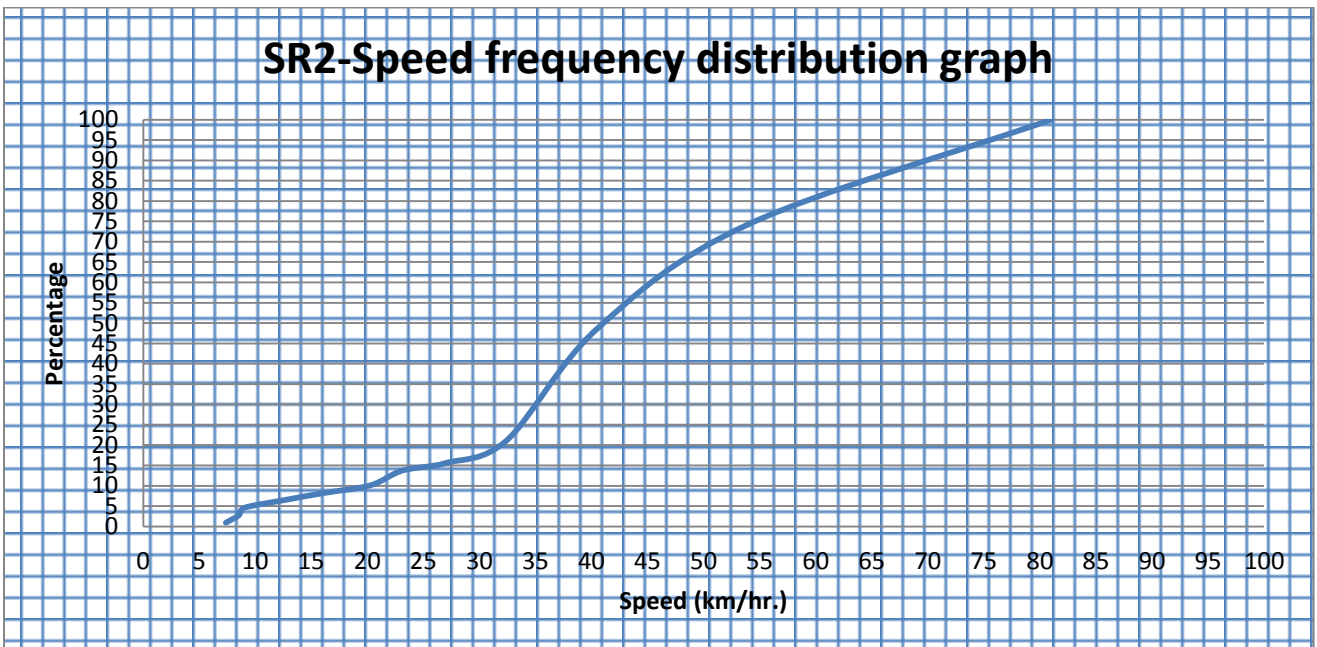


Figure 31:SR1-Speed frequency distribution graph

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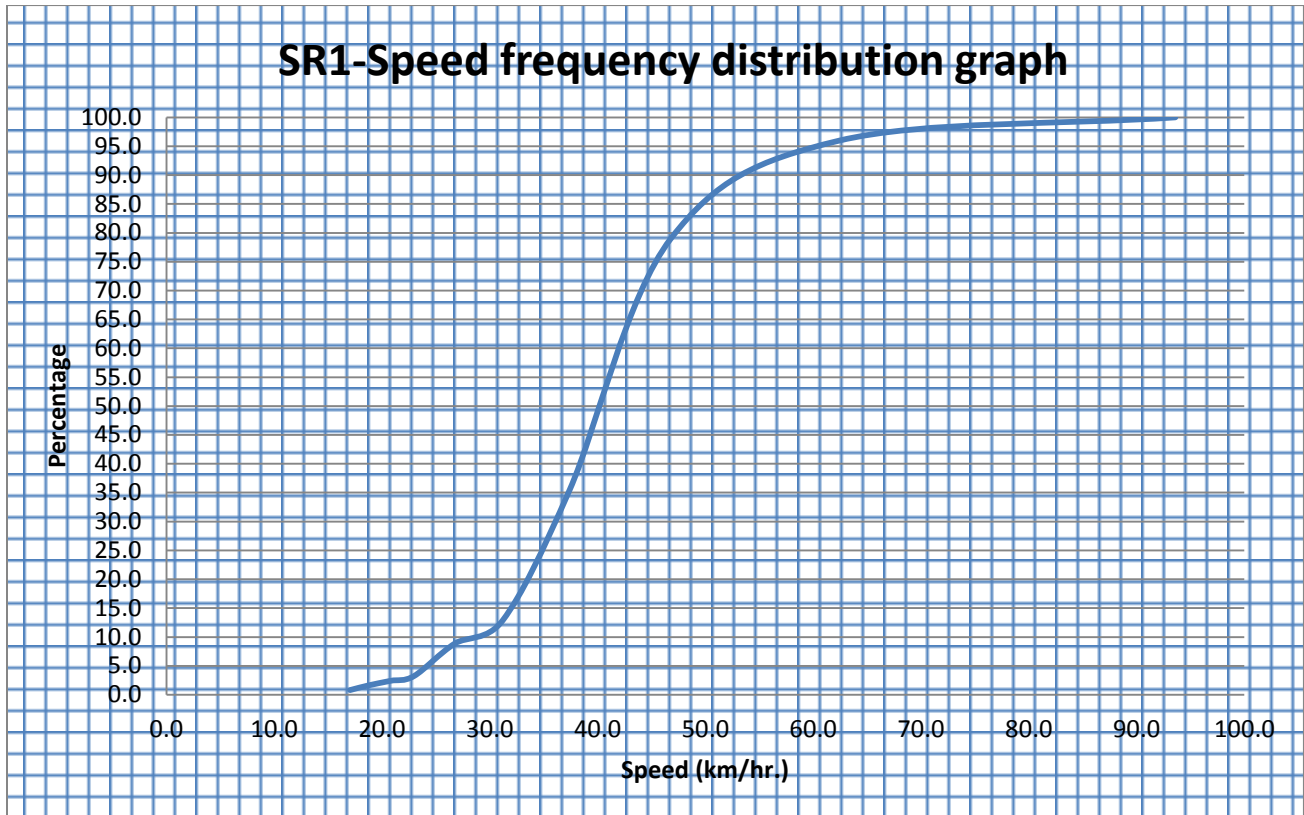


