ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

DEVELOPING PASSENGER CAR EQUIVALENT BY MODELING AVERAGE TRAVEL SPEED USING ARTIFICIAL NEURAL NETWORK

A Thesis in Road and Transportation Engineering

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A Thesis

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APPROVAL

The undersigned have examined the thesis entitled '**Developing Passenger Car Equivalent by Modeling Average Travel Speed Using Artificial Neural Network**' presented by **TADIYOS MARIE**, a candidate for the degree of **Master of Science** and hereby certify that it is worthy of acceptance.

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UNDERTAKING

I certify that research work titled “Developing Passenger Car Equivalent by Modeling Average Travel Speed Using Artificial Neural Network” is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged / referred.

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ABSTRACT

In order to develop the model for studying the effect of traffic volume and composition variations observed in Addis Ababa on PCE, mainline road midblock sections in Addis Ababa ring road with uninterrupted flow in one direction was taken as a case study. A multistage sampling technique was adapted to collect the data from five sections. The data was taken using two video cameras for recording traffic flow; the cameras were placed in entry and exit location of the section. The data used are the traffic flow and average traffic speed of every vehicle type for a 5 minute time interval that meets minimum number of vehicle to be observed as a result a total of 675 datasets are extracted and calculated from the five sections. In order to achieve the desired objectives, average speed was modeled using artificial neural network first and PCE is estimated using **Equation 2-1.** For measuring the accuracy of the model result the study uses coefficient of correlation (R^2). The model is developed using MATLAP, the model divides datasets in to three groups which are training used 70% of the datasets, tasting and validation each uses 15% of the datasets. The developed model use Levenberg–Marquardt as training and tan-sigmoid as activation function because they provide the best generalization from other training and activation functions tried. The model provides 94% and above R^2 value for training, tasting, validation, and all datasets.

The analysis of results from the speed model indicates; increasing the volume of the traffic stream from 300 to 2400veh/hr decrease speed from 76 to 26.8km/hr for PC, 75.6 to 28.6km/hr for pickup and LC, 74.2 to 28km/hr for minibus, 58.9 to 27.3km/hr for bus, and 48.7 to 24.1km/hr for truck and PCE decreases from 1.54 to 1.42 for pickup and LC, 1.65 to 1.53 for minibus, 4.02 to 3.05 for bus, 4.16 to 2.96 for truck. Changing the proportion of vehicle types by keeping the volume constant shows a decrease in traffic stream speed and increase in PCE for all vehicle types except minibus but the effect is pronounced on bus and truck. For example, increasing the percentage of bus from 0 to 130veh/hr decreases the speed from 57.8 to 48km/hr for PC, 59 to 47.78km/hr for pickup and LC, 58.5 to 45.7km/hr for minibus, 60 to 40.6km/hr for bus, 59.6 to 37km/hr for truck and PCE increases from 1.52 to 1.55 for pickup and LC, 1.64 to1.69 for minibus, 3.4 to 3.69 for bus, 2.94 to 3.42 for truck. Finally it's concluded that PCE is different for different traffic and volume scenarios observed in Addis Ababa.

Keywords: passenger car equivalence, average travel speed, artificial neural network, mixed traffic

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LIST OF ABBREVIATIONS

ANN--------Artificial neural network

ATS---------Average travel speed

ERA--------Ethiopian road authority

HCM-------Highway capacity manual

LC---------Land cruiser

LOS-------Level of service

NN--------Neural network

PC---------Passenger car

PCE-------Passenger car equivalence

PCU------Passenger car unit

CHAPTER 1 INTRODUCTION

1.1 General

[1] In concept of stream equivalence factor involving heterogeneous traffic of urban arterial roads stated that traffic conditions are heterogeneous in all cities of the world, including those in the Europe and the United States, but the degree of heterogeneity is different in developing and developed nations. Their study also indicate Roads in developed countries have dominating traffic of cars with very low (5–10%) proportions of light and heavy commercial vehicles while urban traffic in most of the developing countries is naturally heterogeneous.

Accordingly, change of heterogeneous traffic into a flood of homogeneous one by utilizing Passenger Car Equivalency (PCE) values is a significant advance for analyzing blended traffic, formulating traffic management measures, and for relief of congestion on urban street. Other than this, reliable PCE estimation are additionally utilized for capacity and level of service (LOS) examination as well as for traffic engineering exploration and applications.

The most recent release of [2] characterized PCE as the number of traveler vehicles which will bring about a similar operational condition as a single heavy vehicle of a specific kind under determined roadway, traffic and control conditions. PCE for a type of vehicle is described with reference to prevailing roadway, traffic and control condition. Different sets of static PCE values are suggested with respect to roadway and control condition by different manuals and scholars. However, there are limited studies on the impact of traffic volume and its composition on prevailing roadway and control condition. Among them [3] Model stream speed as a function of dynamic control variables like traffic volume and its composition for assessing PCU estimation utilizing artificial neural network approach.

[4] Develop ANN based speed prediction model and use the model for PCE assessment under blended traffic condition.

In Ethiopia we use PCE values for urban, suburban and rural road facilities derived from the US Highway Capacity Manual. As roadway, traffic and control conditions have a direct impact in PCE values of a type of vehicle and these parameters are different in different time and place adapting the same methodology may not work. Therefore, many researches governing our roadway, traffic and control conditions variety should be developed to determine PCE for mixed traffics observed in Ethiopia. This empowers us taking traffic the board measures for modernization of urban streets, analyze capacity and level of service, and for traffic designing examination and applications. Accordingly, this research has its own commitment to be used for predicting the travel speed of a vehicle and estimating the passenger car equivalence under different traffic volume and composition scenarios observed in access restricted arterial urban roads and also as a guide for future study of speed and PCE on different type of urban road.

1.2 Statement of the problem

Urban streets in Ethiopia are characterized by mixed traffic which brings about interaction between various vehicles having wide range of physical dimensions, weight and dynamic qualities. Examining the current working circumstance of urban streets require PCE unit to analyze mixed traffic, forming traffic executives measures for alleviation of congestion in urban streets, for traffic designing examination and applications as well as for appropriate estimation of capacity and LOS.

In Ethiopia passenger car unit used for design and analysis road operation are derived from the US Highway Capacity Manual. Since US Highway Capacity Manual, was empirically derived from conditions in North America, it is not truly represent traffic condition in Ethiopia. In addition many researchers have originated and developed models to describe the relationship between traffic condition and PCE; but a number of these models were investigated traffic volume and composition data of their own country which is different from Ethiopian vehicle volume, vehicle composition, driving behavior and vehicle performance conditions and other factors.

The reason to conduct this research was to create a model used for estimating PCE considering the impact of traffic volume and its composition at present prevailing roadway and control condition in Addis Ababa. This research will help for future study of traffic executive measures for mitigation of congestion and appropriate estimation of capacity and LOS. Beside these the research will support different traffic engineering researches.

1.3 Research question

The research was undertaken to answer the following questions.

I. Which ANN model is predicting average travel speed for each vehicle types with a desired accuracy level?

II. What is the PCE factor of each vehicle types under different volume and composition levels?

1.4 Objective of the study

1.4.1 General objective

The general objective of the study was to develop a model for estimating the passenger car equivalence for mixed traffic present in Addis Ababa.

1.4.2 Specific objective

The specific objectives the study was to:

I. Develop classified average travel speed prediction model.

II. Estimate passenger car equivalent based on average travel speed.

1.5 Scope the study

The study was conducted in Addis Ababa taking Addis Ababa ring road as a case study. One direction traffic flow data at the mainline midblock section of the study area was considered. Traffic variation with in the day and the week which is significant in Addis Ababa was considered by taking traffic data ranging from free flow condition to near capacity level.

1.6 Limitation of the study

For this study the results comes with a set of limitations; consideration should be taken in to account on the following conditions in using the study results.

- This study included only straight tangent urban roads with uninterrupted flow condition.

- Truck trailers and articulated trucks are ignored in studying the effect of traffic composition and volume on PCE because they are rarely observed on the traffic stream.
- Big busses are counted as bus as their number is small and show similar behavior as bus.

1.7 Significance of the Study

This study estimate PCE values from travel speed based on real traffic conditions (composition and volume) and projected area of vehicle type. Therefore, the new PCE value are going to be used for future study of mixed traffic, formulating traffic executive measures for alleviation of congestion, and estimation of capacity and LOS. The study also allows predicting average travel speed by vehicle types which is used for anticipating the travel speed of a driver at different volume levels in the future. The output of this investigation also used for the transport policy makers, urban road planner, traffic engineering research, and traffic manager for design and operational analysis of urban roads.

1.8 Organization of the paper

This study contains five chapters. Chapter one contains main components of the study including introduction, statement of the problem, the general and specific objectives of the study, research question, and scope of study, significance of the study. Chapter two contains literature reviews of recent literatures regarding artificial neural network, passenger car equivalence methods, and application of ANN in PCE estimation. Chapter three describes research methodology including a description of the study area, sample size determination, study design data collection, extraction, modeling average travel speed and PCE estimation for the study. Chapter four was about detailed data analysis and discussion of results. Finally conclusion and recommendations are drawn in chapter five.

CHAPTER 2 LITERATURE REVIEW

2.1 Passenger car equivalence determination

Continuous research works have been carried out to overcome the complexities involved in accurate estimation of PCE. Because of the distinct nature of homogeneous and mixed traffic behaviors, various techniques have been utilized for assessing passenger car unit values for various facility types such as midblock section, signalized intersection, and uncontrolled intersection [5]. As the focus of this study is to estimate PCE for midblock of urban arterials; subsequently, techniques which are appropriate for mid-blocks are talked about as it were. Below some methods are describe which are found more useful for representing heterogeneous traffic conditions of urban arterials particularly in developing countries.

2.1.1 Speed based methods

[6] Present an examination to recognize the impact of lane width on the capacity of a two-lane road under heterogeneous traffic conditions in India. Data for their study is collected at ten locations on two-lane highways in Northern and Eastern India. For PCU estimation from other several techniques available in their literature review. On their paper they mentioned that as The LOS on a segment of highway is explained in terms of operating speed by [2], and they found vehicles in India do not move in lanes due to the poor lane discipline of many road users. Using these conditions as criteria they use a formula given below.

$$Pc = \frac{Vc/Vi}{Ac/Ai}$$ **Equation 2-1**

Where: Vc and Vi are average speeds of car and i type vehicle respectively; and Ac and Ai are projected rectangular areas of the vehicles on the road.

In their study they found that increase in speed is not uniform for all types of vehicles due to a change in their size and acceleration capability and PCU for a type of vehicle increases with increasing lane width.

[7] Used the Chandra's equation using motorcycles to estimate MCUs of vehicles due to high volume of motorcycle traffic and congested motorcycle flows in Vietnam. But effective space of vehicles was considered instead of projected area

$$MCUk = \frac{Vmc}{Vk} \times \frac{Sk}{Smc}$$

Where: *MCUs is motorcycle equivalent unit of type k vehicle; Vmc, Vk is the mean speed of motorcycles and type k vehicle, respectively in m/s; Smc, Sk is the mean projected space for motorcycles and type k vehicle, respectively in* m^2.

This equation incorporates mean projected space along with the speeds of various vehicle types. The mean effective space was incorporated with the thought that space inhabitance of vehicle is a component of operational conduct of a specific vehicle type in the traffic stream.

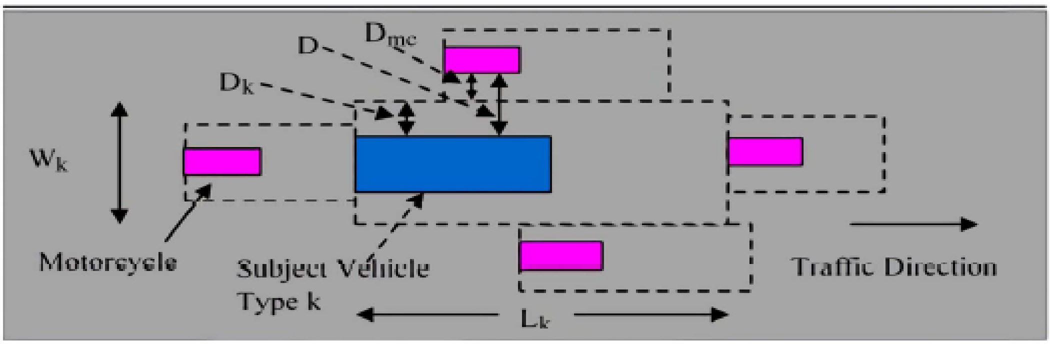

Figure 2-1 Effective space of vehicle

In Figure 2-1, Lk is the effective longitudinal distance of running vehicle including vehicle length in meter; Wk is the effective lateral distance of running vehicle including vehicle width in meter; Dk is the effective space's lateral width of vehicle type in meter; and Dmc is the effective space's lateral width of motorcycles in meter.

On their study they found that when the speed of subject vehicle increases, the effective area is larger and vice-versa. When the speed of the subject vehicle decreases the subject vehicle is surrounded by more number of vehicles. Their study indicates also higher PCU values were obtained for off peak flow condition for various types of vehicles.

[8] On their paper titled as "estimation of passenger car unit for heterogeneous stream of urban arterials" adopt the same method as [6] to find out the dynamic PCU to convert the mixed traffic to a homogeneous traffic and also to develop PCU models for different traffic stream parameters. To achieve this two study sections are selected on four lane divided urban arterial and one study section on six lane divided urban arterial based on various criterion such as, the section should have high variation in proportion of different classes of vehicles, free from the effects of road side friction, intersection, parking facilities, bus stop, pedestrian movements, curvature, gradient and median opening and

others for their study. They found PCU of various classes of vehicles changes linearly with volume increment and *v/c* ratio whereas it is changed exponentially with traffic composition on both urban arterials. They developed mathematical models to depict its variation with different volume levels, composition and volume to capacity ratio. For validating the modal they collect field data at one more four lanes and six lanes divided urban arterial and found that there is no significant difference between suggested and estimated PCU values of vehicles from the modal.

[9] On their examination intends to estimate dynamic PCU values utilizing effective area approach considering the impact of adjoining vehicles under mixed traffic conditions. Data for this study were gathered from four-lane divided and two-lane undivided urban mid-block areas situated in Indian cities (four-lane divided street in Calicut city and a two-lane undivided street in Kollam city). The data were gathered from 6:30 am to 12:30 pm on a normal work day utilizing video-graphic technique For every vehicle type, dynamic PCU values were determined utilizing effective area and speed for six cases considering subject vehicle, pioneer and adjoining vehicles. Traffic flow and composition are gotten for every one minute for six hours.

The adopted formula for determining PCU for each vehicle is given by

$$PCUk = \frac{Vcar/Vk}{Acar/Ak}$$

Where: PCUk is Passenger Car Unit of vehicle type k; Vcar, Vk are average speeds of passenger car and type k vehicle, respectively (m/s); Acar, Ak are mean Effective area of passenger car and type k vehicle, respectively (m2).

A unit PCU value is gotten by calculating the weighted average PCUs for every type of vehicle for the six cases given by: $PCUK = \frac{\sum_{i=1}^{m} Pcui}{\sum_{i=1}^{m} ni}$

Where: PCUk is weighted value of PCU for type k vehicle; m is total number of conditions; PCUi is PCU value for case i; ni is Number of samples of case i.

Their analysis for PCU is based by separating peak, off-peak and moderate flow conditions. On their result they found that higher PCU values for off peak flow compared to peak and moderate flows for various vehicle types. This is because as the flow is very less during off-peak period, the samples numbers obtained for each case is very less and so, vehicles tend to move at a higher speed maintaining more gaps resulting in more effective area.

By far this PCU values estimated using this method are more realistic as the study considers the adjacent vehicle influence. However, the meted for measuring the effective area of each individual vehicle is difficult and tedious to apply.

[10] Introduce a method called stream equivalency factor (SEF) denoted by K to transform different vehicle types to a uniform traffic stream without actually determining the PCU factors for individual vehicle types. To do these they collect a 5-min classified vehicle volume and speed data on different sections of six-lane divided urban arterials in India. The essential thought in their determination of a section is it ought to be liberated from the impact of intersection, bus stop, parked vehicles, curvature, gradient, pedestrian movement, and some other side friction. Also, the segments ought to have wide varieties in extents of various classes of vehicles. They use these data to determine PCU for each type of vehicle using **Equation 2-1**

They convert mixed traffic volume (veh/h) into homogenous traffic volume in PCU per hour. The ratio of these two volumes is explained as the stream equivalency factor (K) for the mixed traffic stream. They utilized Microscopic simulation program VisSim to generate data of speed and volume for two, three, and four categories of cars in the stream. The simulated data are utilized to present a generalized method to obtain the value of SEF for any combination of vehicle categories and for any traffic volume on the road. Stream equivalency factor (K) from simulation ran is

$$k = 1 + 0.269 \times Pcb + 4.072 \times Phv - 0.174 \times P3w - 0.814 \times P2w + 90.88 \times 1/N$$

Where: Pcb is proportion of big cars, Phv is proportion of heavy vehicles, P3w is proportion of three-wheeler, P2w is proportion of two-wheelers, and N is total flow in vehicles per hour.

Thair result shows that the SEF (K) depend on proportional composition and volume of various vehicle types in the traffic stream. Therefore it incorporates multidimensional effects.