Figure 32;SR3-Speed frequency distribution graph

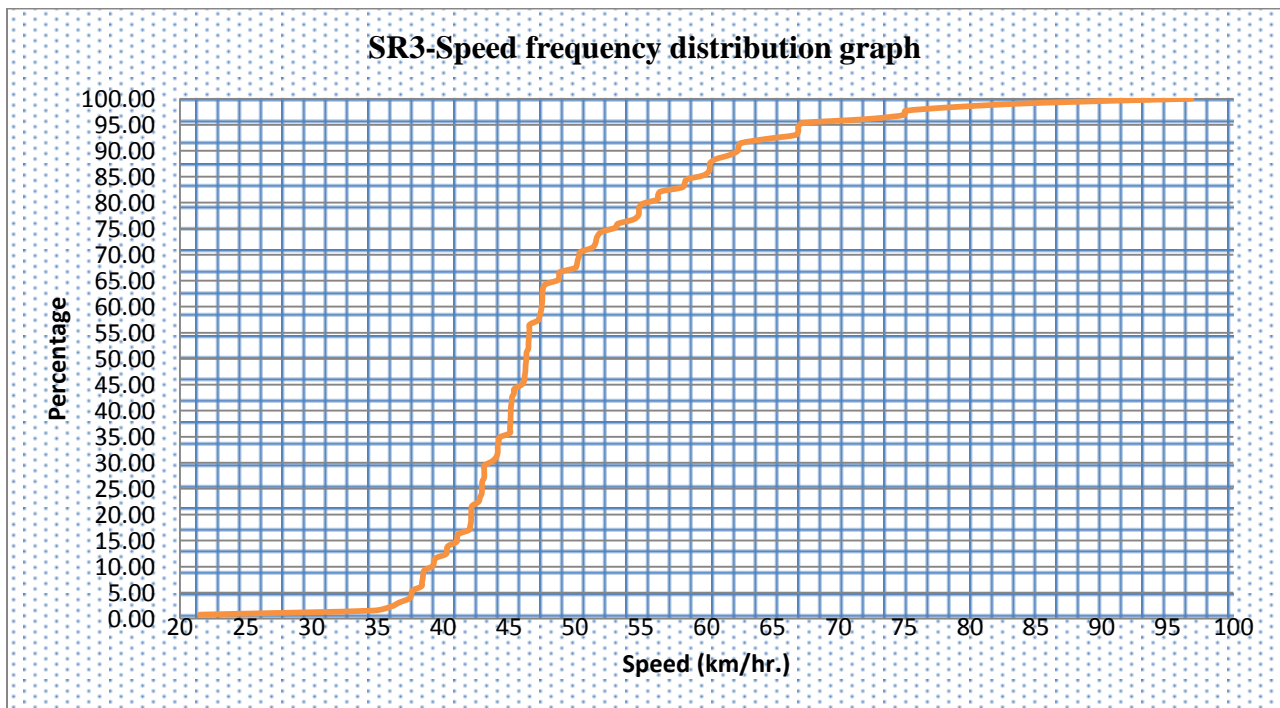


Figure 33:CAR1-Speed frequency distribution graph

# Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

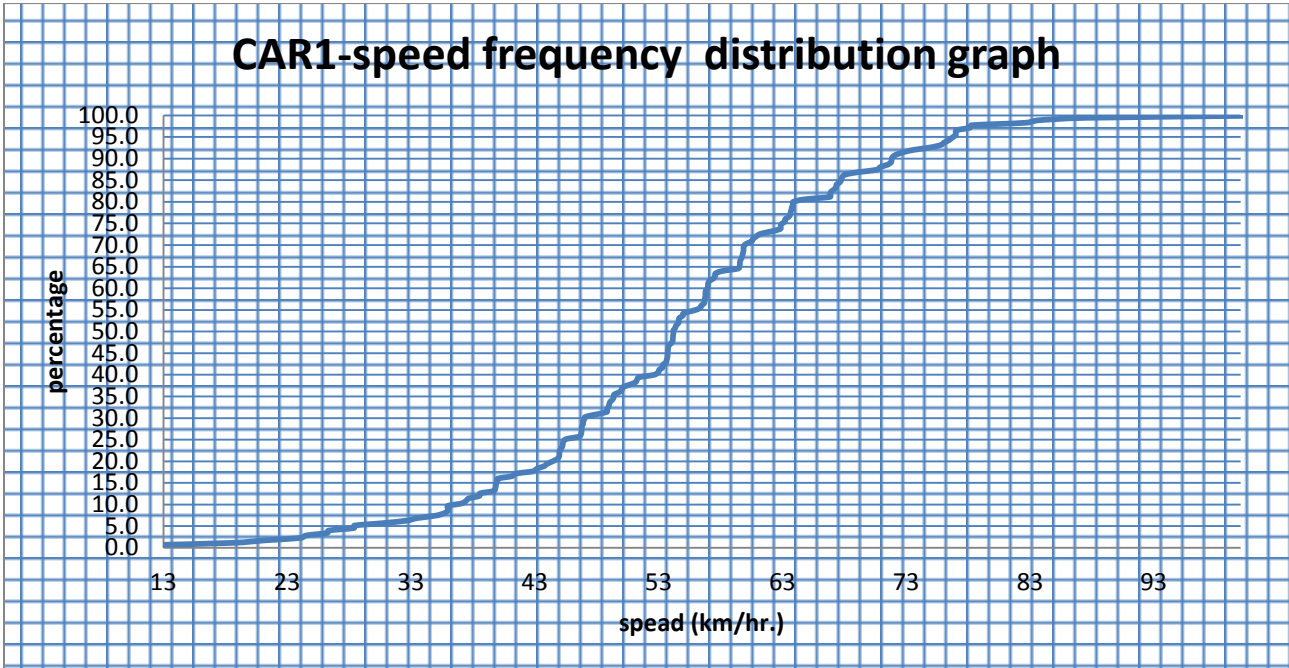
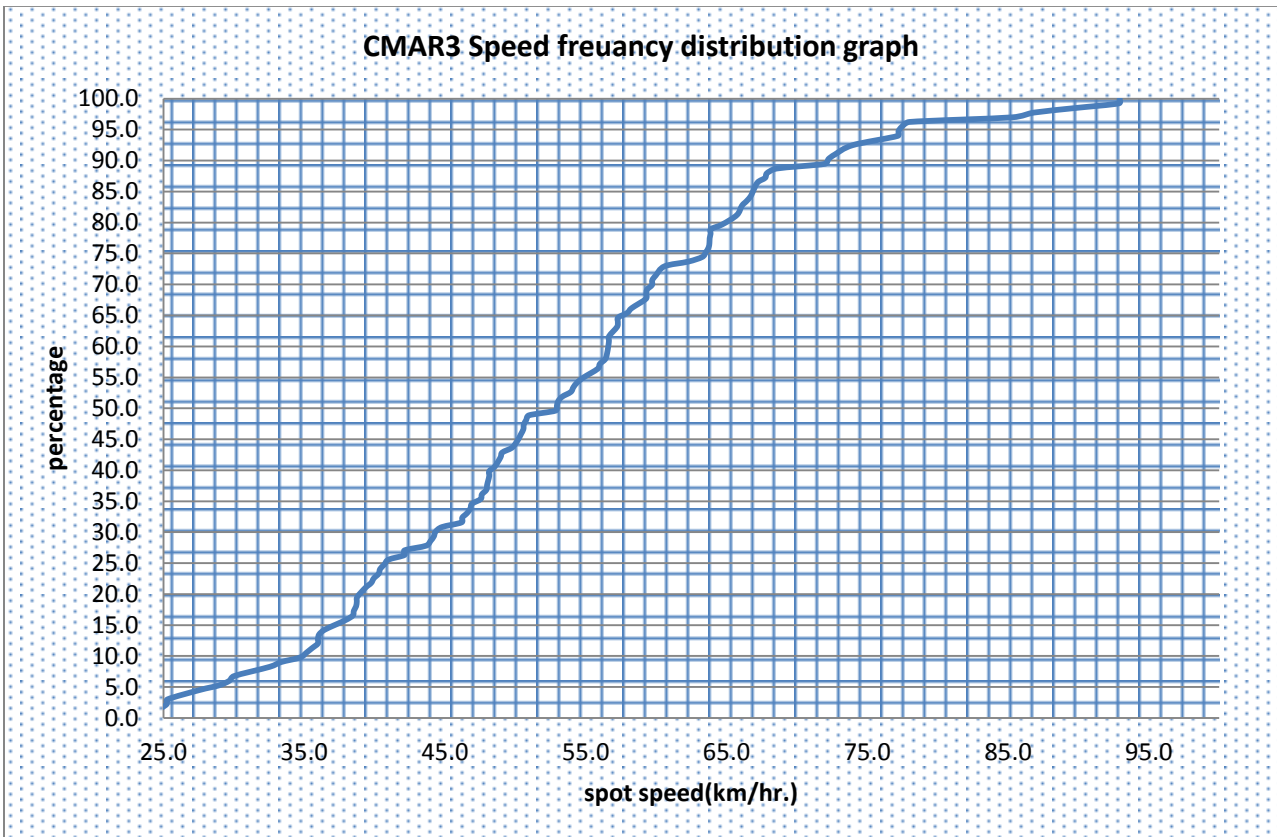


Figure 34: CAR3-Speed frequency distribution graph



# Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

Figure 35: CAR4-Speed frequency distribution graph

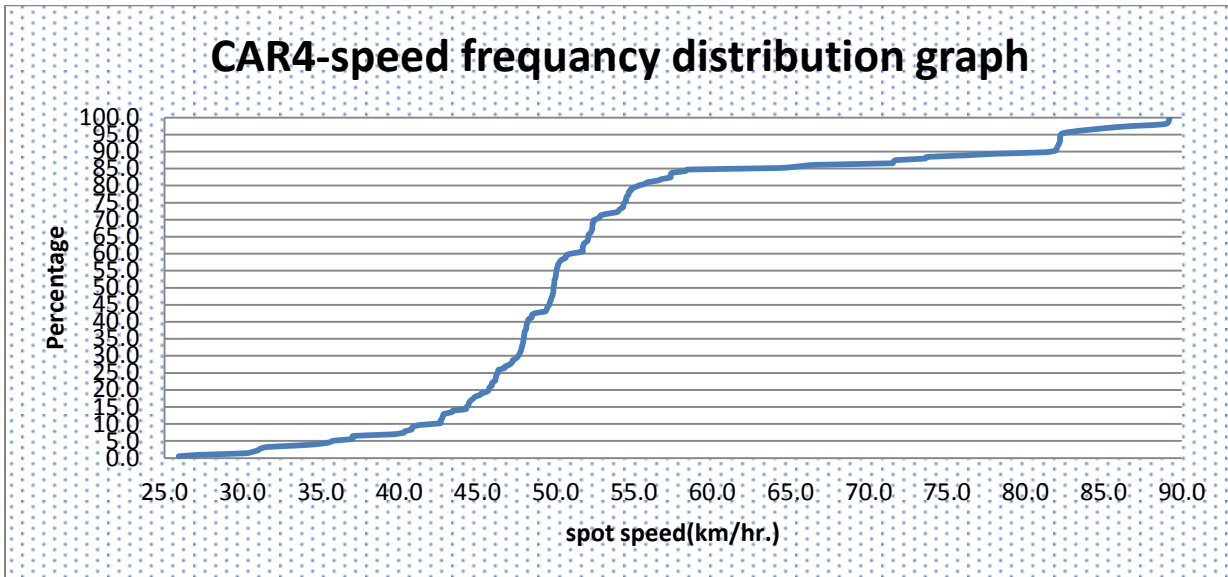
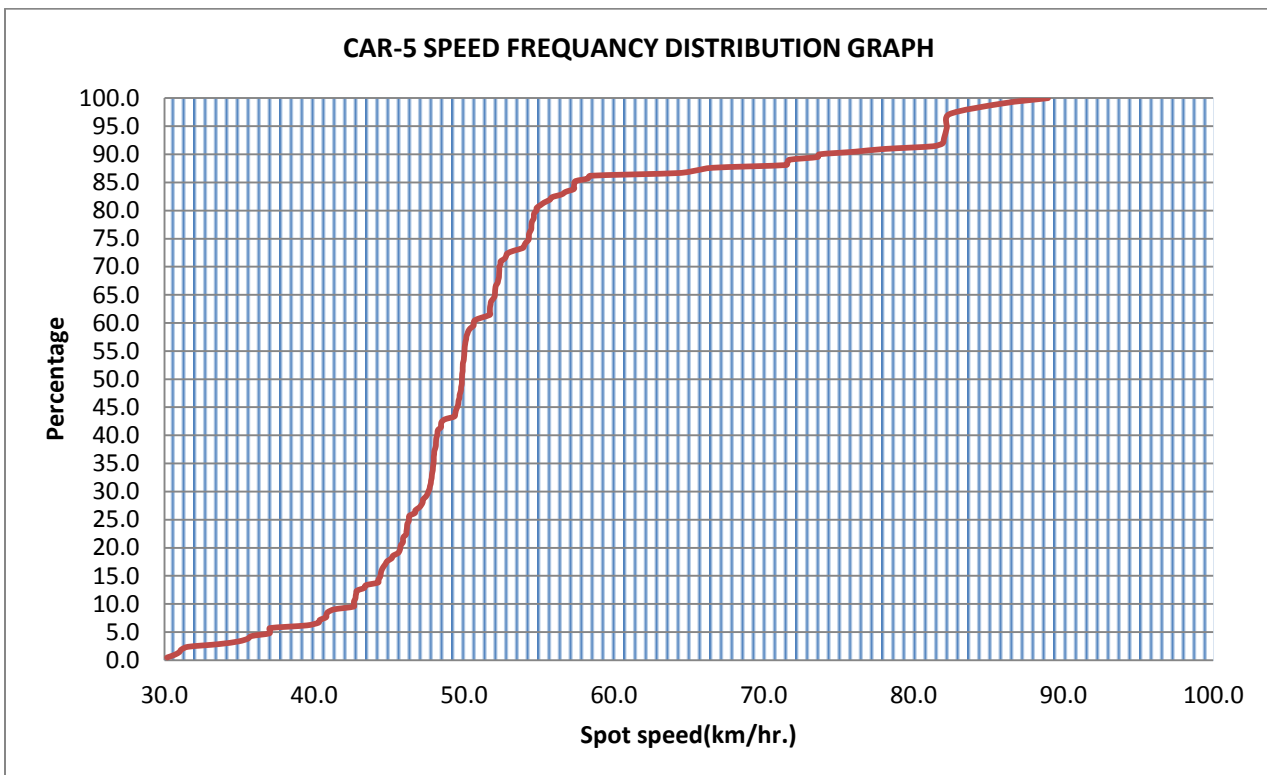