2.1.2 Time headway based methods

Headway method is based on the idea that passenger cars following other vehicles will have higher headway than headway between two passenger cars. [11] Adapt an equation by different scholars containing men headway time of vehicle types for estimating PCE to heterogeneous traffic at midblock section of urban arterials. The equation considers headway differences between trucks and other vehicles, which he applies to midblock section of urban arterials for determination of PCE.

$$PCE = \frac{(1-p)(hpx + hxp - hpp) + (phxx)}{hpp} \qquad \textbf{Equation 2-2}$$

Where: P is proportion of trucks in mixed traffic stream; hxp is average headway in seconds for x vehicle following PC, hpx is mean headway in seconds for PC following vehicle x, hpp is Mean headway time in seconds for PC following PC and hxx is mean headway in seconds for vehicle x following vehicle x.

The equation estimates PCE values considerably close to small car which the distinction of vehicle type categories seems meaningless.

[5] In their study present PCU values using headway method by Patil and Adavi for urban midblock in Pune, India, using the following equation:

$$Ft = \frac{tc}{tv}$$

Where: Ft is PCU for time headway of class v vehicle; and tc and tv is average low time headway of cars and class v vehicle, respectively.

PCE form headway method is used only for steady state traffic states. Under unsteady state, measuring headway is difficult. also, it is difficult to obtain headway for all type of vehicles in the mixed traffic because event of slow-moving vehicles following fast moving vehicles occurs rarely in steady state traffic [5]. This methodology has been used more generally in case where PCE factors are resolved for a signalized intersection [11].

2.1.3 Regression based method

[12] In their study use Regression analysis method to derive PCE factors at signalized intersection with saturation flow condition. They incorporated the following equation for estimation of PCE.

$$S = FFS + a1 * PC + a2 * Bus + a3 * MC + a4 * HV$$

Where: S is Avg. traffic stream speed, *FFS is free flow speed*, *PC is Passenger Cars number*, *Bus is Bus number*, *MC of Motorcycle number*, *HV is Heavy vehicle number and* , *a, b, c, d is marginal effect of respective mode on Average stream speed*.

Their result shows the explanatory variables are addressing the quantity of vehicles of a specific type considered in the examination and these explanatory variables are utilized to clarify average traffic speed for deriving PCE at midblock location. In view of the assessment of the above coefficient in the equation [11] derived PCE factors for various kinds of vehicles on urban arterials, by taking the ratio of coefficient obtained for a specific vehicle type with the coefficient obtained for the reference.

$$PCE = \frac{ai}{a1}$$

The method based on multiple regression analysis is criticized because of the argument that speed usually not a linear function of volume [12].

[11] Present the assessment of PCE factors from four different existing methods that have their basis on different notations and required different data items relevant to traffic stream and vehicles. For his analysis on the assessment of PCE factors speed method from [7], and regression method [12]. For headway method he uses the formula provided in **Equation 2-2**

His data is collected using video records from 12 different arterials of Karachi. The information is from Midblock stretches of metropolitan arterials following exacting imperatives on location choice to stay away from effect of external factors on vehicular interactions. From his results it is observed that the values obtained from regression method by [12] are slightly inconsistent. Furthermore; low value of PCE factor for heavy vehicles compared to buses and HCL is observed. In terms of consistencies and plausibility of results, PCE values obtained from headway method by and speed method are more appropriate. However, PCE factors obtained from headway method reviled values that are comparatively low except for three wheelers and motorcycles. Additionally small difference between Minibus, HCL and pickups is observed. Finally In his analysis he founds speed method is more superior because it incorporates of dynamic and static characteristics of vehicle types.

2.1.4 Summary PCE methods

Of the PCE measures discussed in the preceding sub topic speed method by ([6], [7], [8], [9], and [1] headway method by [11] and [5], and regression method by [12] and[11]) were mostly utilized for assessing PCUs on urban road for urban midblock sections because; d segments. From them, speed-area ratio method is better to be used for assessing PCUs

I. Speed is one of the main factors directly influencing mobility and LOS[6].
II. For urban roads, the travel speed is used as a Measure of Effectiveness for defining the Levels of service [2]

PCU for a type of vehicle depends upon traffic composition, total volume of the road and physical dimension of the vehicle. Any change in the traffic volume or composition of traffic stream influences the speed of individual vehicle type Therefore; speed is viewed as a superb variable to decide the overall impact of individual vehicles on the traffic stream. This method is also simple in its construct, and speed data can be easily collected.

Speed modeling has also disadvantages. [5] On their paper discussed that in speed modeling either average speed of every vehicle type or traffic stream used in the modeling has limitations. Considering average travel speed modeling as a case; they show this speed modeling type has two problems these are:

I. Speed of each vehicle type varies significantly across traffic states and different facility types.
II. At the congested traffic state, the difference in speeds of various vehicle types is lesser. Since the traffic is forced to move at reduced speed.

This causes PCE of a vehicle to shift essentially across the traffic states and produces inaccurate estimate when they are generalized to present a static PCE values. These problems of average travel speed modeling in this paper are overcome by:

1. Taking the study sections having similar geometric properties
2. Allowing estimation of PCE at different traffic composition and volume levels that is developing a dynamic PCE value.

In my study, the PCE of a vehicle type is taken from [8] given by **Equation 2-1**

The physical size of a vehicle is an indicator of pavement occupancy, which is crucial in operational characteristics of traffic stream [6]. In traffic with lane discipline, the inhabitance is constrained by the length of vehicle however; in the condition where vehicles do not follow rigorous, the inhabitance is better reflected by area [6].The road traffic in most developing countries includes vehicles of wide running actual measurements, weight and dynamic qualities. Likewise, the mechanized and non-motorized vehicles share the same road space without any segregation. In Addis Ababa Ring-road vehicles do not move in lanes this is due to high varying physical dimensions and speeds on the road and also poor lane discipline of road users; it becomes difficult to make the vehicles to follow traffic lanes. Consequently, they tend to choose any advantageous road position based on space availability. Therefore the occupancy in this paper is better to be reflected by area.

This thesis also gives the advantage for estimating travel speed of each vehicle for different traffic volume and composition observed in the road.

2.2 Review of local studies on PCE

[13] Estimate passenger car equivalence for Addis Ababa - Adama expressway using flow rate density method given by [14] equation below.

$$ET = \frac{1}{\sum_{i}^{n} pi}\left(\frac{qB}{qM} - 1\right) + 1$$

Where: ET is equivalence of truck, Pi is proportion of i type truck, q_B is base flow rate; only PC, and q_m is mixed flow rate; includes PC and trucks.

His data is collected at four midblock sections (selected based on percent and length of grade locations) for three hours during pick flow condition. On his analysis Proportion of percentage of bus and truck for 10, 15, 25, 35, 40, 45, and 50 are extracted and base and mixed flow rate are determined then after E_T is determined. His result shows as the proportion of trucks and bus increase the PCE decreases and vise verse. His study also shows PCE also increase as the length and percentage of grade increase.

[15] Estimate passenger car equivalence on Addis Ababa ring road using the formula given by **Equation** 2-1. He collects traffic data at three different sections for 6 hour at pick period from 7:30-4:30 morning and 15:00-18:00 afternoon local time at midblock location. Static and dynamic PCE values are determined for 5 classes of vehicles these includes passenger car (taxi), big car (pickup, land cruiser, vans and ambulance), minibus, bus (medium and large), and truck (small, medium and articulated). The static PCU is calculated taking the mean value of each PCE from three sections; the values of static PCU are 1.45, 1.49, 3.98 and 4.48 for big cars, minibus, bus, and truck respectively. To estimate the dynamic PCU the speed of vehicles is modeled using VISSIM and PCU of different categories of vehicles is estimated at eight different volume levels: from the result it is observed that PCU value of buses and truck decrease as volume

increase from 3.7 to 3.6 for bus and 4.2 to 4 for truck, for big car and minibus the PCU is shows a very small change as volume gets increases.

[16] Estimate the PCE for through vehicles at signalized intersection by headway ratio method using equation from literature's given below.

$$ex = \frac{hc - x - hx - c - hc - c}{hc - c}$$

Where: hc-c is mean headway of a car followed by a car, hc-x is mean headway of a car followed by x type vehicle, and hx-c is mean headway of x type vehicle followed by a car; The data was collected from 6:30 to 9:00 local time in the morning from four selected signalized intersections on the ring road. The PCE values are determined for 4 classes of vehicles these include small bus (Class 3), large bus (Class 4), truck (Class 5-10), and truck trailer (Class 11&12) according to [17] with respect of lane groups. His result shows shown that PCE of truck trailers are the largest ranging from 3.62 to 3.72, PCE of large buses is the second ranging from 1.95 to 1.99 and PCEs of small Buses are third ranging from 1.49 to 1.68 whereas PCEs of trucks are the smallest from the rest ranging from 1.62 to 1.44.

2.3 Artificial neural network

ANN is a hugely parallel disseminated processor that uses experiential information to develop the abstract representation of a system or an object [18].

Artificial Neural Networks are generally unrefined electronic models dependent on the neural structure of the brain. The mind essentially learns as a matter of fact which is in a real sense an exceptional perplexing, nonlinear, and parallel information processing system. ANN resembles the mind in two main perspectives these are the network gets knowledge from its environment through learning and the neuron connections which are vary in connection strength, known as "weights" provide an analogous mechanism that is used to store the acquired knowledge [18]. With the learned knowledge, an artificial neural network can perform a number of tasks, such as pattern recognitions, data associations, function approximations and data filtering, and many others. Currently, only a few of these neuron-based structures, paradigms actually, are being used commercially. One particular structure, the feed-forward, back-propagation network, is by far and away the most popular [19].

2.3.1 Artificial neural network model

Neural networks are comprised of simple elements called artificial neurons which can provide elementary nonlinear computations. These artificial neurons are normally termed as nodes or processing elements [19]. The computation of a neuron passes two typical processes these are receives and sums input signals and transforms the summation of the inputs through a transfer function to produce an output as shown **Figure 2-2** [18].

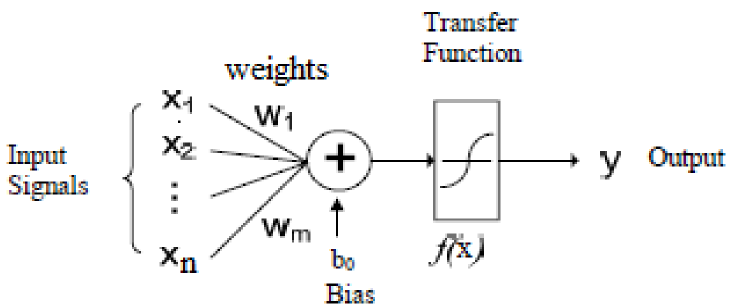

Figure 2-2 Neural network model

In mathematical form ANN is described as follows $y = f\left(\sum_{i=1}^{n} wixi + bo\right)$

Where: x_i is the *i*-th input data from a total of *n* inputs; w_1, w_2, …, w_n are the weights that connect the *n* input signals to the computation neuron; b_0 is the bias and is an external parameter of the neuron that applies an affine transformation to the output of the summing junction in the model; *f*(x) is the activation function, which takes the result of the linear combiner as the argument of a differentiable function to produce the final outcome of the neuron model.

Most form a neural network consists of two outer layers; one input and one output layer and some inner layers or hidden layers such that the computational power of such a system has been boosted exponentially and is capable of handling high-dimensional and non-linear problems [18].

The transfer function is used such that the range of the weighted sum of input signals is compressed by a curve such that the output signal value never exceeds a relatively low level regardless of the value of input [20]. Artificial neural networks utilize nonlinear activation functions, which can help the network, learn complex information, register and adapt almost any function representing a question, and provide accurate predictions.

The bias value associated with each node allows the activation function to be moved to one side or right, to more readily fit the information.

2.3.2 Artificial neural network learning

The primary significance of a neural network is the ability to learn from its surroundings and to improve its performance through learning. Since the very inception of ANN development, a set of learning rules have been explored and defined [18]. There are two approaches of learning a neural network. One is supervised learning in this kind of learning both input and the output data are given. The network at that point measures the information sources and thinks about its subsequent output against the ideal output. Errors are then back through the framework, making the framework changes the weights which control the network. This cycle happens again and again as the weights are consistently changed. The set of information which empowers the training is known as "training set." During the training a similar set of information is handled ordinarily, as the association weights are at any point refined [19].

The other kind of learning is called unsupervised learning. In unsupervised learning, the network is furnished with inputs yet not with wanted outputs. The system itself should then choose what highlights it will use to input data. This is frequently alluded to as self-organization or adaption. Right now, unsupervised learning is not surely known.

In the context of neural network for modeling average travel speed, the input output parameters are developed to achieve accurate modeling of travel speed. Therefore, all the networks to be developed are trained in the supervised learning [19].

2.3.3 Benefits of artificial neural networks

Artificial neural network got many advantages in performing a number of tasks. It is generally recognized that proper constructions of artificial neural network architectures can approximate any nonlinear mappings to arbitrary accuracies [18]. Presenting ANN with unique input data and corresponding response data and learning a network in supervised learning technique creates input output mappings in a statistical manner without prior assumptions. In addition, the plasticity behavior of a neural network also allows its weights to be adjusted in real time in order to stay adaptive to a non-stationary environment [18]. The parallel distributed computation system in artificial neural network possesses a great engineering characteristic of fault tolerance. This trait minimizes the vulnerability of potential failures due to noisy or even false inputs to a certain extent [4]. All these features have popularized the neural networks in many different fields of studies, and the artificial neural networks therefore are considered suitable in studying the dynamics of traffic behavior [3].

2.3.4 Artificial neural network as a modeling tool

The hypothesis demonstrated by [21] states that a multilayered feed-forward artificial neural network with one secret layer can approximate any continuous function up to an ideal level of exactness, given in that it contains an adequate number of nodes in the hidden layer. This neural network has three types of nodes that is input, output and hidden. Input nodes receive input signals from sources outside the network. Output nodes transmit signals that are output values outside the network all other nodes between input and output nodes are the hidden layers. The nodes of one layer are connected to the nodes of the adjacent layer. Each node transmits signals of different strengths to its neighboring nodes.

[3] On their study shows under mixed traffic conditions, stream composition plays a pivotal role in determining the speed since it is quite expected that different vehicle categories present in a stream of traffic would have different influences on overall mobility. Considering same condition, vehicles of different sizes respond differently to the same traffic volume condition. Under such condition ANN has a big role to play in traffic engineering field where a high degree of complex non-linear cause-effect relationship exists. Neural nets are additionally profoundly uncaring toward the noise allowing precise prediction if questionable information and errors are included [4].

There are various kinds of models which are utilized for estimating average travel speed in urban midblock sections this includes like multiple linear regression models, weighted regression modal and artificial neural network and others. [22] in his paper taking road type, day time, traffic volume, and Proportion of heavy vehicles as the major effective parameters for estimating average speed of vehicles and evaluate artificial neural network with simple and weighted linear regression models and his results indicates artificial neural network has the best performance in estimation of average speed he also investigate that the performance measure of neural network can be improved when an appropriate network is considered.

2.3.5 Use of artificial neural network for modeling PCE

[3] Model stream speed as a function of dynamic control variables, traffic volume and its composition using NN, to exhibit a methodology they use an urban mid-block section, with four lane divided road and 7.0 m carriageway width. A 5-minute traffic state data points are developed for analysis. Their model is a three layer feed-forward type in which input vectors indicate hourly flow rate by a type vehicle and output vector indicates stream speed per hour. A neural network of feed-forward type with standard back propagation technique using gradient descent rule is used for their study.

They drive PCE by comparing a decrease in stream speed brought about by marginal increment in traffic volume by a vehicle type to redaction caused by same marginal increment by a reference vehicle (old technology car). The PCE of a type of vehicle (i) at given volume level (v) and composition (m), is estimated by

$$PCEi, v, m = \frac{Mdi, v, m}{MDoc, vm}$$

Where: $MD_{i,v,m}$ a decrease in stream speed brought by a vehicle type 'i' at a base volume 'v' and base composition 'm'; and $MD_{OC},_{v},_{m}$ is decrease in stream speed brought by old technology car at a base volume 'v' and base composition 'm'.

Their result shows PCE values are going to increase with an increase in traffic volume. However, the impact of portion of a vehicle type on PCE of a similar vehicle type is discovered to be viable with the size of vehicle and its mobility as well as speed capability.

[23] Model PCU using ANN considering some of known affecting factors as input and PCU value for bus as output. In developing this model Levenberg-Marquardt training algorithm with local minima avoidance is used. A network with four inputs and one output vector is used. The network inputs are width of the Pavement, Shoulder condition, Direction Split of slow Moving vehicles the network has one hidden layer. The results so obtained are compared with the quoted results in by different researchers under varying affecting parameters and high degree of correlation is observed

[24] In this Study foster an Artificial Neural Network (ANN) based model utilizing MATLAB for the assessment of PCE esteems for various kinds of vehicles, includes Bus, Mini-bus, Large Truck, Medium Truck, CNG/Mahindra and Motorcycles in Khulna Metropolitan City. Data are collected at four different roads where all the vehicles move freely without any restriction. In order to develop artificial neural

network model, four most affecting factors as pavement width, shoulder condition, directional split, and percentage of slow moving vehicles are considered as the input and the corresponding PCE values as output or target. His results are compared with the values established by Geometric Design Standards for Roads & Highways Department in Bangladesh.

The result shows PCE values for buses and trucks is almost near to the standard results but in case of mini-bus, medium truck, PCE is deviated from the standard values. His discussion on the factors cause this deviation are due to faulty road geometry, insufficient roadway width, poor shoulder conditions, frequent side roads enter increasing amount of slow moving vehicles on the road, pedestrian movement observing on the site greatly hampered PCE value of any vehicle due to these speed restrictions. [4] On their study see the impact of traffic volume and its composition on individual speed and PCE in the context of urban mixed traffic by modeling the individual vehicle speed using ANN. Traffic information on classified traffic volume and speed data were gathered at six-lane divided arterial mid-block street areas in New Delhi, India All vehicles were classified into five categories: small car, big car, heavy vehicle, motorized three-wheeler and motorized two-wheeler. They found that the combination of 'Levenberg–Marquardt backpropagation' algorithm and 'tan-sigmoid' transfer function as the best options for ANN modeling in their case than other possible combinations.

They use PCE formula proposed by [6] for their PCE evaluation. Their result shows for increase in volume; vehicles with larger size and poor operating characteristics have higher speed reduction rate in comparison with small cars but the impact is very marginal for small-sized vehicles this also causes PCE of two-wheeler to decreases and PCE of other vehicles to increase. An increase in the proportion of larger-sized vehicles in the traffic stream results redaction in speed of other vehicles especially for big cars, heavy vehicles and three-wheelers this also causes PCE of two-wheeler to decreases and PCE of other vehicles to increase and reverse if proportion of small sized vehicles (two-wheeler) increase.

CHAPTER 3 RESEARCH METHODOLOGY

On this chapter the methodology to study the impact of traffic volume and composition levels observed in Addis Ababa on passenger car equivalence is organized. The study area, study sections, data sampling, data collection, study design, data extraction, research method, traffic data properties, research material and analysis methodology are presented hear under to meet the objectives needed. The impact of different traffic volume and composition levels ranging from free flow condition to near capacity level was studied. The study was conducted on Addis Ababa ring road midblock location. The study is completed in three phases:

I. Data collection
II. Developing volume based average travel speed prediction model and
III. Estimation of PCE factors based on travel speed.

3.1. Description of the study area

The Addis Ababa ring road allows the vehicle entering the city from the five main radial roots to bypass portion of the city; to avoid the city center. Those radial routes are the main road entering from Jimma, Bishoftu, Debrebirehan, Ambo and Gojjam. Thus the ring road have main sections which connect Debrebirehan road with Bishoftu roads, Bishoftu road with Jimma roads, Jimma roads with Ambo roads, Ambo roads with Gojjam roads. It is a divided multilane highway with limited control of access and has two lanes of 7.2m mainline roads for the separate use of trough traffic in both direction and two lanes of 6.6m frontage road for local traffic. The basic design philosophy for the Ring road Project was to ensure ease of movement for through traffic. To achieve this, on mainline part of the Addis Ababa ring road direct access to and from adjacent property is not permitted. Access to and from mainline road are limited to ramp locations and intersections. For the purpose of mixing the two lanes mainline and frontage roads, it’s designed to merge them in to a three lane road before any junction. This three lane carriageway continuous trough the roundabout and the cross section to come to the original two lane condition. The road operates under uninterrupted flow in long segments between points of fixed interruption.

The criteria for selecting the Addis Ababa ring road for demonstrating the effect of traffic volume and composition on PCE and travel speed of every vehicle types in Addis Ababa is due to the following reasons.

- The ring road has long uninterrupted mainline highway with uniform carriageway width which makes other variables that will affect the travel speed be limited.
- The data collection section should be straight tangent with no rise and fall; the ring road can afford this.
- The ring road covers large area; which can provide data that covers wide range of traffic composition and volume scenario observed in Addis Ababa.

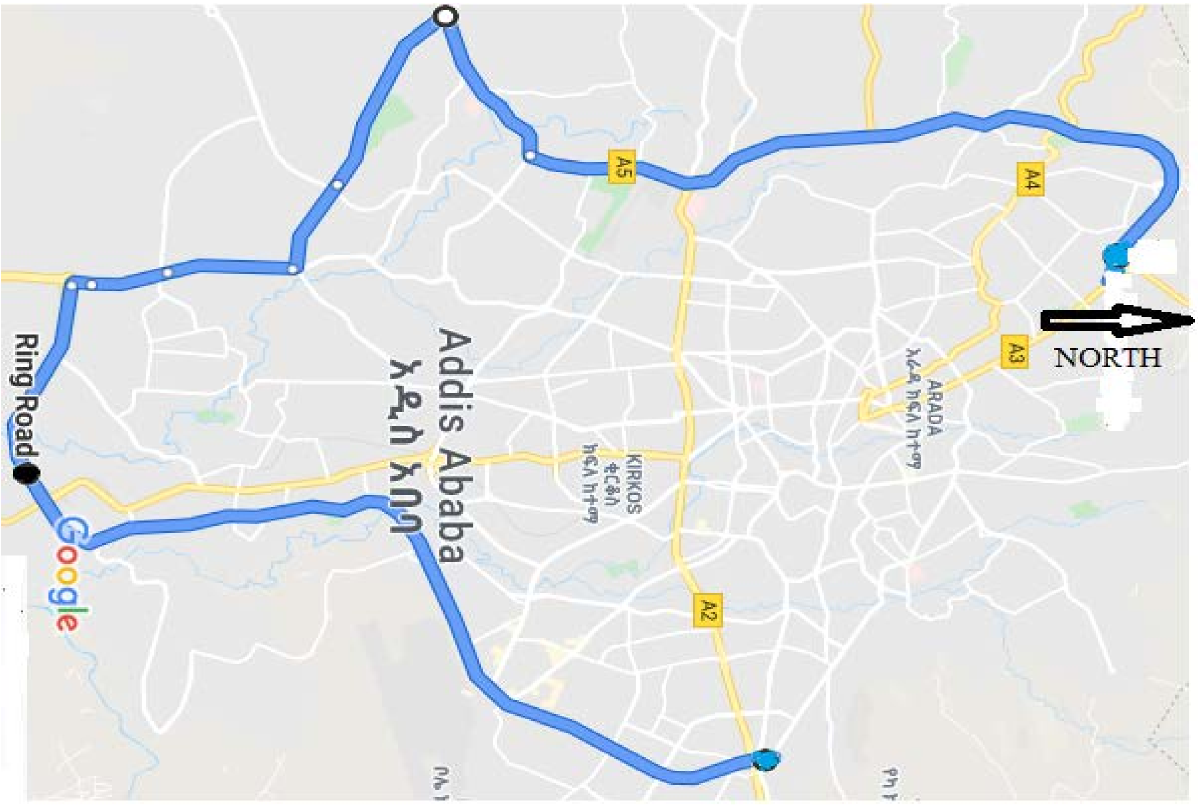

Figure 3-1 Addis Ababa ring road map

3.1.1 Study sections selection

Road stretches for measuring travel speed on the ring road was selected on tangent section with no rise and fall as well as there is no merging or diverging of any vehicles in the given stretch and also there was no access points (Intersections or raps, merging and diverging points) on the stretches in order to well understand the impact of traffic volume and composition on PCE. The study sections also were out of the influence area by access points.

The influence area extends backward, the size of this area includes the most distant extent of any queue expected to occur during the study period [2] The influence area is was set above 76.2m for all sections measured from the rare queue observed during the data collection time [2].

Table 3-1 length of section from intersections

Sections	Influence area measured from rare queue
Section 1	100m measured from the mainline lane beginning
Section 2	150m measured from abo intersection
Section 3	120m measured from the bridge around Yemen embassy
Section 4	80m from Atenatera intersection
Section 5	120m measured from Germen roundabout

The dual two lane carriage way width of 7.2m of the mainline road used by tough traffic in one direction are used for the study as it is away from influence of bus stop, away from parking areas and has uninterrupted flow for long section.

Figure 3-2 Cross section of Addis Ababa ring road

3.2. Data Sampling

The sampling technique used for this study is multistage sampling.

3.2.1. Stratified sampling of sections

As the main objective of the ring road is for accommodating vehicles entering to the Addis Ababa city from the five main radial roots to bypass portion of the city to exclude the city center a total number of five study sections was selected from nearby areas to radial roots on the ring road considering the land development variation of the area and pavement condition. All the five sections that are used for the study were geometrically identical.

I. Section one: Megenagna to Bole airport

This section is located on the northeastern part of the city and helps to bypass traffic entering from Debrebrahan main radial route toward a Bishoftu main radial route. This Section also helps vehicles movement within the city between Megenaga and Bole. The traffic data traveling on the mainline in one direction from megenaga to Bole was recorded before Ambesa-bus garage; the land development of the area is institutional.

Figure 3-3 Study section 1 location

II. Section two: Kality roundabout to Bole airport

This section is located on the south part of the city and helps to bypass traffic entering from Bishoftu main radial route toward a Debrebrahan main radial route. This Section also helps vehicles movement within the city between Kaliti and Bole. The traffic data traveling on the mainline in one direction from kality roundabout to bole was recorded before Saries abo intersection; the land development of the area is commercial.

Figure 3-4 Study section 2 location

III. Section Three: Ayer-Tena to Tor-Hailoch

This section is located on the south west part of the city and helps to bypass traffic entering from Jimma main radial route towards Ambo main radial route. This section also facilitates vehicle movements within the city between Ayer-Tena and Tor-Hailoach. The traffic data traveling on the mainline in one direction from Ayer-Tena to Tor-Hailoach was recorded before Tor-Hailoch roundabout; the land development of the area is institutional.

Figure 3-5 Study section 3 location

IV. Section four: Winget to Tor-Hailoch

This section is located on the north part of the city and helps to bypass traffic entering from Gojjam main radial rote toward Ambo main radial and rote and vise verse. This Section also helps vehicles movement within the city between general Winget square to Torhailoch. The traffic data traveling on the mainline in one direction from Winget to Tor-Hailoach was recorded around 18bridge; the land development of the area is residential.

Figure 3-6 study section 4 location

V. Section five: Haile garment to Ayertena

This section is located on the south part of the city and helps to bypass traffic entering from Adama main radial rote toward Jimma main radial rote. This Section also helps vehicles movement within the city from haile garment to Ayer- tena. The traffic data traveling on the mainline in one direction from Haile garment to Ayertena was recorded before Germen roundabout; the land development of the area is buildup.

Figure 3-7 Study Section 5 location

3.2.2. Systematic sampling of data collection time

Data selection requirement in ANN for training is that the data should be representative. That is, the samples in the data set should be evenly spread over the expected range of data variability [25]. In my study the accuracy can be increased by including more representative inputs to do this various traffic flows was considered.

[26] Found variations of travel demand between different weekdays he found that variation is related to variations in activity patterns and [27] Found that travel demand varies on seasonal occasions. There is also weather related variations which are significant, but small when weather conditions are not extreme [28] accounting all this and obtaining all variations in volume and composition of traffic is impossible due to limitation of resource and time.

[29] States that in ANN model the number of weights in the network should be less than the number of training data points. For this study the length of data collection time was set to meet the requirement.

Previous studies on speed estimation using ANN method considering traffic volume and composition variations on their study are summarized as follows.

[3] Collect classified volumes and speeds of different vehicle types on one side midblock section of the study area to get total dataset of 330 data points, each representing 5-minute traffic state for a 5-3-1 developed network. [4] Collect traffic data on speed and volume during peak as well as off-peak hours. [30] Gazers data from 5 different sections and data on every section is collected for various conditions which are home to work, work to restaurant and back to work, from work to home, and finally a journey from home to a particular destination.

Traffic data for this research was collected in a way that a good variation of traffic flow was observed. To do this traffic data was collected at three different times considering high, moderate and free flow traffic conditions observed in Addis Ababa. Its observed in Addis Ababa traffic flow is high on weekday morning or evening and the flow is medium on afternoon and traffic flow is almost free in Sunday. For my study data was collected for three conditions; for high flow conditions traffic data was collected on weekdays in the morning from 2:00 to 2:45 hour local time, for moderate flow condition traffic data was collected on weekday in afternoon from 6:30 to 7:15 hour local time and for free flow conditions traffic data was collected on Sunday morning from 2:00 to 2:45 hour local time.

Table 3-2 Data collection day and time

DAY	Monday		Tuesday		Wednesday		Thursday		Friday		Sunday
TIME	Local time		Local time		Local time		Local time		Local time		Local time
FLOW	High	moderat	High	moderat	High	moderat	High	moderate	High	moderat	Free
Section 1	2-2:45	6:30-7:15									2-2:45
Section 2			2-2:45	6:30-7:15							2-2:45
Section 3					2-2:45	6:30-7:15					2-2:45
Section 4							2-2:45	6:30-7:15			2-2:45
Section 5									2-2:45	6:30-7:15	2-2:45

The amount of data collected is governed by the principle of neural network. Neural networks require the data to have a range from free flow to high flow conditions, consider different scenarios of traffic composition that could be observed and have more datasets than the connection weights which are 300. For this research a 45 minute traffic data which can give more datasets 675 of traffic flow and average travel speed is acceptable which agrees with [25] and [29] sampling technique.

3.2.3. Random sampling of vehicles

The vehicles considered in this study are those which travel on the selected stretch section of road during data collection time.

The vehicles present in each data points should have a minimum number of vehicles for the average speed to be representative [31]. They provide an equation for calculation minimum number of vehicles for speed calculation given by;

$$sample.size = \left[\frac{z \times \partial}{e} \right] \qquad \textbf{Equation 3-1}$$

Where: e is tolerance, ± mph Z (normal standard) =1.96 for 95% confidence interval Based on [32] the standard deviation of speed is 5 and the error is 1.0 mph. Therefore, the sample size (N) is given by

$$\text{No of car (N)} = [(1.96 \times 5\text{mph})/(1.0\text{ mph})]\hat{}2 = 97 \text{ vehicle speeds}$$

The validation is checked in **Equation 4-1.**

3.3. Developing output and input variables of the model

The average travel speed of vehicle types is set as output variable of the model because the average travel speed from the model is going to be used for PCE estimation and the PCE for urban midblock sections is better reflected by speed due to the following reasons;

I. Speed is one of the main factors directly influencing mobility and LOS [6].

II. For urban roads, the travel speed is used as a Measure of Effectiveness for defining the Levels of service [2].

III. PCE for a type of vehicle depends upon traffic composition, total volume of the road and physical dimension of the vehicle. Any change in the traffic volume or composition of traffic stream influences the speed of individual vehicle type

Therefore; speed is viewed as a superb variable to decide the overall impact of individual vehicles on the traffic stream.

Traffic flow of each vehicles is used as input variables because as [1] States that vehicle to vehicle interaction in a traffic stream is dependent on the flow and proportion of a specific type of vehicle. Increasing the flow results in increasing the density of the traffic stream leads to a change in travel speed of individual vehicle types. Therefore, considering classified traffic flow as input variables was a better approach for better estimating average travel speed.

3.4. Study design

To achieve the specific objectives set, ANN model is applied for predicting the average travel speed of each vehicle types observed on the study site and [4] formula is used for estimating the PCE of every vehicle type. Average travel speed of vehicles types is the dependent variable in the model and traffic flows of each vehicle groups are independent variables that govern the change in travel speed. Other factors like geometric parameters and environmental conditions for roadway also affect the average travel speed [1]. However, they were kept constant for the study by taking uniform sections and collecting the data in similar environmental condition so only traffic characteristics like traffic composition, traffic volume and traffic density should govern the changes in speed. The model estimated average travel speed and projected area of vehicle groups was used to estimate PCE which is the next dependent variable. PCE is given by the ratio of average travel speed of passenger car to average travel speed of vehicle type divided by the ratio of projected area of a passenger car to projected area of vehicle type.

3.5. Data collection

To achieve the objectives of this study, primary source of data is used for all variables. Primary data was obtained directly from the field in the form of videography survey and field linear measurement. So as to collect all necessary field data for the ANN model first 5 straight tangent sections was selected using preliminary survey which meets the criteria considered in study section selection. At each selections traffic data was collected so that a good variation in traffic composition and volume indicating free flow condition to near capacity level was observed.

3.5.1. Video graph survey

Video graph survey was employed for data collection by recording the movement of vehicle on selected road sections. The video recording was 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 by vehicles to traversing the section.

Study length of road section is most of the time recommended based on average speed of traffic stream for reliable observer reaction time [33]. They present three conditions listed below;

I. For traffic stream average speed less than 40 km the study length is recommended to be 30m.
II. For traffic stream speed less between 40-65 km/hr. the study section is recommended to be 60m.
III. For traffic stream average speed greater than40 km the study length is recommended to be 90m.

The study length of road section for this study was decided by assuming the average speed of vehicle traffic is equal to posted speed limit. The mainline highway of the ring road posted speed limit is 70km/hr as shown in **Figure 3-8**. Therefore; the study length of road section taken was above 90m.

Figure 3-8 Ring road posted speed limit

Figure 3-9 Video recorded around Megenagna institution area

Figure 3-10 Video recorded around German roundabout buildup area

Figure 3-11 Video record around Saris abo commercial area

Figure 3-12 Video recorded around Atenatera residential area

Figure 3-13 Video recorded around Tor hayiloch institutional area

3.5.2. Field linear measurement

Length and width of every type of vehicle and stretch length was obtained using field linear measurement on the road segment using linear tape.

3.6. Research method

Overall sequences followed for this research is presented hear under.