Figure 36: CAR5-Speed frequency distribution graph



# Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

Figure 37:AD1-Speed frequency distribution graph

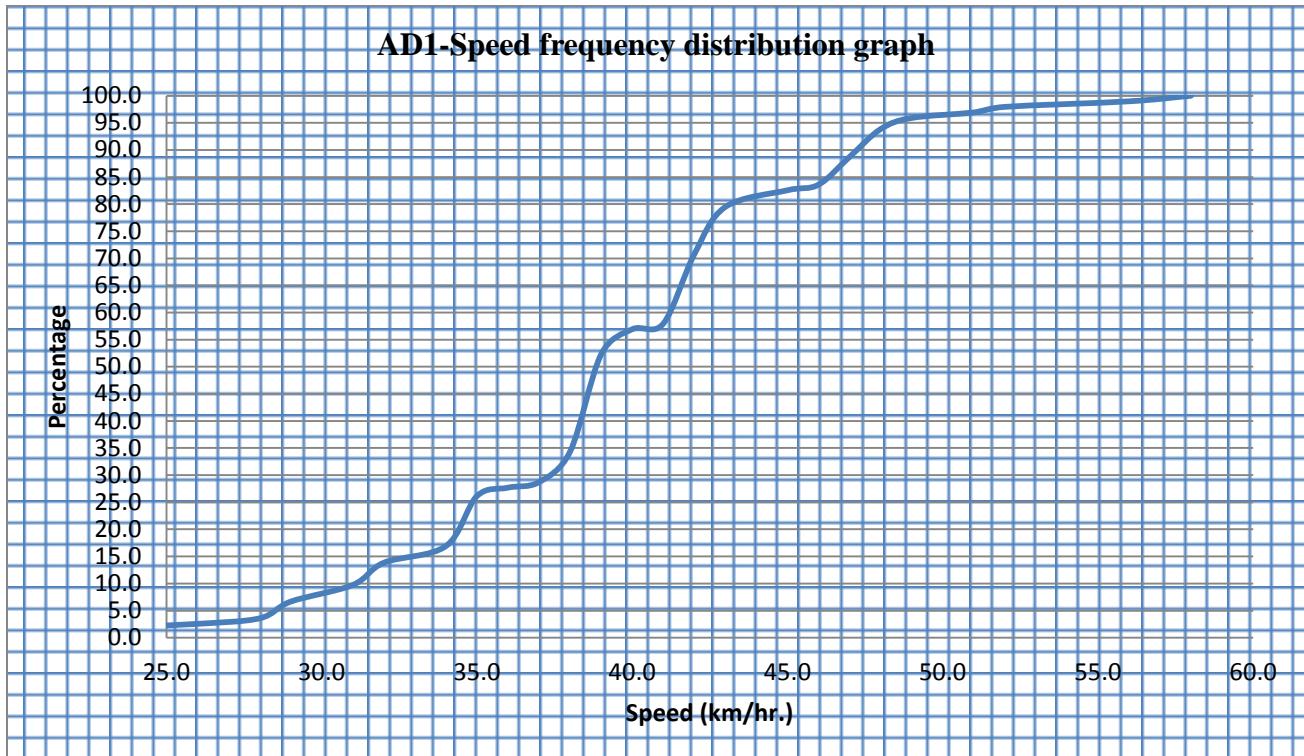
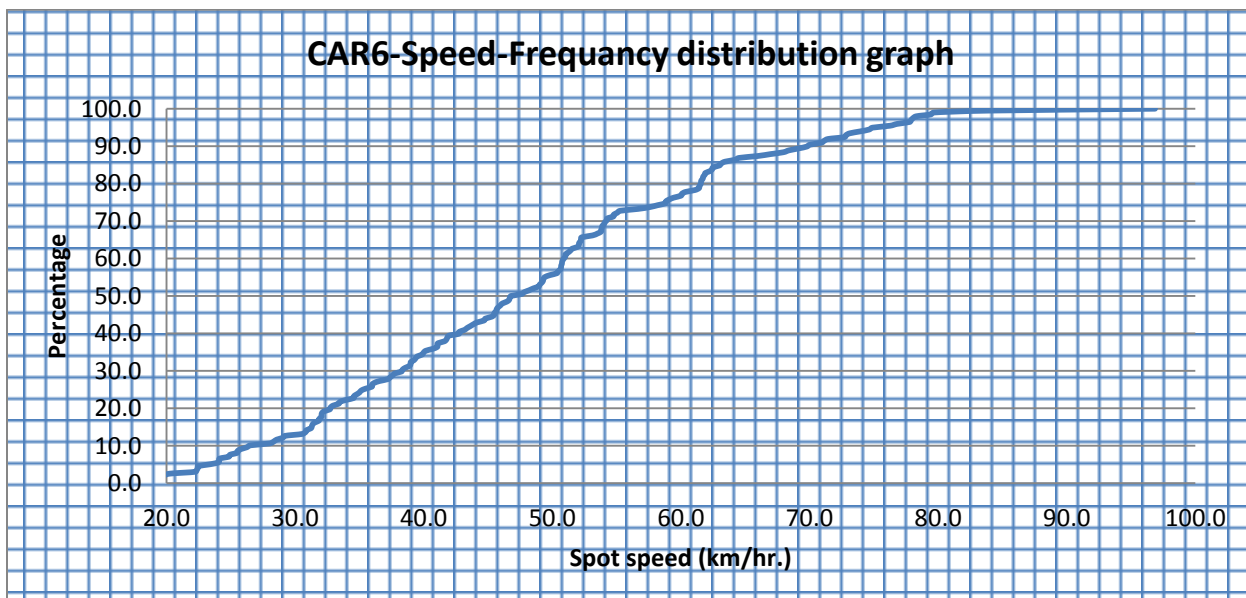