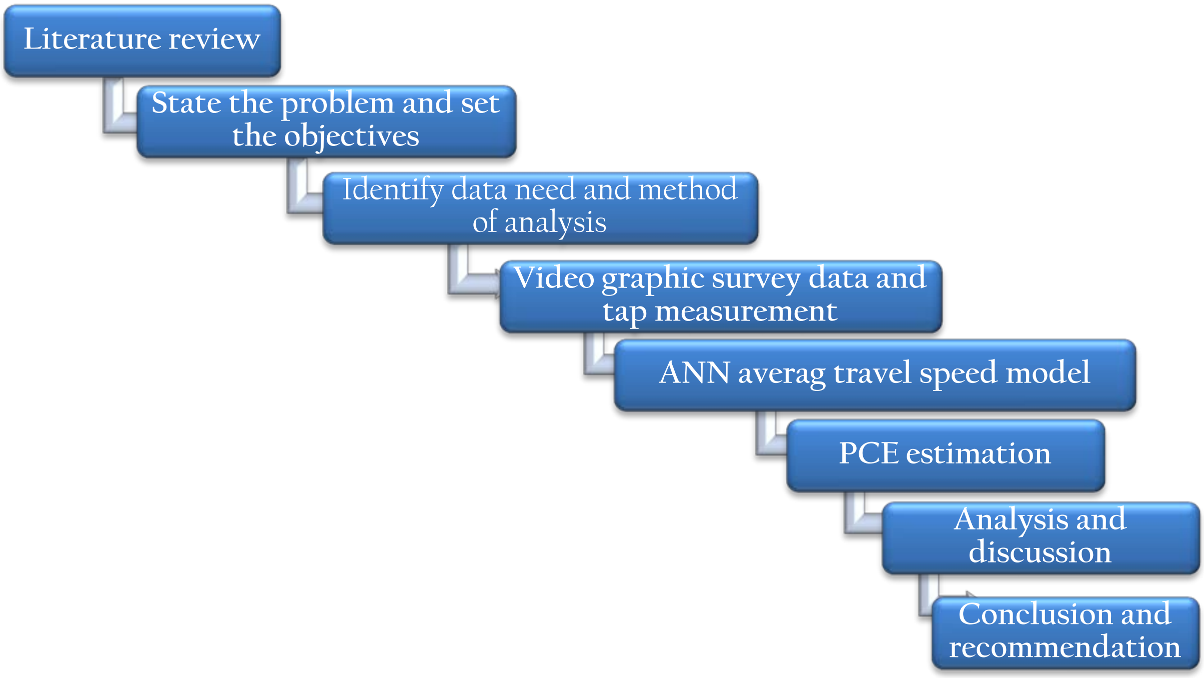

Figure 3-14 Adapted research method

3.7. Data Extraction

After all data are collected for each study section, data required for the study was extracted from recorded video which includes vehicle types, beginning and ending time of individual vehicle.

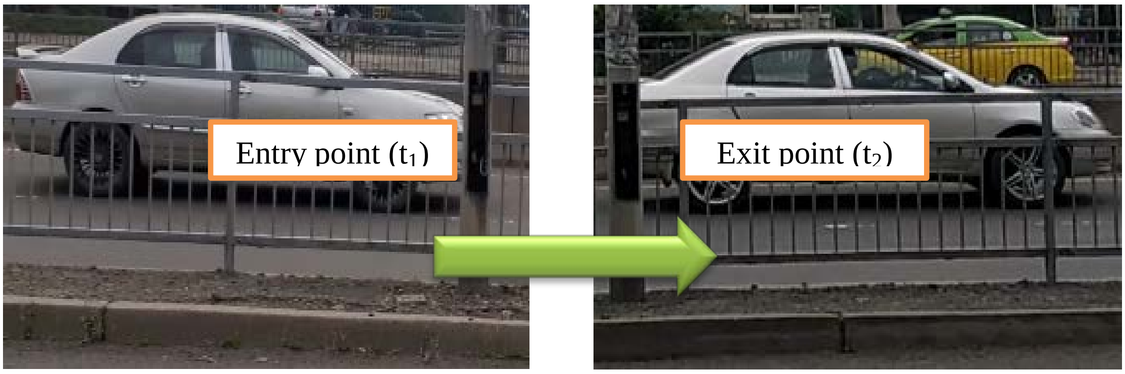

Figure 3-15 Vehicle entry and exit time

3.7.1. Vehicle classification

All vehicles were classified into five categories based on Addis Ababa transport agency classification and size of the cares which affects the travel speed of a traffic stream observed during data collection. Heavy trucks and track trailers are observed in the road very rarely and they are ignored also big bus are summed up with bus as their number in a 5 minute data set is very small.

I. **Passenger car:** This group includes vehicles in which their primarily function is carrying passengers. Vitz, Yaris, Corolla, Taxi and other four wheel small cares are included in this group. The projected area of these vehicles was measured in the field by taking average of all observed small vehicle types.

II. **Pickup and Land cruiser:** These groups of vehicles include pickup, ambulance and land cruiser which has a relative high projected area than PC. The projected area of these vehicles was measured in the field by taking the average of pickup and land cruiser.

III. **Minibus:** This group of vehicles can carry a maximum of 15 passengers. The projected area of this vehicle is measured in the field.

IV. **Bus:** This includes all types of buses carrying passengers with two axles and six tires the projected area was measured in the field for medium bus only because the observed number of large buss in a 5 minute data point is very rare.

V. **Truck:** This class includes trucks which have two axles. The projected area of this vehicle is measured in the field.

Table 3-3 Projected area of vehicles

vehicle type	PC	Pickup & LC	Minibus	Bus	Truck
Length (m)	3.2	4.6	4.6	7.7	6.6
Width (m)	1.7	1.8	1.9	2.2	2.2
Projected Area (m^2)	5.44	8.28	8.74	16.94	14.52

Passenger car and taxi was used as passenger cars and the rest vehicle types PCE was estimated by taking the passenger car and taxi as reference vehicle for PCE estimation.

3.7.2. Spot speed data extraction

After linear measurement and video data recorded, the filmed video was played using VLC video player which count by minute, second and millisecond. Travel time of each vehicle was fond by deducting the end and beginning time of individual vehicles and travel speed of each vehicle was calculated by dividing length of segment to travel time.

$$Travelspeed(V)(kph) = \left[\frac{[Streatchlength(m)]}{[time(t2-t1)(\sec)]}\right] \times 3.6$$

Table 3-4 Sample spot speed data extraction

Length of Section											
205.4m											
No	Vehicle type	Entry Time(Sec)			Entry Time second	Exit Time(sec)			Exit Time second	Speed (m/s)	Speed (km/s)
		minute	second	milli sec.		minute	second	milli sec.			
1	pc	0	9	370	9.37	0	19	736	19.74	19.8	71.333
2	Truck	0	14	420	14.42	0	29	391	29.39	13.7	49.391
3	Pc	0	17	522	17.522	0	30	677	30.68	15.6	56.210
4	Minibus	0	20	813	20.813	0	32	311	32.31	17.9	64.310
5	Pc	0	21	258	21.258	0	35	67	35.07	14.9	53.5
6	LC	0	22	594	22.594	0	34	365	34.37	17.4	62.8
7	Truck	0	22	851	22.851	0	37	1	37.00	14.5	52.3
8	Truck	0	31	640	31.64	0	45	172	45.17	15.2	54.6
9	Pick up	0	32	791	32.791	0	44	495	44.50	17.5	63.2
10	Pick up	0	33	213	33.213	0	45	449	45.45	16.8	60.4

For 45 minute traffic data collected three times in each section considering different flow scenarios a total of 14344 vehicular spot speed data are collected. A one sample is shown in appendix **Table A-1.**

3.7.3. Average speed and flow calculation

Average travel speed and flow data's were determined taking a 5 minute traffic data which allows at list a minimum required number of vehicles set in sample size are observed.

I. Average travel speed: It is the average of all travel speed of each vehicle types under study for a 5 minute time interval.

$$Average travel speed (v)(kph) = \frac{\sum number of travel speed}{\sum number of vehicles}$$

II. Flow rate: It is the number of vehicles that pass a pre-determined section length with in 5 minute for each vehicle types.

$$Flow rate (q)(vehicle / hr) = \frac{\sum number of vehicle}{time interval (minute)} \times 60$$

Table 3-5 Sample of average travel speed and flow calculation

Average speed calculation (5min)			
Vehicle Type	Number	Average Speed (km/hr.)	Flow (veh/hr)
Pc and taxi	31	57.6	372
Pick up and LC	28	61.3	336
Minibus	18	60.4	216
Bus	5	52.6	60
Truck	27	48.1	324

For 45 minute traffic data collected three times in each section considering different flow scenarios a total of 675 flow and average travel speed datasets are calculated. A sample of calculation of average travel speed and flow for a five minute time interval is shown in **Table A-2.**

3.8. Data analysis method

This section describes the overall data analysis methodology of the research. For this study, a new technology called artificial neural network was used. The ANN model was employed after an appropriate statically analysis and correlation study.

3.8.1. Average travel speed modeling technique

For this study artificial neural network which works by training the model using known input and output variables was implemented. It is understood that vehicle categories present in the traffic stream would have different influences on overall mobility, these could be handle using the well accepted complex and non-linear relation modeling technique [3]. Their study also indicates ANN has a big role to play in traffic engineering field where a high degree of complex non-linear cause-effect relationship exists. ANN has got best performance in estimation of average speed than simple and weighted linear regression models [22].

ANN model was developed after a care full extraction of input and output variables of the model which are flow rate (q) and average travel speed (V) determined during data extraction phase from videography. A 5 input and 5 output nodes as per the vehicle classification was developed for estimating the average travel speed. Correlation coefficient (R^2) was used for measuring the accuracy.

3.8.1.1.Model development procedures

I. Data division

In this study 70% of the data was used for training, 15% of the data for testing and the remaining 15% for validation.

II. Feed-forward neural network

A multilayered feed forward network with one hidden layer was developed as shown in the finger below; the input signal extends forward through several layers, while it is being processed to estimate the network’s output signal. Each node in hidden and output layers are a processing element associated with the corresponding activation function by which the weighted sum of input values is transformed to determine the output value.

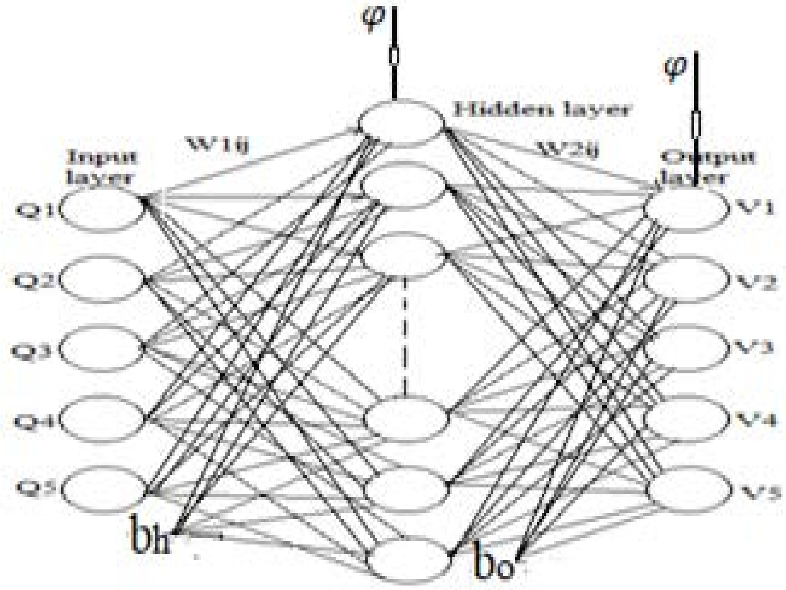

Figure 3-16 Artificial feed-forward neural network model

Where: - Q1 and V1 are flow and average speed of passenger car, Q2 and V2 are flow and average speed of pickup and land cruiser Q3 and V3 are flow and average speed of minibus, Q4 and V4 are flow and average speed of bus, and Q5 and V5 are flow and average speed of truck, $W1_{ij}$ *and* $W2_{ij}$ *is the weight,* b_h *and* b_o *are the biases, and* φ *is activation function*

The hidden and output layer node values are calculated using matrix multiplication as shown below

$$\text{Hidden node } \varphi \left\{ \begin{bmatrix} W1(1,1) & W1(2,1) & - & W1(5,1) \\ W1(1,2) & W1(2,2) & - & W1(5,2) \\ W1(1,3) & W1(2,3) & - & W1(5,3) \\ - & - & - & - \\ W1(1,12) & W1(2,12) & - & W1(5,12) \end{bmatrix} \times \begin{matrix} Q1 \\ Q2 \\ Q3 \\ Q4 \\ Q5 \end{matrix} + \begin{matrix} bh1 \\ bh2 \\ bh3 \\ - \\ bh12 \end{matrix} \right\} = \begin{matrix} H1 \\ H2 \\ H3 \\ - \\ H12 \end{matrix}$$

$$\text{Output node } \varphi \left\{ \begin{bmatrix} W2(1,1) & W2(2,1) & - & W2(12,1) \\ W2(1,2) & W2(2,2) & - & W2(12,2) \\ W2(1,3) & W2(2,3) & - & W2(12,3) \\ W2(1,4) & W2(2,4) & - & W2(12,4) \\ W2(1,5) & W2(2,5) & - & W2(12,5) \end{bmatrix} \times \begin{matrix} H1 \\ H2 \\ H3 \\ - \\ H12 \end{matrix} + \begin{matrix} bo1 \\ bo2 \\ bo3 \\ bo4 \\ bo5 \end{matrix} \right\} = \begin{matrix} V1 \\ V2 \\ V3 \\ V4 \\ V5 \end{matrix}$$

Generally: The hidden layer is given by $\mathrm{Hi} = \varphi\{\mathrm{W1(ij)} \times \mathrm{Qj} + \mathrm{b1j}\}$ and

The speed is given by $\mathrm{Vi} = \varphi\{\mathrm{W2(ij)} \times \mathrm{Hj} + \mathrm{b2j}\}$

Then the network uses the output from the neural network and compares it with the correct output to work out an error and the error is used to refine the neural network. This process is done continuously until network outputs which are related with correct output with acceptable error was fined. This is done using back-propagation training function.

III. Back-propagation

Back Propagation is a way of training the neural network.

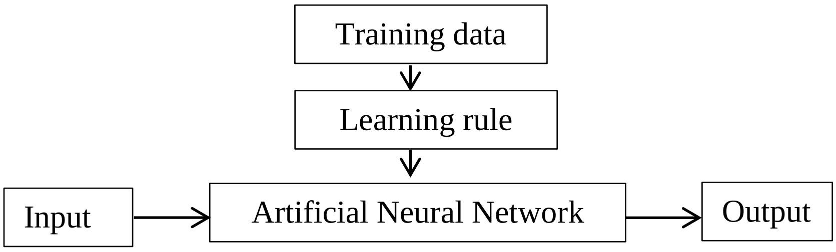

Figure 3-17 Learning method

The ANN model is trained using supervised learning method which uses already known input and output of the data. The training data contains inputs and correct outputs. In MATLAB2 different training and activation functions are available which are shown **Table 3-4.**

Table 3-6Training and activation functions

Back propagation training function	Activation function
BFGS Quasi-newton (TF1)	Log-Sigmoid (AF1)
Baysesian regularization (TF2)	Pure line (AF2)
Conjugated gradient with beale-powell restart (TF3)	Tan-sigmoid(AF3)
Conjugate gradient with Polka-Ribiere update (TF4)	-
Gradient descent (TF5)	-
Gradient descent with momentum (TF6)	-
Gradient descent with adaptive learning rate (TF7)	-
Gradient descent with momentum and adaptive learning rate (TF8)	-
Levenberg-Marguardt (TF9)	-

Back propagation training function	Activation function
One step secant (TF10)	-
Random weight/bias rule (TF11)	-
Resilient back propagation (TF12)	-
Scale conjugated gradient (TF13)	-
Log-Sigmoid Pure line Tan-Sigmoid (TF14)	-

Therefore, different combinations of these training and activation functions are tasted and the one which yields the best performance is chosen.

- **Error calculation for output and hidden layer**

Neural networks learn by updating their link weights. This is guided by the error the variation between the right answer given by the training data and their actual output. The error at the output nodes is simply the difference between the correct and actual output however; the error associated with internal nodes is not obvious.

- **Updating the weight for output and hidden layer**

A neural network's error is a function of the internal link weights. Improving a neural network means reducing this error by changing those weights. Choosing the right weights directly is too difficult.

IV. Preparing data for the artificial neural network

The neural network rescales the collected input and output data to the range as the activation function used in the ANN model development. As a result the maximum value from the collected data takes the maximum and the minimum value from the collected data takes the minimum of the activation function value during normalization. The developed model is going to estimate future output with in this range of datasets.

3.8.2. Passenger car equivalence estimation approach

PCE factor by [8] which includes speed and projected area of every vehicles in their equation is used for these study; this is associated with the following advantages.

- Speed is precisely quantifiable in field, and it represents the working condition on the road by mobility and LOS [1].

- For urban principal arterial roads, the travel speed is utilized as a measure of effectiveness for defining the levels of service [2].
- Speed is viewed as a great variable to decide the general impact of individual vehicles on the traffic stream [6].
- The actual size of a vehicle is a pointer of asphalt inhabitance, which is essential in operational attributes of traffic stream [5].

The physical size of a vehicle is an indicator of pavement occupancy, which is crucial in operational characteristics of traffic stream. In traffic with lane discipline, the occupancy is controlled by the length of vehicle however; in the condition where vehicles do not follow lanes strictly, the occupancy is better reflected by area [6]. This case represents the existing condition more precisely than other possible options as presented in the literature review of this paper. Therefore; PCE for this study is estimated using the formula given by **Equation 2-1.**

The speed of the vehicles was found from the model. The projected area was measured for each vehicle type observed in the field.

3.9. Collected traffic data property

3.9.1. Volume and composition of observed vehicles

The table below shows number and composition of vehicles observed during data collection passenger car are predominant with 46.69% whereas composition of other vehicles categories (land carouser and pickup, minibus, bus, and tuck) varies from 5.41% to 19.62% as shown in **Table 3-5.**

Table 3-7 Volume and composition of collected data

Vehicle type	Passenger car and taxi	Land-cruiser and Pickup	Minibus	Bus	Truck
Number	6697	2814	2799	776	1246
Percentage (%)	46.69	19.62	19.59	5.41	8.69

3.9.2. Traffic composition in each section

The volume of traffic at Atenatera section is small compared to other section. Haile garment and Ayertenat sections characterized high percentage of large size vehicles (Bus and Truck) compared to other sections. All sections have high percentage of small cars compared to other vehicle type from this Kality section has high percentage of small cars followed by Megenagna section as shown in **Figure 3-18.**

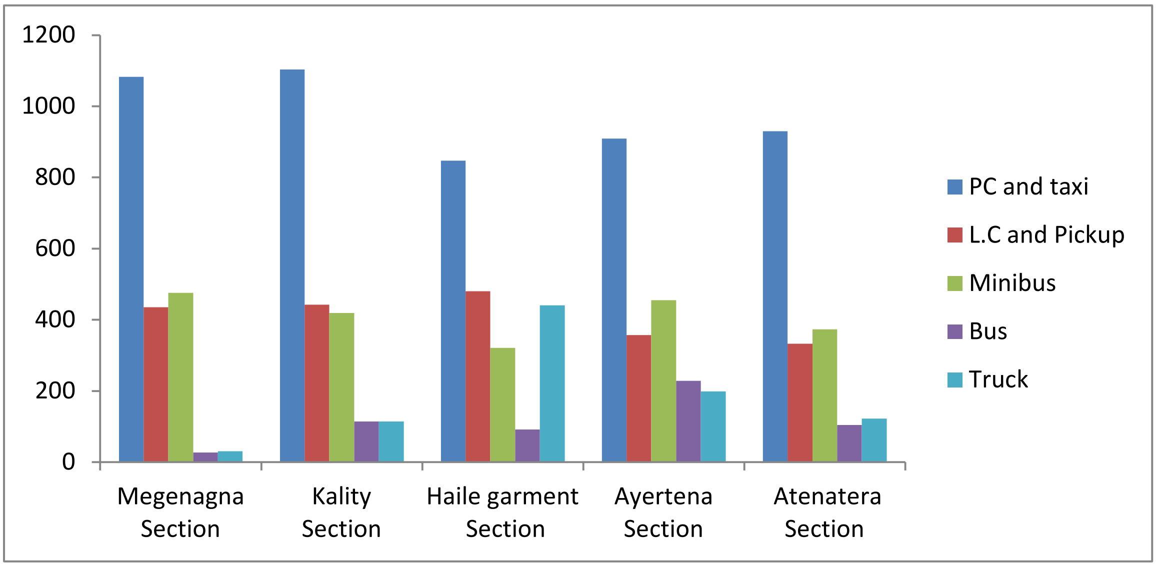

Figure 3-18 Traffic composition of all section.

3.10. Research Materials

The following software's were used in the preparation of the research;

- Linear tape –To measure stretch length and length and width of vehicle type.
- VLC video player – For extracting the spot speed data.
- Microsoft Word 2010- For main text writing.
- Microsoft Excel 2010- For data analysis, manipulation, and plot.
- STATASe13 and IBM SPSS- Statistics 22 for statistical analysis.
- MATLABR2015a for speed model development.

CHAPTER 4 RESULT AND DISCUSSION

In this part, the result and discussion of artificial neural network model for determining the average travel speed of vehicle groups from different composition and volume scenario analysis were conducted first then passenger car equivalence relation with volume and composition is characterized taking small vehicles as a reference vehicle.

4.1 Checking the adequacy and consistency of data

The adequacy and consistency of data is used for checking the data points for average travel speed and flow calculations have at least the required minimum number of vehicles estimated in $sample.size = \left[\frac{z \times \partial}{e} \right]$ all sections data points are checked for the minimum number of vehicles for average speed study given by **Equation 3-1** which is 97. It’s cheeked as shown in table for each datasets developed in all five sections and the agreement is indicated in **Table A-5 Checking adequacy and consistency of data**

4.2 Checking statistical requirements of ANN model

4.2.1 Descriptive statistics

The descriptive statistics for average travel speed and traffic flow rate is indicated in **Table 4-1**

Table 4-1 Descriptive statistics for collected data

Variable	Obs.	Mean	Median	Minimum	Maximum	SD
Average Speed (km/hr.)	675	56.26	55.33	23.6	90.8	20.08
Flow	675	187	144	12	1248	184.47

The descriptive statistic indicates that the mean and median of speed are almost equal and the standard division of Average travel speed is high. This indicates that the average travel speed is nearly normally distributed and there is grate variability between spot speeds of each vehicle.

4.2.2 Validity of sample size

The validation of sample size for minimum number of vehicles used for average travel speed calculation is important to cheek the number of vehicles used for average travel speed estimation was enough or not. To do this the sample size required for real traffic data is calculated by using standard deviation and root mean square error of the collected data. The standard deviation of the collected speed data is 20km/hr and mean root square error of the model for all vehicles 4.1km/hr as shown in **Table A-7** . Therefore, the required number of vehicles for speed determination is calculated below

$$samplesize = \left[\frac{1.96 * (20 * 0.621)mph}{(4.1 * 0.621)mph}\right] = 92 vehiclespeed \qquad \textbf{Equation 4-1}$$

The minimum number of vehicles from the 5minitue dataset in which average travel speed and flow is calculated is 97 which are above the required 92.

4.2.3 Dependent and independent variables relation.

If the number of independent variables are more than one the relation between independent variables should be investigated as the neural network method requires that; there should not be strong relation between independent variables, but as we have one independent variable the correlation between dependent and independent variables is cheeked. There should be an interaction between the dependent variable and the independent variable and this is checked by pairwise correlation coefficient.

Table 4-2 Pairwise correlation of dependent and independent variables

Variable	V	Q
V	1	-0.2691
Q	-0.2691	1

The above table indicates that the relation between average travel speed and flow rate is -0.2691. This indicates an increase in flow rate results a decrease in travel speed by 27%

4.2.4 Dependent variable requirement

The dependent variable should be continuous and normally distributed. The normal distribution of dependent variable can be observed by plotting histogram and using kurtosis and skewness. As shown in bell-shaped normal distribution graph **Figure 4-1,** it was almost normally distributed which has almost equal mean and median.

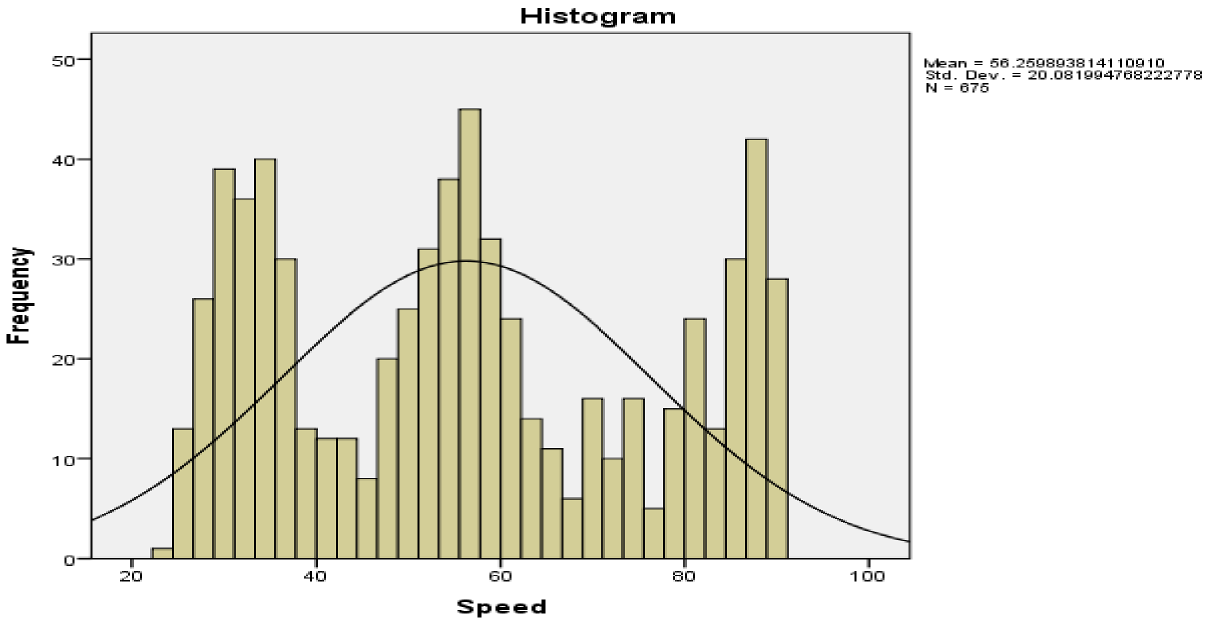

Figure 4-1 Normal distribution graph

Kurtosis and skewness are descriptive Statistics used to evaluate the normality of continuous dependent variable depend on the number of sample. If the number of sample is greater than 300 the absolute value of skewness and kurtosis should be less than 2 and 7 respectively as shown in **Table 4-3** below the criteria meets.

Table 4-3 Normality test using kurtosis and Skewness

	N	Skewness		Kurtosis	
	Statistic	Statistic	Std. Error	Statistic	Std. Error
Speed	675	.212	.094	-1.187	.188
No sample	675				

4.2.5 Checking Outlier data

The box plot is used for identifying the outlier data point in the dataset. Outlier data should be excluded from the analysis because it is different from the other datasets and considered as false data. The box blot show as the outlier data and the data should be in the range of first and fourth quartile to be used for further analysis; if there is data outside this it should be ignored. Accordingly, the box-plot in **Figure 4-2** assured that, there was no outlier for the speed data.

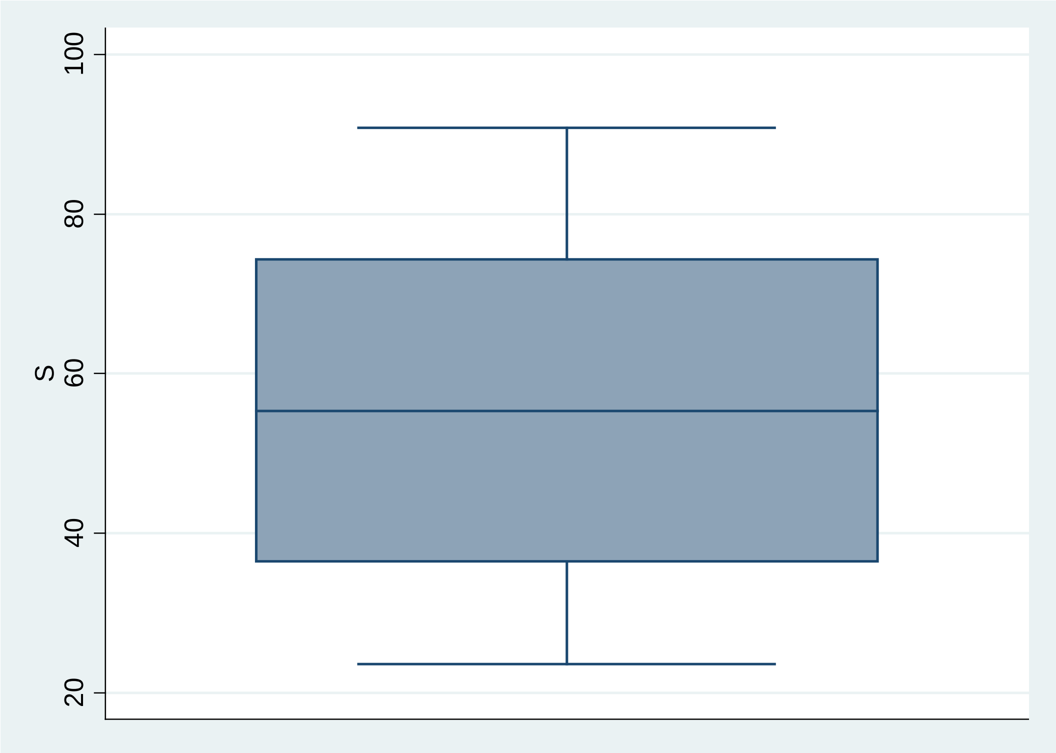

Figure 4-2 Boxplot to see outlier data

4.3 Developing artificial neural network model

After all the requirements from the statistical analysis for ANN model are satisfied the neural network is constructed using MATLAB. Since we have five categories of vehicle types a five input by a five output neural network is developed.

4.3.1 Data processing

The total of 135 samples of every vehicle types datasets is randomly divided for training (70% of the data), tasting (15% of the data), and validation (15% of the data) in ANN model.

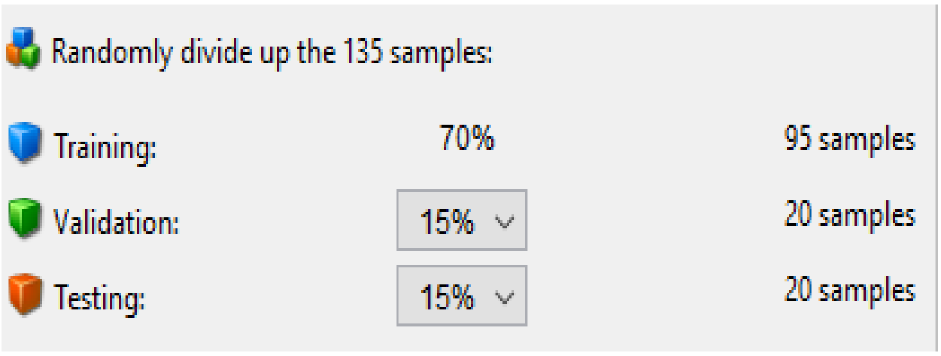

Figure 4-3 Datasets divided for training, validation, and testing

4.3.2 Constructing ANN

A five input (classified traffic flow) and a five output (classified average travel speed of vehicles) artificial neural network was developed.

- **Finding the optimum number of hidden neurons**

For this case the network is trained for default training and activation function (Levenberg-Marquardt and Tan-sigmoid) by varying the number of hidden neurons and measuring the accuracy to get the optimum number. The accuracy is measured using correlation coefficient (R^2) which indicates the degree of determinacy of independent variables to dependent variable.

From the **Figure 4-4,** a 12 hidden neuron number gives the maximum correlation coefficient value is chosen on hidden layer. This value indicates flow rate of each vehicle type determines the speed of the vehicles for each vehicle class considered 94.5%.

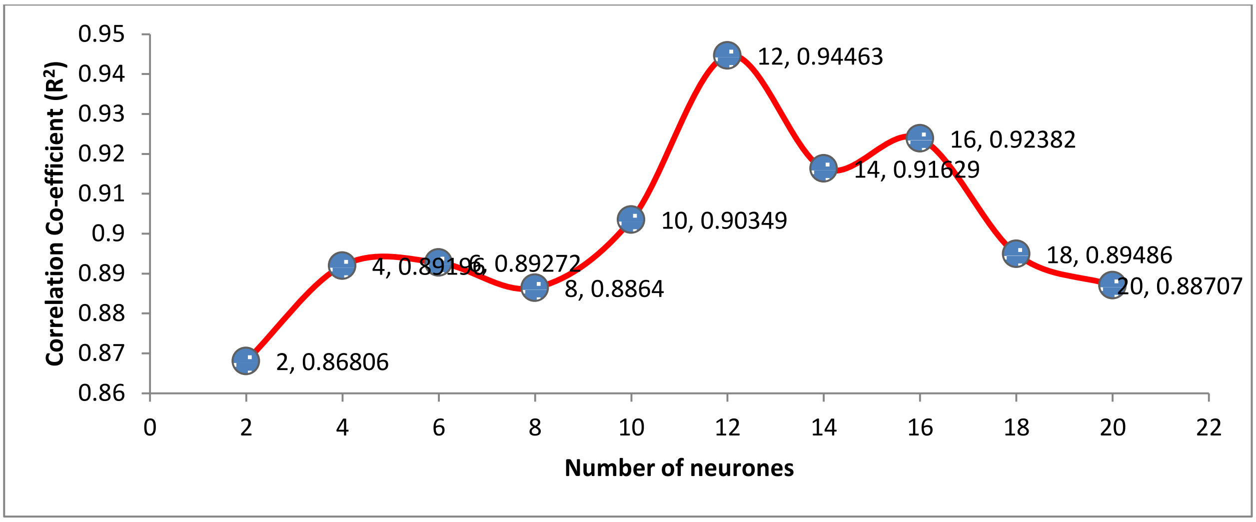

Figure 4-4 Optimum number of neurons

- **Finding the best training and transfer function**

Different ANN models are tried by a combination of training and transfer functions available in the MATLAB as shown in **Table 3-6** with the optimum number of neurons. After training all combinations for all collected datasets the one which yields high correlation coefficient (R^2) is selected. From this taste the combination of Levenberg marquardt (TF9) training function and tan-sigmoid (AF3) activation produces the best generalization with 94.5% determining capacity as shown in **Figure 4-5.**