Figure 38:Speed frequency distribution graph



# Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

Figure 39: Speed frequency distribution graph

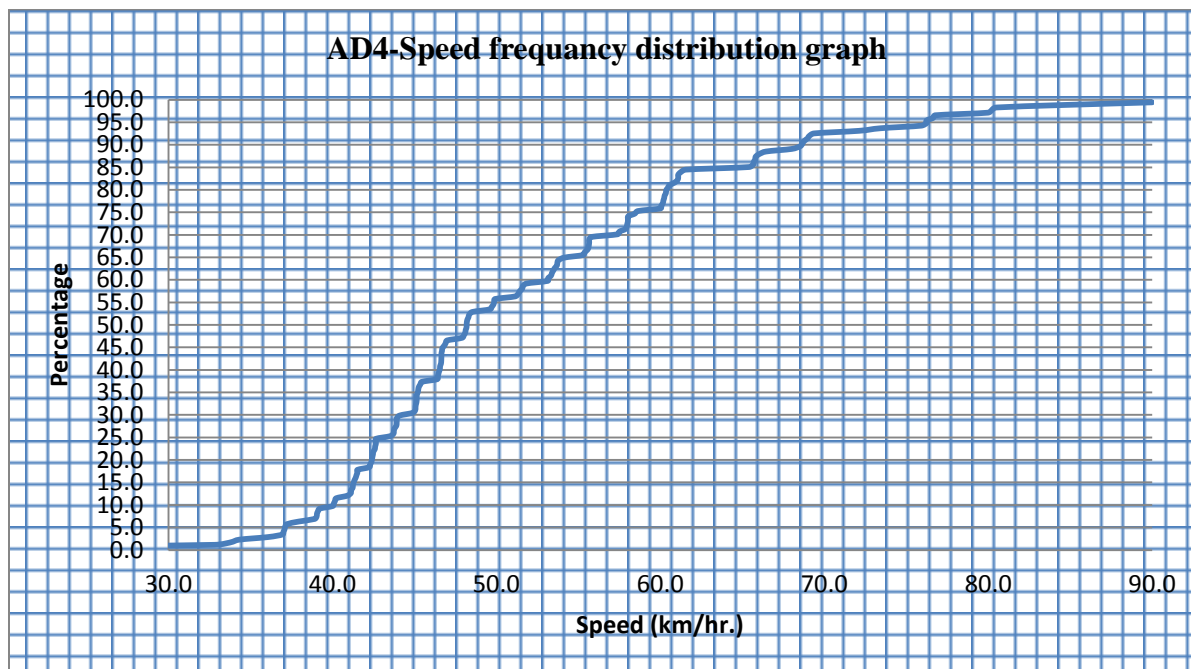


Figure 40: Speed frequency distribution graph

# Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