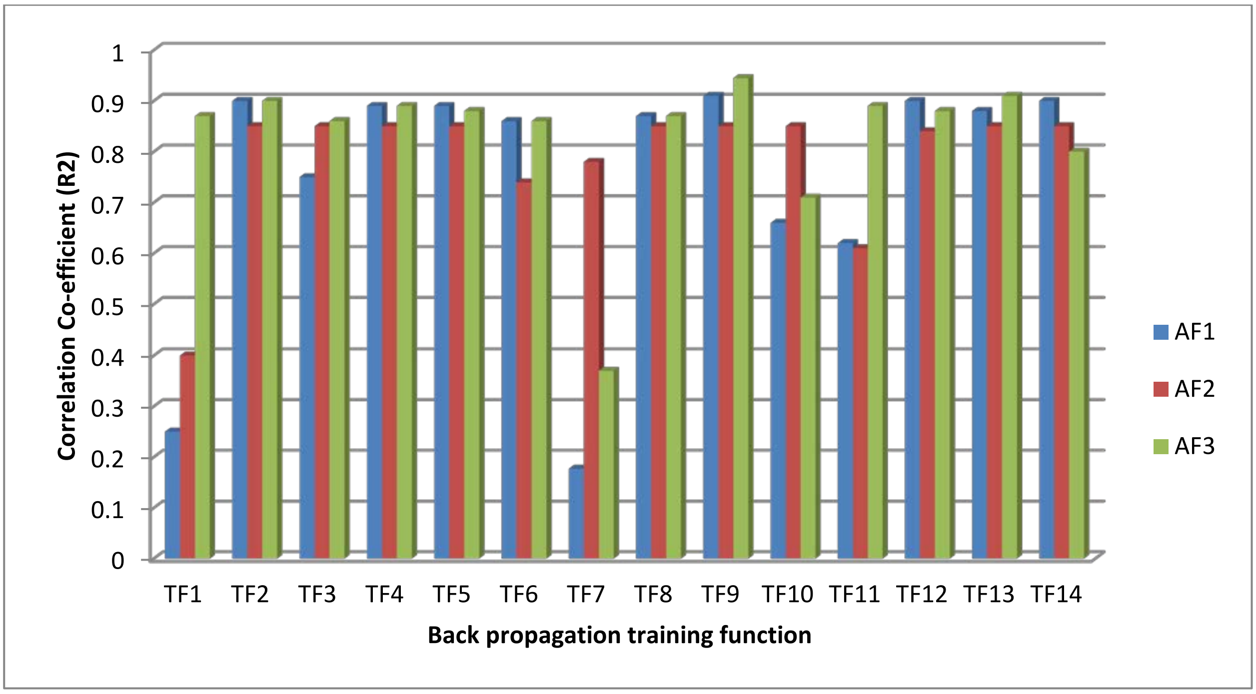

Figure 4-5 Best fitting training and activation function

Creating the network

The network is created using MATLAB as shown in **Figure 4-6.**

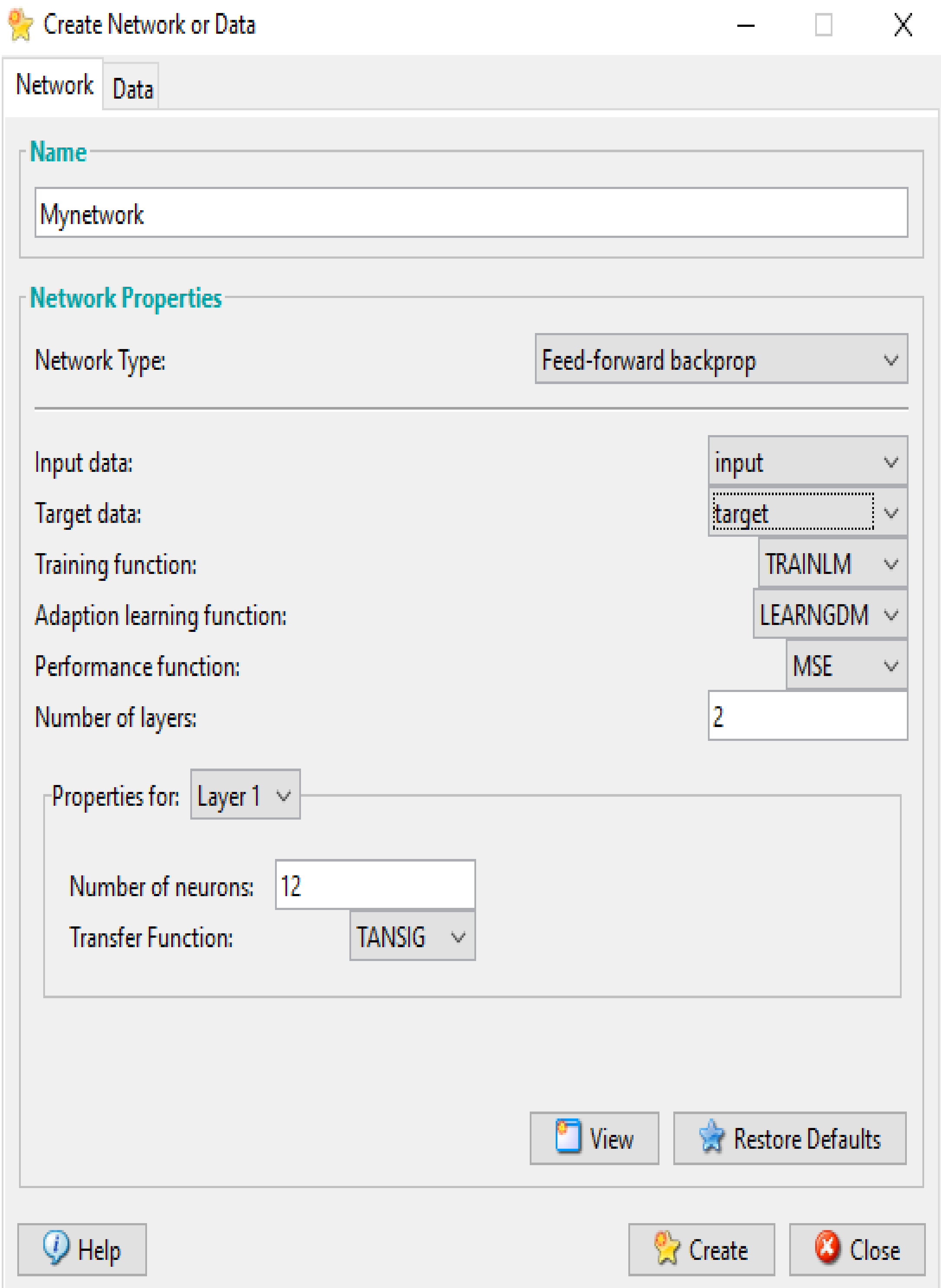

Figure 4-6 Artificial neural network creation

Develop architecture of ANN

For developing the architecture of the artificial neural network we have five inputs which pass through a hidden layer which have weights, biases and an activation function then pass through an output layer which also has weights and biases which then passes through an activation function to give an output as shown in **Figure 4-7.**

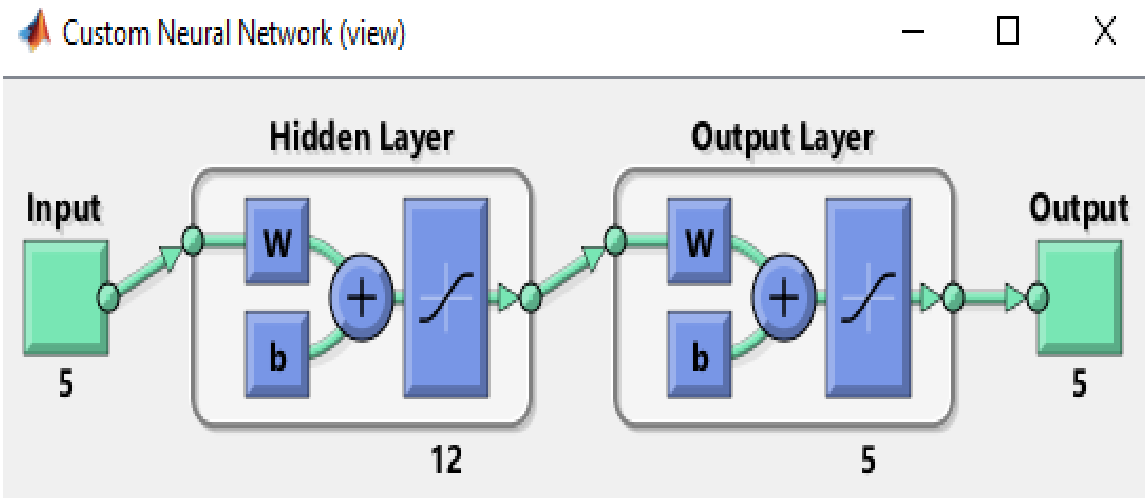

Figure 4-7 Artificial neural network architecture

4.3.3 Training the network

This data are presented to the network during training and the network is adjusted according to errors until the network stops improving with acceptable R^2 value. The network is trained for 90 datasets from each vehicle groups.

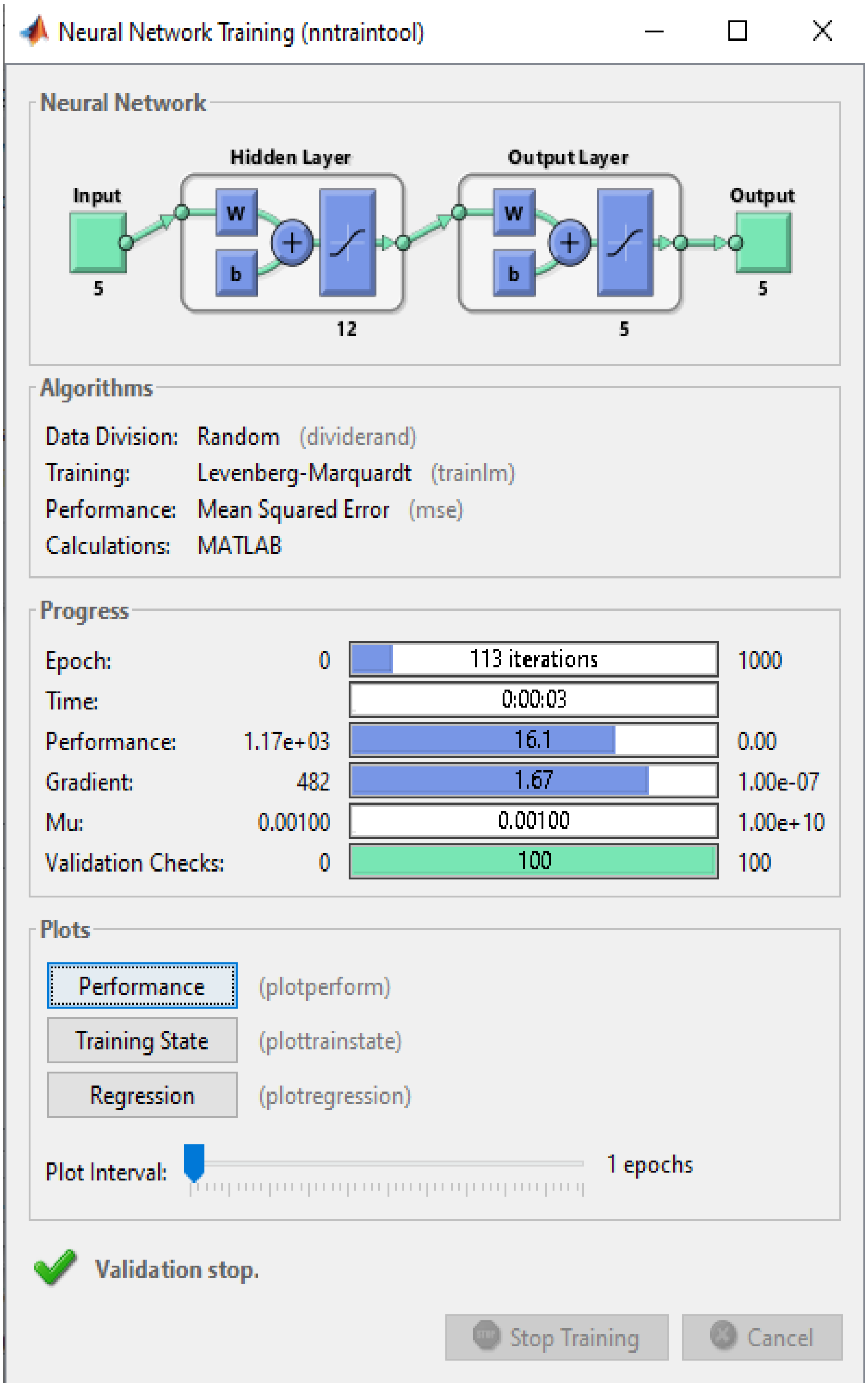

Figure 4-8 Artificial neural network training

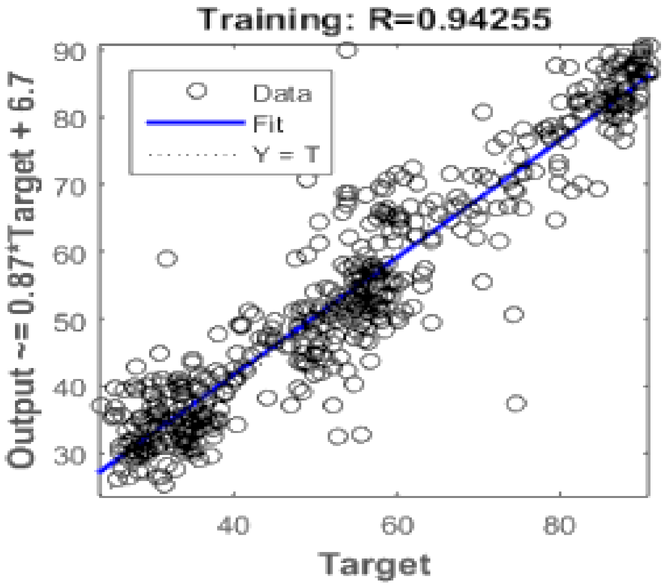

Figure 4-9 Regression plot of ANN output with respect to training set

- **Tasting**

These have no impact on training; it's a free measure of network performance during and after training. Through this process, the ANN finds the predicted values and compares them with the target output values using data that was not used in the training or validation process. After training the network is given with tasting data of 20 datasets from each vehicle groups to check the performance of the network.

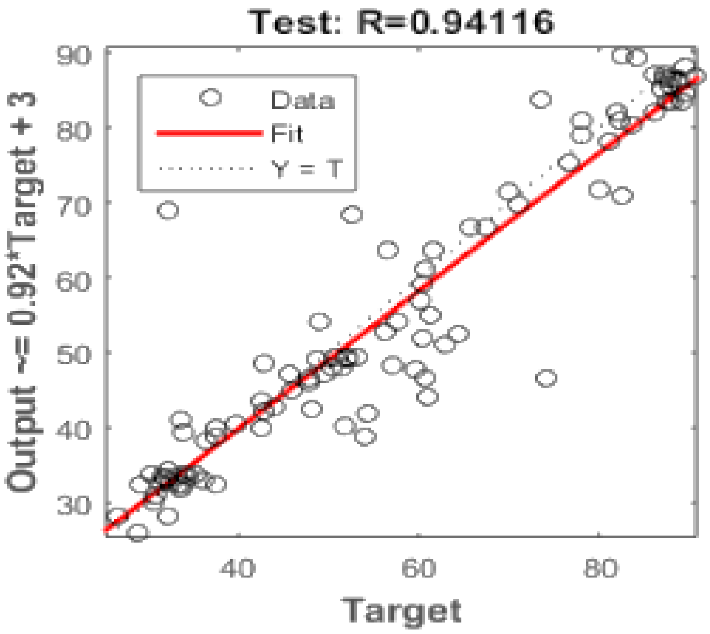

Figure 4-10 Regression plot of ANN output With respect to test set

- **Validation**

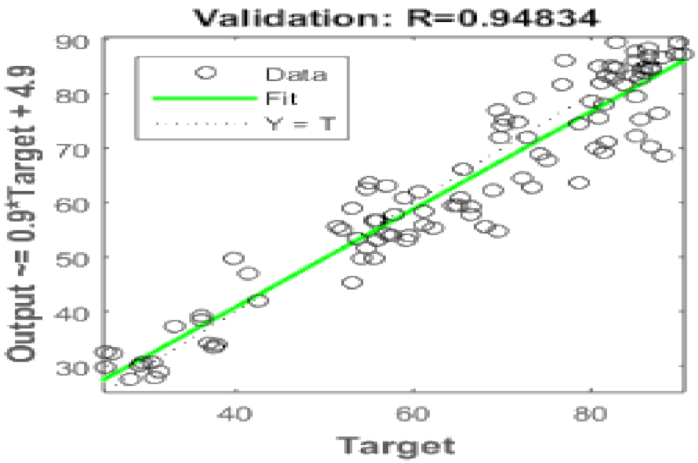

Figure 4-11 Regression plot of ANN output with respect to validation set

This are utilized to quantify network generalization and to end training when generalization quits improving. On this process, no adjustment occurs to the weights. After training the network is given with the validation data 20 datasets from each vehicle groups and then the predicted data is compared with the training process to improve the performance of the model.

- **All datasets**

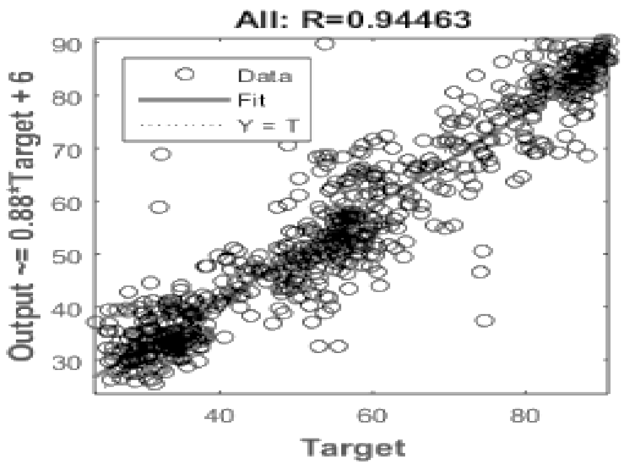

Figure 4-12 Regression plot of ANN output with respect to overall data set

For an ideal fit, the data should fall along a 45-degree line, where the network yields are equivalent to the targets. For this research as can be seen from **Figure 4-9** for training dataset, **Figure 4-10** for tasting dataset **Figure 4-11** for validation dataset and Figure 4-12 for all datasets the fit is reasonably good with 94% and above the network outputs are equivalent to the target values. The artificial neural network also produces a comparison between the actual and the predicted values using the ANN model produced in the 675 results shown in **Table A-6 Model estimate output**.

4.3.4 Data normalization

The neural network toolbox applies some transformation to the given input and target data in the range of -1 and 1 as of the activation function used to do this the network uses the maximum and the minimum value of the dataset from each vehicle group.

$$Xnew = \frac{(X - (\frac{\max + mi))}{2}}{(\max - (\frac{\max + \min}{2}))}$$

Where X is the collected data, Xnew is the transformed data; min and max values are the maximum and minimum value of the collected data from each vehicle group

4.3.5 Model output

- **Weight and bias values from the model**

The weight and bias values are the basic output of the model used for future estimating of travel speed of vehicle types under different volume and travel condition.

i. Weight to hidden layer from input

Table 4-4 Hidden layer weight value

-0.41307	1.1202	0.44719	1.9258	1.0974
2.4848	0.66833	-0.79208	-2.234	0.57332
-3.4647	5.1426	0.15845	0.19524	0.10244
3.9947	-0.97889	0.017269	-0.56411	0.70968
-3.0111	-0.574	2.962	-1.2269	4.9247
-7.3456	3.3174	2.3979	2.9071	-1.6971
8.8427	-0.99312	3.8287	-0.8816	-2.5037
-0.54485	0.45545	-0.83111	0.4031	-0.31994
3.4353	-2.7455	3.3919	-2.2367	3.3288
1.8439	0.34872	-1.0556	1.1223	-2.1121
1.0053	-1.1913	2.4131	-1.3908	5.47
2.1786	-3.2674	5.4221	7.1007	1.1794

ii. Bias to hidden layer

Table 4-5 Hidden layer bias value

-3.2169	-3.74	2.0793	0.44488	0.23124	0.39383	4.179	-1.1254	6.0042	3.4427	-4.4742	12.0341

iii. Weight to output layer from hidden layer

Table 4-6 Output layer weight value

-0.22573	2.5673	-0.32032	-1.6862	-0.62657	-0.50195	-0.67054	-4.2408	-2.3414	1.4358	1.2537	-0.4652
-0.19018	0.84463	-0.36541	-1.8496	-0.65121	-0.60488	-0.70432	-4.7248	-2.7103	1.4634	1.2522	-0.47576
0.18168	0.91329	-0.39689	-1.7521	-0.69503	-0.59023	-0.71732	-4.7153	-2.188	1.4341	1.1761	-0.62045
1.974	0.093497	-0.14876	-1.9262	-0.63814	-0.77392	-0.60054	-4.9099	0.52399	0.59231	3.2787	-2.0765
0.22675	0.66657	0.064012	-1.5867	-0.61738	-0.64974	-0.5501	-5.1931	-2.6503	1.3449	1.1004	-0.60212

iv. Bias to output layer

Table 4-7 Output layer bias value

1.2575	-0.45097	-0.38825	1.7873	-0.92603

v. Transfer function

The transfer function used is tan sigmoid given by $\varphi = (\frac{2}{1+\exp^{-2*X}}) - 1$

4.4 Estimating average travel speed of vehicles

Based on the weight and bias result of the neural network the average travel speed of a vehicle is given by the matrix equation below. To calculate average travel speed the following steps are used.

Step 1: The new flow data for each vehicle types are transferred using the equation below

I. $Pcflow = \frac{(flow - 678)}{1248 - 678}$

II. $PickupandLC = \frac{flow - 228}{444 - 228}$

I. $Minibusflow = \frac{(flow - 210)}{396 - 210}$ **Equation 4-2**

III. $Busflow = \frac{(flow - 144)}{(276 - 144)}$ and

IV. $Truckflow = \frac{(flow - 204)}{(396 - 204)}$

Step 2: Estimating the magnitude of hidden layer

$$\varphi\left\{\begin{bmatrix} -0.4130 & 1.1202 & 0.44719 & 1.9258 & 1.0974 \\ 2.4848 & 5.1426 & -0.79208 & -2.234 & 0.57332 \\ -3.4647 & -0.97889 & 0.15845 & 0.19524 & 0.10244 \\ 3.9947 & -0.574 & 0.017269 & -0.56411 & 0.7096 \\ -3.0111 & 3.3174 & 2.962 & -1.2269 & 4.9247 \\ -7.3456 & -0.99312 & 2.3979 & 2.9071 & -1.6971 \\ 8.8427 & 0.45545 & 3.8287 & -0.8816 & -2.5037 \\ -0.54485 & 3.4614 & -0.83111 & 0.4031 & -0.31994 \\ 3.4353 & -2.7455 & 3.3919 & -2.2367 & 3.3288 \\ 1.8439 & 0.34872 & -1.0556 & -1.39083 & -2.1121 \\ 1.0053 & -1.1913 & 2.4131 & -1.3908 & 5.47 \\ 2.1786 & -3.2674 & 5.4221 & 7.1007 & 1.1794 \end{bmatrix} \times \begin{matrix} Qpc \\ Qpickup\&LC \\ QMinibus \\ QBus \\ QTruck \end{matrix} + \begin{matrix} -3.2169 \\ -3.74 \\ 2.0793 \\ 0.44488 \\ 0.23124 \\ 0.39383 \\ 4.179 \\ -1.1254 \\ 6.0042 \\ 3.4427 \\ -4.4742 \\ 12.0341 \end{matrix}\right\} = \begin{matrix} H1 \\ H2 \\ H3 \\ H4 \\ H5 \\ H6 \\ H7 \\ H8 \\ H9 \\ H10 \\ H11 \\ H12 \end{matrix}$$ **Equation 4-3**

Step 3: Estimating average travel speed of each vehicle types

$$\boldsymbol{\varphi}\left\{\begin{bmatrix} -0.22573 & 2.5673 & -0.32032 & -1.6862 & --0.62657 & -0.50195 & -0.67054 & -4.2408 & -2.3414 & 1.4358 & 1.2537 & -0.4652 \\ -0.19018 & 0.84463 & -0.36541 & -1.8496 & -0.65121 & -0.60488 & -0.70432 & -4.7248 & -2.7103 & 1.4634 & 1.2522 & -0.47576 \\ 0.18168 & 0.91329 & -0.39689 & -1.752 & -0.69503 & -0.59023 & -0.71732 & -4.7153 & -2.188 & 1.4341 & 1.1761 & -0.62045 \\ 1.974 & 0.093497 & -0.14876 & -1.9262 & -0.63814 & -0.77392 & -0.60054 & -4.9099 & 0.52399 & 0.59231 & 3.2787 & -2.0765 \\ 0.22675 & 0.66657 & 0.064012 & -1.5867 & -0.61738 & -0.64974 & -0.5501 & -5.1931 & 0.52399 & 1.3449 & 1.1004 & -0.60212 \end{bmatrix} \times \begin{matrix} H1 \\ H2 \\ H3 \\ H4 \\ H5 \\ H6 \\ H7 \\ H8 \\ H9 \\ H10 \\ H11 \\ H12 \end{matrix} + \begin{matrix} 1.2575 \\ -0.45097 \\ -0.38825 \\ 1.7873 \\ -0.92603 \end{matrix}\right\} = \begin{matrix} VPC \\ VPU\&LC \\ Vminibus \\ Vbus \\ V5truck \end{matrix}$$ **Equation 4-4**

Step 4: Reverse transformation of network output

I. $Pcspeed = networkoutput \times (90.8 \times 58.7) + 58.7$

II. $PickupandLCspeed = networkoutput \times (90.6779 - 59.589) + 59.589$

III. $Minibusspeed = networkoutput \times (90.8 - 59.4) + 59.4$ **Equation 4-5**

IV. $Busspeed = networkoutput \times (89.8527 - 57.5263) + 57.5263$

V. $Truckspeed = networkoutput \times (89 - 56.3) + 56.3$

4.4.1 Effect of traffic composition and volume on average travel speed

This model is used for estimating the average travel speed of a vehicle type in different volume and composition scenario observed in the ring road. To see the impact of traffic volume and composition on the travel speed of every vehicle type two conditions are considered below.

4.4.1.1. Impact of traffic volume on average travel speed

These conditions allow as seeing the change in travel speed of a vehicle types when the traffic volume varies. The traffic volume is varied with in the observed range of vehicle types and the composition is constant which is related to the observed composition of vehicles during data collection **Table 3-5.**

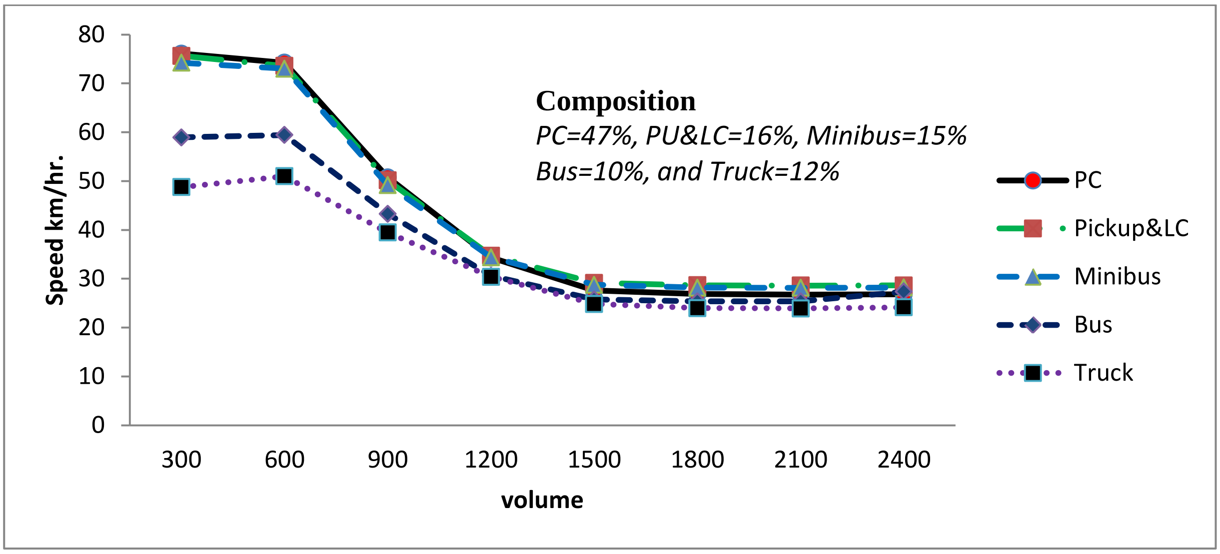

Figure 4-13 Effect of volume on travel speed of vehicles

From the **Figure 4-13** it's observed that the speed of a vehicle decreases (from 76 km/hr to 26.8 km/hr for PC, 75.6 km/hr to 28.6 km/hr for Land cruiser and pickup, 74.2 km/hr to 28 km/hr for bus, and 48.7 km/hr to 24.1 km/hr for truck) as the traffic volume increases which agree with the study done by [7]. However, the speed reduction is significant for moderate flow conditions whereas for pick and free flow the reduction in speed is very low. This is because at free flow the vehicles are traveling without any restriction, when the volume gets increased their speed is going to restricted by the presence of other vehicles in the traffic stream this results in reduction of travel speed. The reduction in travel speed is not uniform for all vehicles, trucks and bus reduce their speed at a relatively low rate compared to other vehicle types this is associated with small vehicles that are PC, pickup (land cruiser), minibus travel at a very high speed in unsaturated conditions compared to truck and bus as the volume gets increase they also maintain high speed than truck and bus because of their advantage to use small space created in the traffic stream but their speed reduction compared to their speed in unsaturated condition is comparably high than large size vehicles which contradicts a little bit with the study by [4] this is a result of poor driving behavior of small car drivers that is driving at a very high speed on the road during unsaturated condition of the road and presence of old truck and bus on the traffic stream reduces the average speed of large size vehicles, which leads a speed change between small size vehicle drivers to have high rate of change in speed when the traffic stream changes from free flow to moderate flow condition than large size vehicle drivers. When the volume is approaching to capacity all vehicles are going to follow each other and their speed is becoming almost uniform.

4.4.1.2. Impact of composition on average travel speed

This condition allows seeing the impact of ever vehicle type proportions on the travel speed of the stream. To see this; traffic volume and composition of other vehicles except the concerned vehicle at a time is kept constant the change in proportion of a vehicle type is composite with a change in proportion of passenger cars. These is done because passenger cars are the small size cares observed in the study as a result their effect in travel speed of other vehicles is expected to be small [6].

The number of composition proportion to see the change in speed is set five as shown in **Table 4-8.** Composition of other vehicles except the concerned vehicle and passenger car are approximately equal with the observed compositions of the study and the traffic flow is set to a value equal to 1000 veh/hr considering the effect of the interaction between vehicles on mobility is observed as shown in Figure 4-13.

Table 4-8 Vehicle type proportions

Composition effect study vehicles	Estimated proportion of vehicles				
	PC	Pickup and Land cruiser	Minibus	Bus	Truck
Truck	0.55	0.2	0.2	0.05	0
	0.5	0.2	0.2	0.05	0.05
	0.46	0.2	0.2	0.05	0.09
	0.42	0.2	0.2	0.05	0.13
	0.39	0.2	0.2	0.05	0.16
Bus	0.51	0.2	0.2	0	0.09
	0.47	0.2	0.2	0.04	0.09
	0.44	0.2	0.2	0.07	0.09
	0.41	0.2	0.2	0.1	0.09
	0.38	0.2	0.2	0.13	0.09

Composition effect study vehicles	Estimated proportion of vehicles				
	PC	Pickup and Land cruiser	Minibus	Bus	Truck
Minibus	0.51	0.2	0.15	0.05	0.09
	0.46	0.2	0.2	0.05	0.09
	0.41	0.2	0.25	0.05	0.09
	0.36	0.2	0.3	0.05	0.09
Pickup and Land cruiser	0.51	0.15	0.2	0.05	0.09
	0.46	0.2	0.2	0.05	0.09
	0.41	0.25	0.2	0.05	0.09
	0.36	0.3	0.2	0.05	0.09

I. Effect of change in proportion of bus

As demonstrated in the **Figure 4-14**; the speed of every vehicle is reduced (from 57.8 km/hr to 48 km/hr for pc, 59.4 km/hr to 47.3 km/hr for LC and pickup, 58.5 km/hr to 45.7 km/hr for minibus 60 km/hr to 40.6 km/hr for bus, and 59.6 km/hr to 37.5 km/hr for truck) as proportion of bus on the traffic stream is increased (from 0 veh/hr to 130 veh/hr) for a fixed total volume. The reduction in speed of traffic stream is because as the percentage of bus increases the flow rate of the traffic stream decreases which restrict the stream speed capability because bus has high projected area and relative low speed compared with small cares, which contains high proportion of the traffic stream. The reduction in speed is associated with the vehicle type that is large size vehicles show high reduction than small size vehicles; this is because small size vehicles found relative freedom to travel on small free spaces created on the travel lane and have a capability to overpass large size vehicles this allows them the restriction of travel speed effect to be low whereas for large size vehicles they can’t take any small space created or overpass small vehicles due to their size this results the restriction to be pronounced on them which agree with the study by [3].