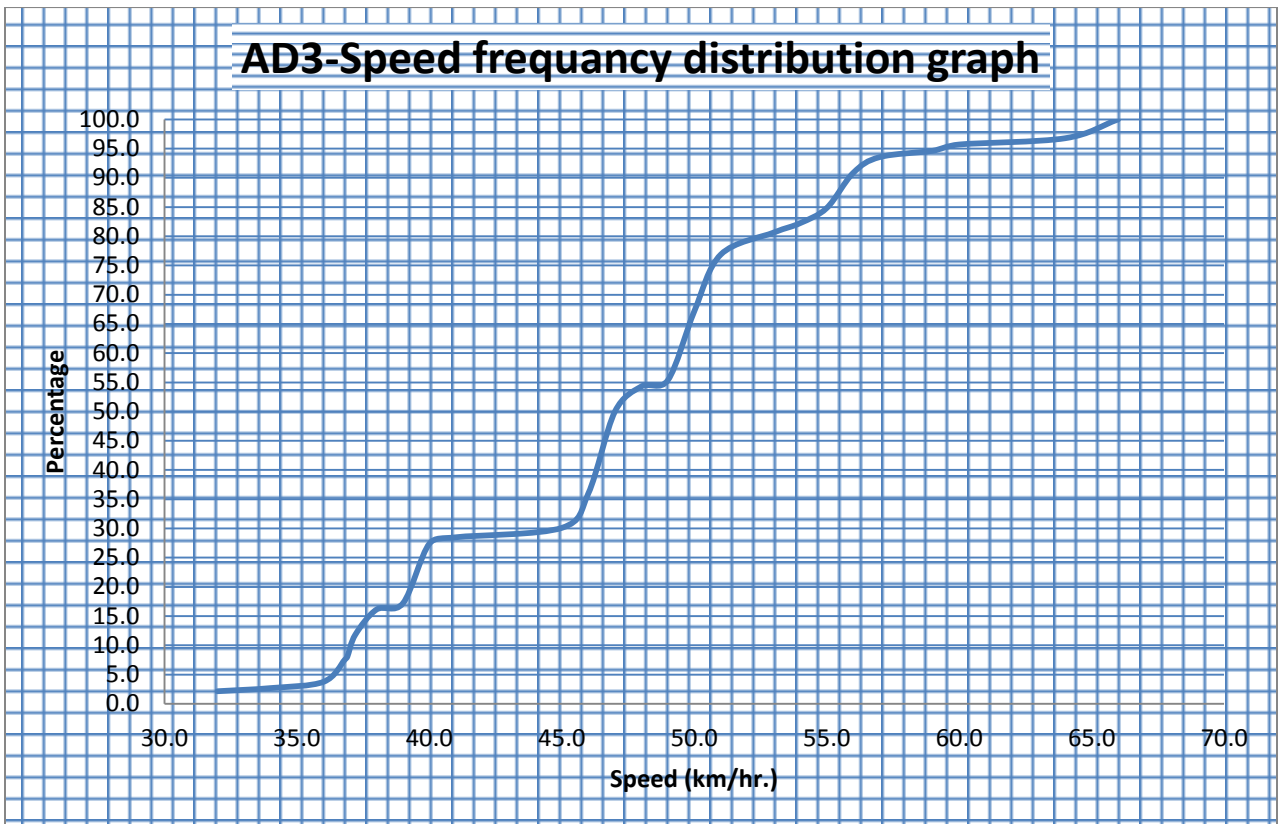


Figure 41: Speed frequency distribution graph

# Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

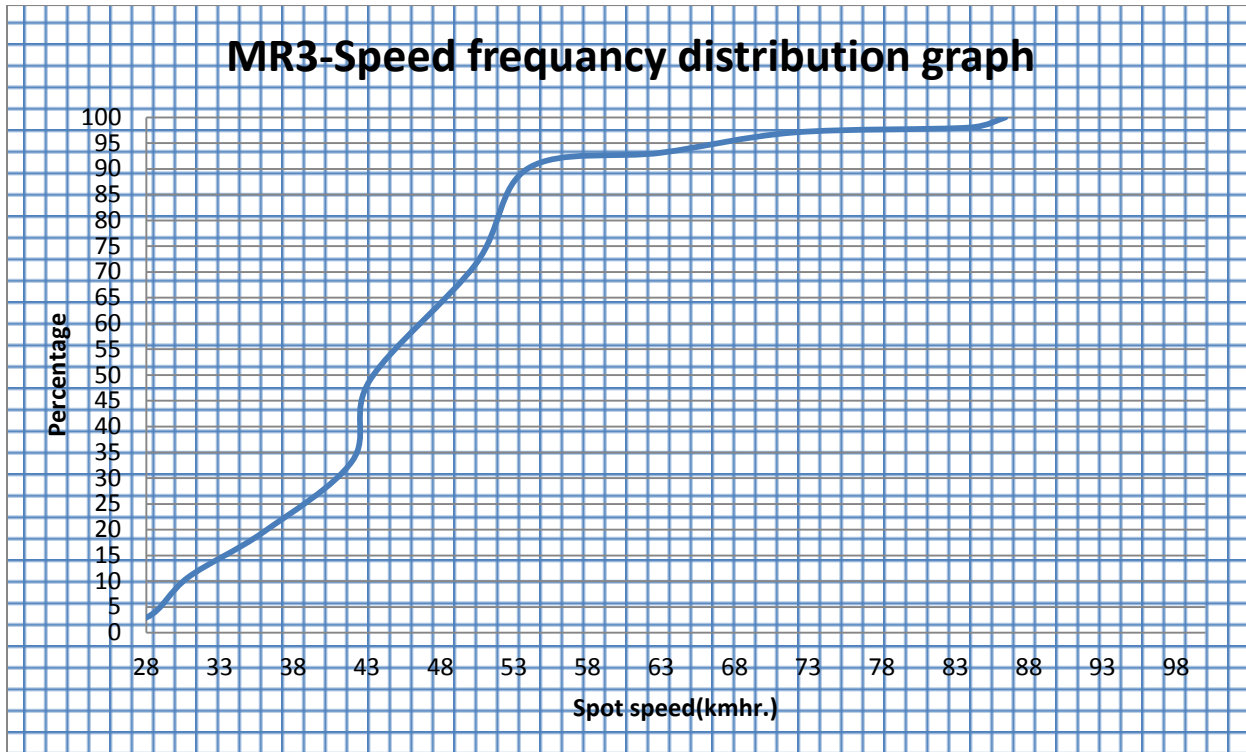


Figure 42: Speed frequency distribution graph

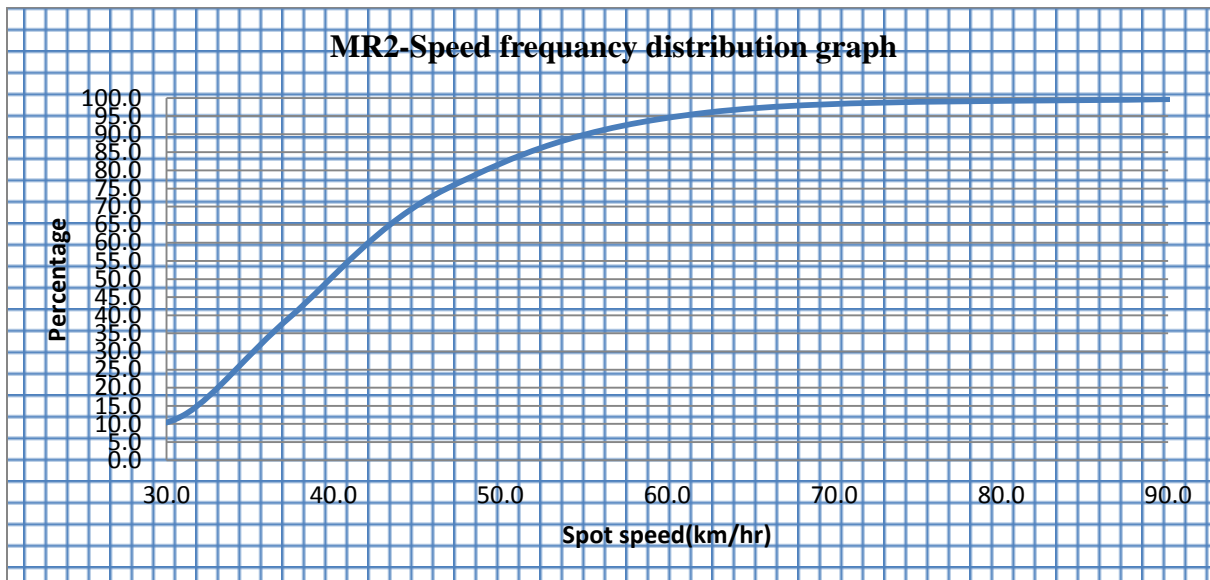
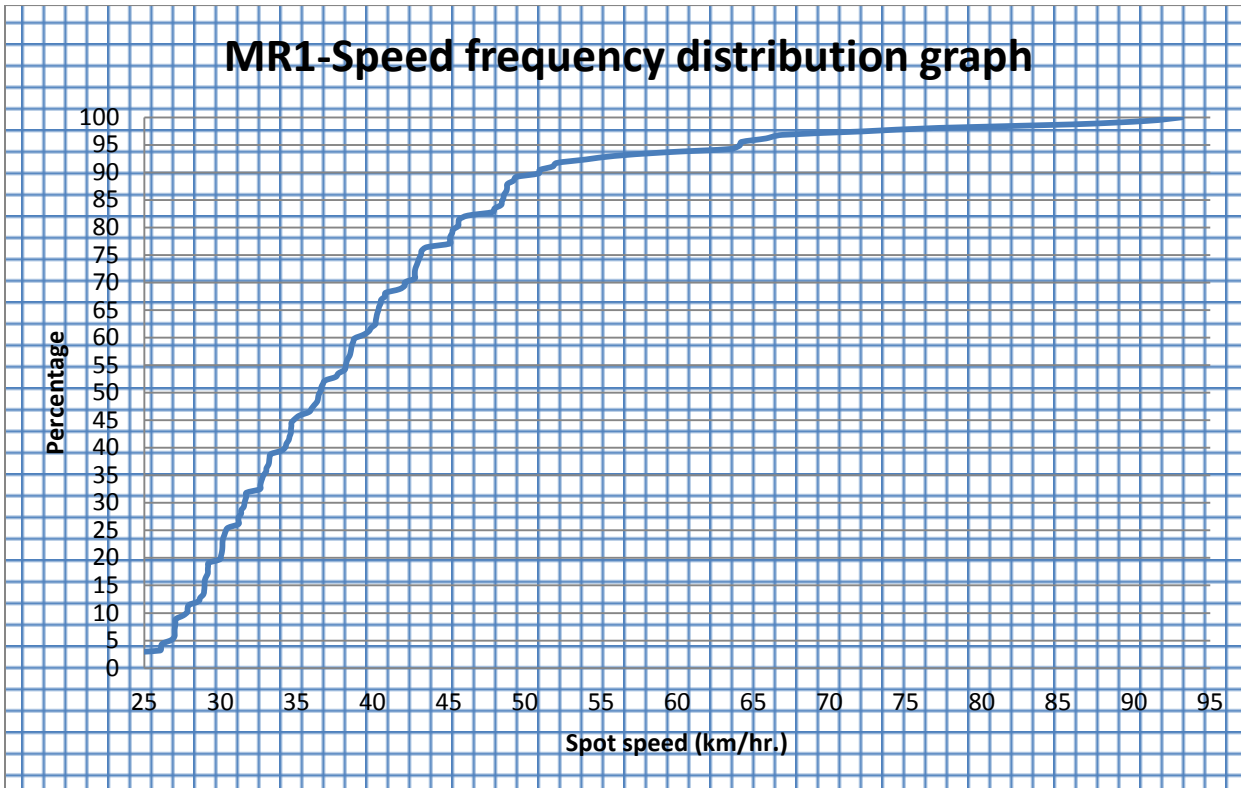


Figure 43: Speed frequency distribution graph

# Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads



# Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

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## Appendix'2: Driver speeding attitudinal survey questionnaire

Dear respondent, I am a student of road and transport from Addis-Ababa institute of technology master's program. The purpose of this questionnaire is to collect data for study of driver frequent reason in Addis-Ababa urban road. Your cooperation is essential for the success of this research. It is not necessary to write your name. Thank you for your kind cooperation

### 1. Driver and vehicle demographic characteristics

1.1 Gender: 1. Male 2. Female 3. Others

1.2. Age: 1. (18-24) 2. (25-30) 3. (31-40) 4. (41-50) 5. (Greater than 50)

1.3. Family status: 1. Single 2. Marriage 3. Divorced

1.4. Education level: 1. Grade 8 2. High school 3. Preparatory 4. Diploma  
5. Degree 6. Masters and above

1.5. Vehicle type you currently drive: 1. Passenger car 2. Pick-up 3. Land cruiser  
4. Mini-bus 5. Truck 6. Buses.

1.6. Vehicle ownership: 1. Owner 2. Government 3. Employee

1.6. Experience of driving: 1. Less than 2 year 2. (2-3) year 3. (4-5) year 4. (6-10) year  
5. (11-15) year 6. (16-20) year 7. Greater than 20 years.

### 2.0 The following questions are concerned about drivers past speeding and accident history

2.1. How often would you travel in Addis-Ababa urban road per week?

1. Always 2. Most time 3. Sometime 4. Rarely 5. Never

2.2. Have you received a speeding ticket from traffic police in the past two years?

1. Yes. 2. No. 3. I don't remember

2.3. If you say yes, how many speeding tickets did you receive in the past two years?

2.4. Have you faced any traffic accident in the past two years?

1. Yes 2. No.

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2.5. If you say yes, is speeding was the main cause of accident based on traffic police report?

1. Yes      2. No.

3.0 The following questions are concerned about driver attitude and belief about speeding

3.1. Would you believe lowering the speed limit would reduce injury severity?

1. Strongly believe to be false,      2. Believe to be false,      3. I don't know,  
4. Believe to be true                      5. Strongly believe to be true

3.2. The main reason police target speeding vehicle is to make money for government

1. Strongly believe to be false,      2. Believe to be false,      3. I don't know,  
4. Believe to be true      5. Strongly believe to be true

3.3. Lowering speed limit would create more pleasant environment for you and your environment.

1. Strongly believe to be false,      2. Believe to be false,      3. I don't know,  
4. Believe to be true      5. Strongly believe to be true

3.4. Lowering speed limit would reduce toxic emission by car and reduce global warming

1. Strongly believe to be false,      2. Believe to be false,      3. I don't know,  
4. Believe to be true      5. Strongly believe to be true

4.0. The possible cause of speeding of driver

4.1. Why did you speeding?

Possible Reason	Always reason (1)	Most times(2)	Sometimes reason(3)	Rarely (4)	Not all reason(5)
Absences of traffic police on the road.					
I am enjoying while driving fast.					
I can drive safely over posted speed limit.					
There is low road side object.					
I did not consider speed limit while drive					

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I am hurry when running late?					
I am not sure what speed limit is?					
Posted speed limit is too low					
Speed limit signs are not intentional.					
I am distracted while drive.					
There is low traffic volume.					
Speed limit signs are not visible.					
There is comfortable and wide carriage way.					
There is low parked vehicle on the side of the road.					
There is low pedestrian movement.					

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በአዲስ አበባ ከተማ ውስጥ የሚገኙ ሹፈሮች ስለፍጥነት ወሰን የተዘጋጀ የጽሁፍ መጠይቅ

በትድሚያ ለጽፍ መጠይቁ ስለተባበሩኝ በጣም አምሰግናለሁ። ስሜ አደራው ስጦታው ተሾመ ሲሆን የአዲስ አበባ ዩኒቨርሲቲ ቱክኖሎጂ ኢንስቲትዩት የ2ኛ ዲግሪ መንገድና ትራንስፖርት ተመራቂ ተማሪ ነኝ። ስለሆነም እሁን የመመረቂያ ጽሑፍ የምሰረው በአዲስአበባ ውስጥ ስላሉ የፍጥነት ወሰን የግንባቤ ደረጃና ችግሮች ላይ ያተኮረ ነው። እያንዳንዱን ጥያቄ በጥምና ካነበቡ በኋላ የእርሶን ሃሳብና እምነት ያንጸባርቃል የሚሉትን አንድ ምርጫ ከተሰጡት መካከል መርጠው  $\sqrt{\text{ምልክት}}$  ያስቀምጡ።

**1. የሹፈሩ ግዳጃ መረጃ**

- 1.1. ጸቃ፡ ወንድ  ሴት
- 1.2. እርጫ፡
- 1.3. የትምህርት ደረጃ (8ኛ -10ኛ) ክፍል  (11ኛ -12ኛ) ክፍል  ዲፕሎማ   
ድግሪ  ማስተርስ ድግሪ  ዶክትረት ድግሪ
- 1.4. የጋብቻ ሁኔታ፡ ያገባ  ያላገባ  የፈታ
- 1.5. የሽፍርና ጊዜ የሰራለምድ፡
- 1.6. ከመኪናው ጋር ያለው ግንኙነት፡ ባለቤት  ሰራተኛ  የመንግስት
- 1.7. የመኪናው አይነት፡ የቤት መኪና  ፒሳፕ  ሚኒ-ባስ   
አውቶብስ  ታክሲ  የጭነት መኪና

**2. የሹፈሩ ፍጥነትና ትራፊክ ለጋ ጾባ**

- 1. በሳምንት ምን ያህል ጊዜ ዩኑዳሉ?  
ሁል ጊዜ  አብዛኛው ጊዜ  አልፎ አልፎ  በፍጹም አልገዳም
- 2. ከአሁን በፊት በፍጥነት ምክንያት ተተጥተው ያውቃሉ? አዎ  የለም
- 3. አዎ ካሉ ላልፉት ሁለት አመት ስንተ ጊዜ ተተጥተዋል
- 4. ከአሁን በፊት የመኪና አደጋ ገጥሞት ያውቃሉ? አዎ  የለም
- 5. አዎ ካሉ ለአደጋው ምክንያት ከፍጥነት ሰጠዎት ለጊዜ መንዳት ነው? አዎ  አይደለም

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**3. የሽራሩ ሀሳብና ወገን ግንጥራቱ ጥያቄዎች**

**1. ፍጥነትን መቀነስ የጉዳት መጠንን ይቀንሳል በግላው ሃሳብ ይስማማሉ?**

በጣም እስማማለሁ  እስማማለሁ  አላውቀውም   
አልስማማም  በጣም አልስማማም

**2. ትራፊክ ፖሊስ በግራፊት መኪናዎችን ትኩረት የሚያደርገው ለመገንባት ገቢ ለማስገኘት ነው።**

በጣም እስማማለሁ  እስማማለሁ  አላውቀውም   
አልስማማም  በጣም አልስማማም

**3. የፍጥነት ወሰንን መቀነስ ለሀገት እና ለአካባቢው ምቹ ሁኔታን ይፈጥራል።**

በጣም እስማማለሁ  እስማማለሁ  አላውቀውም   
አልስማማም  በጣም አልስማማም

**4. ፍጥነት ወሰንን መቀነስ የአካባቢን ብክለት ይቀንሳል ።**

በጣም እስማማለሁ  እስማማለሁ  አላውቀውም   
አልስማማም  በጣም አልስማማም

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4. የሚከተሉት ጥያቄዎች የሚፍጥነት ምክኒያት የሚጠይቁ ሲሆን ከታች ከተጠቀሱት ውስጥ አንድ ና ዘዴ በላይ የሆነ ከተሰጡት መካከል መርጠው ✓ ምልክት ያስቀምጡ።

ለምን ይፈጥሳሉ?	ሁለጊዜ ምክኒያት ነው	አጠቃላይ ጊዜ ምክኒያት	አንዳ -አንዳ ጊዜ ምክኒያት	አልፎ አልፎ ምክኒያት	በፍጥነት ምክኒያት አይሆንም
የትራፊክ ፖሊስ በምንገድ ላይ ሳይኖር ሲቀር.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
በፍጥነት ስነ ስለሚያስደስተኝ	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ከፍጥነት ወሰን በላይ በብቃት መንገዳት ስለምችል	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
የመንገዱ ዳር እቃዎች ዝቅተኛ ስለሆኑ	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ስለ ፍጥነቱ በቂ ትኩረት አልሰጠውም	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
በዝግታ ስነ ምሥራቅ አይሰጠይም	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
የፍጥነት ወሰን ምን እንደሆነ አልውቀውም	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
የፍጥነት ወሰን በጣም ዝቅተኛ ስለሆነ	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
የፍጥነት ወሰን ትኩረት አይሰጠውም	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ስነ ሌላ ነገር አስጠይቀው	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ብዙ መኪና ስለ ሌላ	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
የፍጥነት ወሰን አይታዩም	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
መንገዱ ምቹና ሰፊ ስለሆነ	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
የቆመ መኪና ስለሌለ	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
የግረኞች መጠን ዝቅተኛ ስለሆነ	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

## Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

Table 41: Correlation coefficient of speeding factor

Speeding reason	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
R1	1.000	-.173	.318	.483	-.425	.398	-.185	.202	.246	-.061	.865	.157	.913	.938	.894
R2	-.173	1.000	-.020	-.681	.717	-.427	.365	.097	.105	.135	-.180	-.023	-.167	-.177	-.156
R3	.318	-.020	1.000	.407	-.440	.710	-.430	.123	.134	-.063	.315	.234	.318	.284	.266
R4	.483	-.681	.407	1.000	-.836	.747	-.548	.120	.050	-.134	.449	.255	.465	.460	.437
R5	-.425	.717	-.440	-.836	1.000	-.724	.601	-.101	-.095	.121	-.411	-.205	-.408	-.403	-.377
R6	.398	-.427	.710	.747	-.724	1.000	-.553	.162	.072	-.041	.374	.249	.391	.367	.375
R7	-.185	.365	-.430	-.548	.601	-.553	1.000	.114	.113	-.029	-.183	-.064	-.179	-.154	-.147
R8	.202	.097	.123	.120	-.101	.162	.114	1.000	.368	-.048	.148	.407	.167	.171	.166
R9	.246	.105	.134	.050	-.095	.072	.113	.368	1.000	.081	.202	.323	.219	.226	.214
R10	-.061	.135	-.063	-.134	.121	-.041	-.029	-.048	.081	1.000	-.084	-.052	-.068	-.075	-.058
R11	.865	-.180	.315	.449	-.411	.374	-.183	.148	.202	-.084	1.000	.180	.919	.859	.797
R12	.157	-.023	.234	.255	-.205	.249	-.064	.407	.323	-.052	.180	1.000	.172	.137	.139
R13	.913	-.167	.318	.465	-.408	.391	-.179	.167	.219	-.068	.919	.172	1.000	.896	.840
R14	.938	-.177	.284	.460	-.403	.367	-.154	.171	.226	-.075	.859	.137	.896	1.000	.905
R15	.894	-.156	.266	.437	-.377	.375	-.147	.166	.214	-.058	.797	.139	.840	.905	1.000

## Evaluating the effect of road geometry and posted speed limit on 85 percentile speed of urban roads

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Table 42: Component score coefficient matrix

<b>Component Score Coefficient Matrix</b>				
	1	2	3	4
R1	.225	-.046	-.023	.019
R2	.043	-.118	.097	.450
R3	-.037	.251	.091	.397
R4	-.016	.191	.018	-.192
R5	.035	-.214	-.014	.170
R6	-.049	.273	.058	.138
R7	.058	-.291	.130	-.199
R8	-.052	-.048	.457	-.112
R9	-.003	-.042	.369	.070
R10	.009	.107	-.083	.584
R11	.217	-.044	-.035	.007
R12	-.092	.040	.432	-.075
R13	.226	-.046	-.033	.022
R14	.233	-.061	-.041	-.004
R15	.225	-.057	-.038	.010
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				