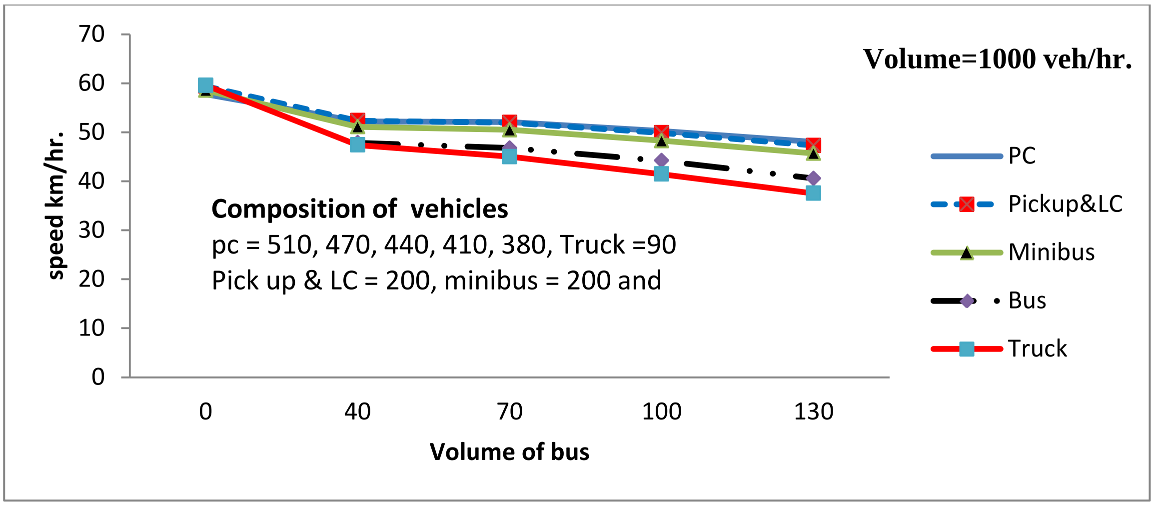

Figure 4-14 Effect of bus proportion on travel speed

II. Effect of change in proportion of truck

As shown in the **Figure 4-15**; the speed of every vehicle is reduced (from 58.7 km/hr to 37.4 km/hr for pc, 59.6 km/hr to 38.6 km/hr for LC and pickup, 59.4 km/hr to 36.4 km/hr for minibus 57.5 km/hr to 34.4 km/hr for bus, and 56.3 km/hr to 32.9 km/hr for truck) as proportion of truck on the traffic stream is increased (from 0 veh/hr to 160 veh/hr) for a fixed total volume. The reduction in speed of traffic stream is associated with various proportions of trucks at low and high proportion of trucks the speed reduction is very low. This is because low proportion of trucks will not affect the traffic stream this is because the truck interaction with other vehicles is low, since there is minimum number of trucks which results the speed change due to truck to be low. High proportion of trucks affect the traffic stream speed highly because the vehicle to truck interaction is high as a result the traffic stream is forced to follow trucks mostly which have low speed compared with other vehicle types this yields speed of the traffic stream to be low and uniform. For medium proportions truck the travel speed of vehicles reduces significantly as percentage of truck increases; this is associated with trucks interaction with other vehicles on the traffic stream is increased from a certain proportion until the effect of the truck proportion forced other vehicles to follow it on the traffic stream this intern results redaction in speed since trucks have high projected area and low speed which almost agrees with the study done by [4].

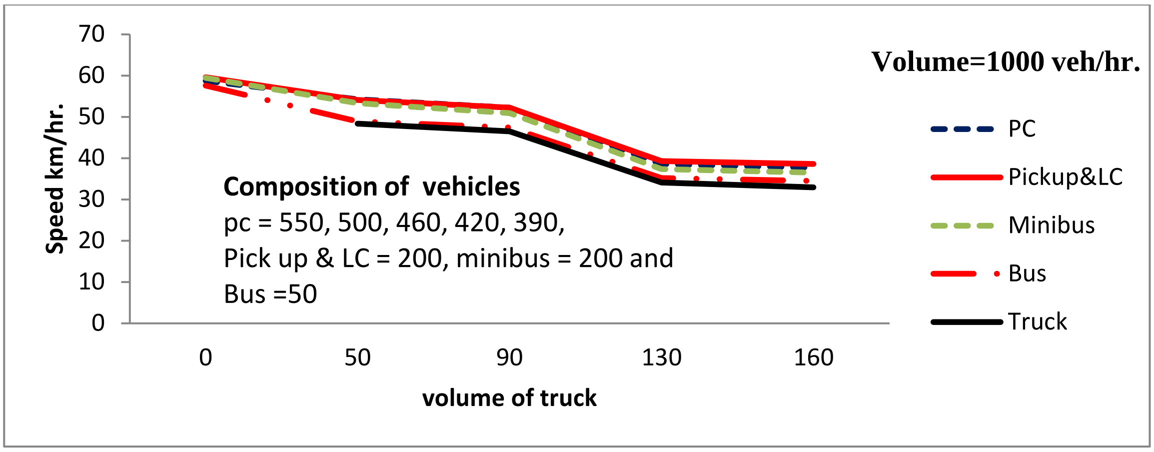

Figure 4-15 Effect of truck proportion on travel speed

III. Effect of change in proportion of minibus

As indicated in **Figure 4-16** the number of minibus increases to a certain level in the traffic stream the speed of other vehicles also increase; this can be associated with the observed high speed of minibus on the traffic stream as a result other vehicle types found freedom to travel at a higher speed also. However, as the proportion of minibus in the traffic stream continuous to increase the travel speed of the traffic stream gets decrease; this also can be associated with minibus have relatively large vehicle size compared to PC and pickup or land-cruiser which contains large share of the traffic stream, leading to the traffic flow rate to decrease as a result stream speed is getting low.

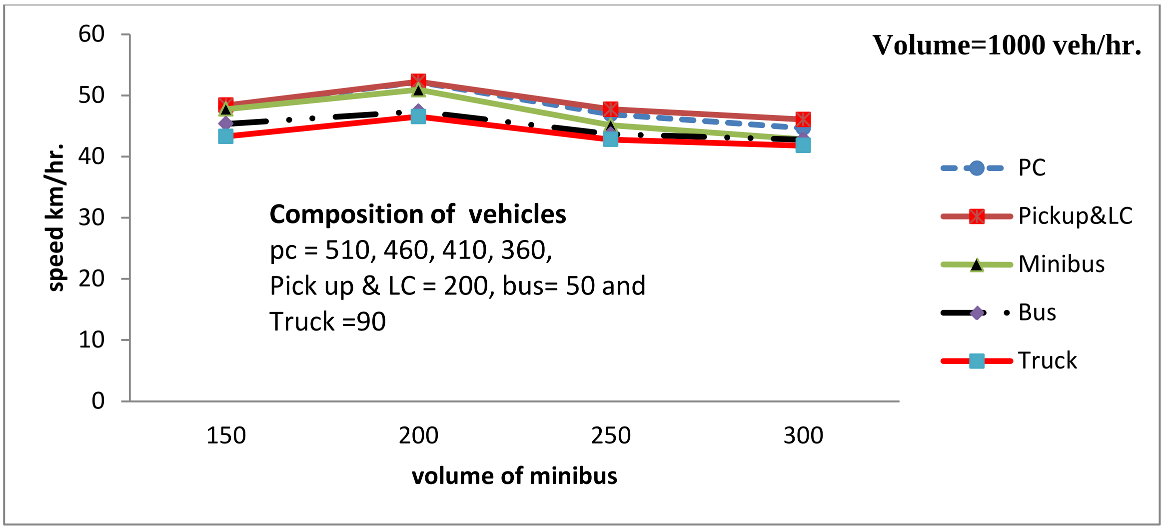

Figure 4-16 Effect of minibus proportion on travel speed

IV. Effect of change in proportion of pickup and land cruiser

Figure 4-17 Show the travel speed of every vehicle is decreased (from 55 km/hr to 46.1 km/hr for pc, 56.6 km/hr to 45.5 km/hr for LC and pickup, 56.3 km/hr to 43.6 km/hr for minibus 53.8 km/hr to 38.9 km/hr for bus, and 53 km/hr to 36 km/hr for truck) as the proportion of pickup and land cruiser increases (from 150 veh/hr to 300 veh/hr). Their impact on speed of truck and bus is high compared with minibus; this is due to that pickup and land cruiser consume the traffic stream space utilized by truck and bus highly, but minibus also compute to overtake bus and truck and with other small vehicles for any space available in the traffic stream as a result the effect on it is minimum. Therefore, the travel speed of bus, truck is forced to decrease highly and minibus small which agrees with the study done by [4].

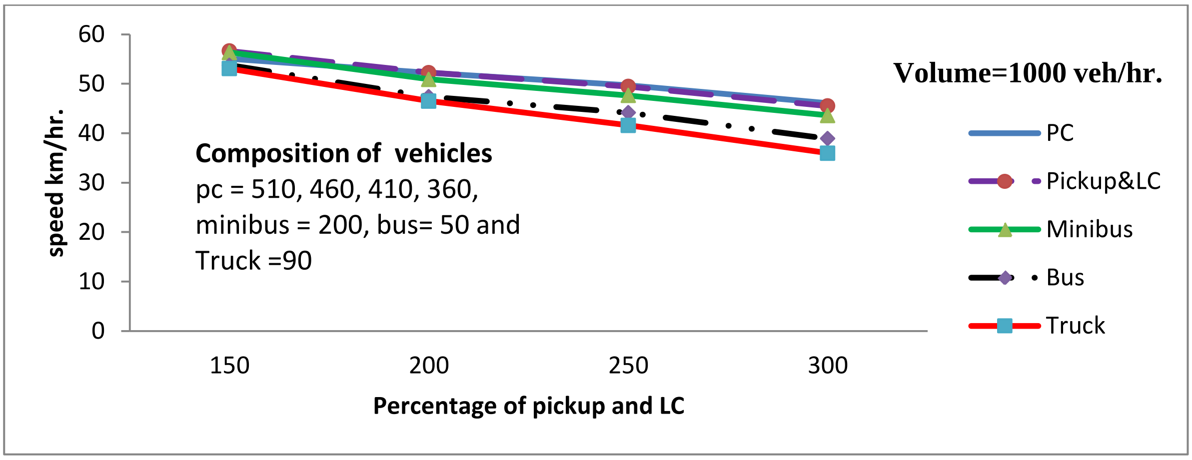

Figure 4-17 Effect of pickup and land-cruiser proportion on travel speed

4.5 Estimation of passenger car equivalent

The passenger car equivalent is estimating using the average travel speed predicted from the model and collected projected area of the vehicle types using the equation developed by [8] given by **Equation 2-1**

4.5.1 Effect of traffic composition and volume on PCE

The passenger car equivalence is variable and associated with the change in proportion of vehicle types and traffic volume observed in the traffic stream. To see the change in the PCE with the variation in the volume and composition of the traffic stream the following cases are developed.

4.5.1.1.Effect of traffic volume on PCE

Changing the volume of traffic from unsaturated condition to saturated condition gradually results a decrease in PCE for large size vehicles (from 4.02 to 3.05 for bus and 4.16 to 2.96 for truck) as shown in **Figure 4-18**; these output agree with the study by [9][7][15].

The PCE for pickup, land cruiser and minibus is almost constant (decrease insignificantly) when the volume changes; these is because this vehicle groups show same behavior like PC on the traffic stream that is when the traffic stream speed changes from unsaturated to saturated condition the speed of this vehicle types changes like PC; this is associated with pickup, land cruiser, and minibus compute with passenger cars which have small projected area compared with other vehicle types on the traffic stream for use of any small space formed on the road when the volume gets increased as a result they maintain almost similar speed change like passenger cares. However, trucks and bus shows a reduction in PCE significantly this is associated with as volume changes from unsaturated to saturated condition vehicle become closer and over passing opportunity decrease; this causes a decrease in speed of passenger cars and PCU.

The result of this study contradicts with highway capacity manual which assume at flat terrain PCE is constant; the study shows PCE value varies with volume.

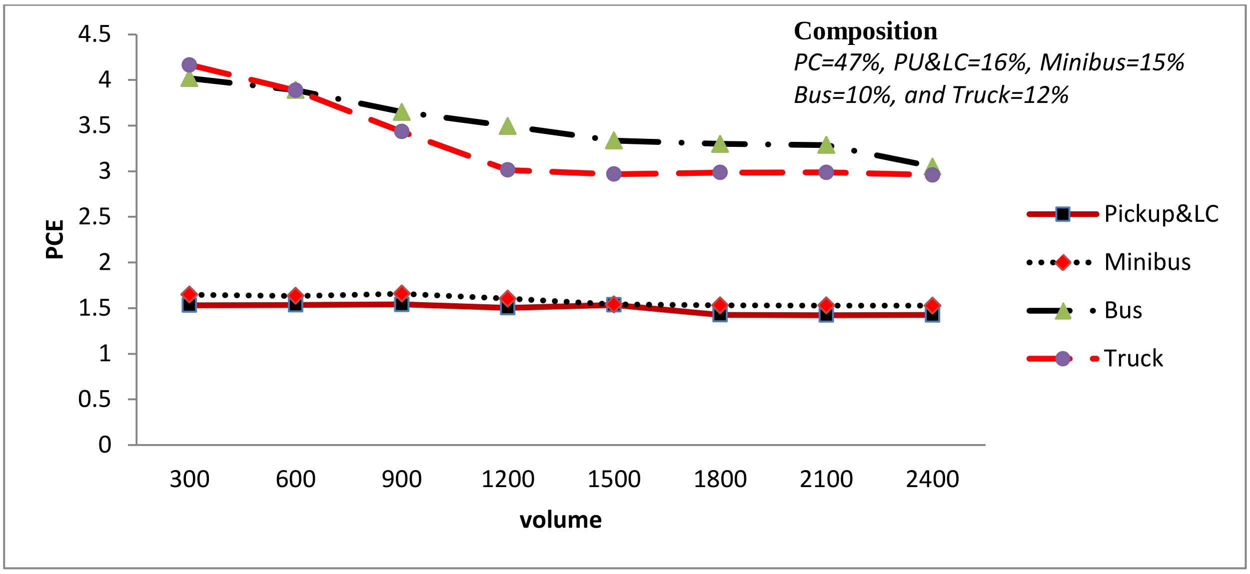

Figure 4-18 Effect of traffic volume on PCE

4.5.1.2.Effect of traffic composition of vehicles on PCE

I. Effect of bus on PCE

The PCE of a vehicle increases (from 1.52 to 1.55 for LC and pickup, 1.64 to 1.69 for minibus, 3.4 to 3.69 for bus, 2.94 to 3.42 for truck) as the proportion of bus changes (from 0 veh/hr to 130 veh/hr) keeping the total volume of the traffic stream constant as shown in **Figure 4-19**; this is due to the traffic stream founds difficult to travel on the road when percentage of bus keeping the volume constant is increased. This is associated with bus travel at a relative low speed and has high projected area; increasing the number of vehicles with low speed and high projected area restricts the function of the facilities. However, the change in PCE of a vehicle is not constant that large size vehicles shows a relative high change than small size vehicles these is due large size vehicles found high resistance to travel in the traffic stream than small size vehicles because; small size vehicles have the advantage to overtake any space available in the traffic stream due to their size and high speed but large size vehicles can't which agrees with a study by [4]. However, the result contradicts with the study by [13]; this indicates there is more vehicle to vehicle interaction present in this study than Addis Ababa – Adama expressway.

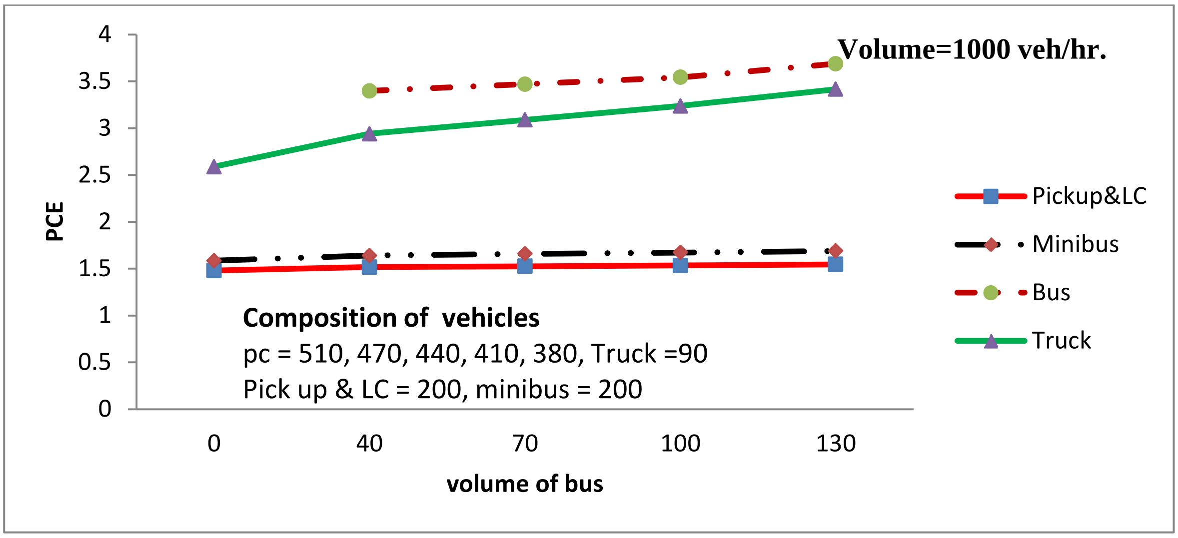

Figure 4-19 Effect of percentage of bus on PCE

II. Effect of truck on PCE

The PCE of a vehicle increases (from 1.49 to 1.53 for LC and pickup, 1.59 to 1.66 for minibus, 3.18 to 3.46 for bus, 2.78 to 3.06 for truck) as the proportion of truck changes (from 0 veh/hr to 160 veh/hr) keeping the total volume of the traffic stream constant as shown in **Figure 4-20**; this is due to the traffic stream founds difficult to travel on the road when percentage of truck keeping the volume constant is increased. This is associated with trucks travel at low speed and has high projected area; increasing the number of vehicles with low speed and high projected area restricts the function of the facilities. However, the change in PCE of a vehicle is not constant that large size vehicles shows a relative high change than small size vehicles these is due large size vehicles found high resistance to travel in the traffic stream than small size vehicles because; small size vehicles have the advantage to overtake any space available in the traffic stream due to their size and high speed but large size vehicles can't which agrees with a study by [3]. However, the result contradicts with the study by [13]; this indicates there is more vehicle to vehicle interaction present in this study than Addis Ababa – Adama expressway.

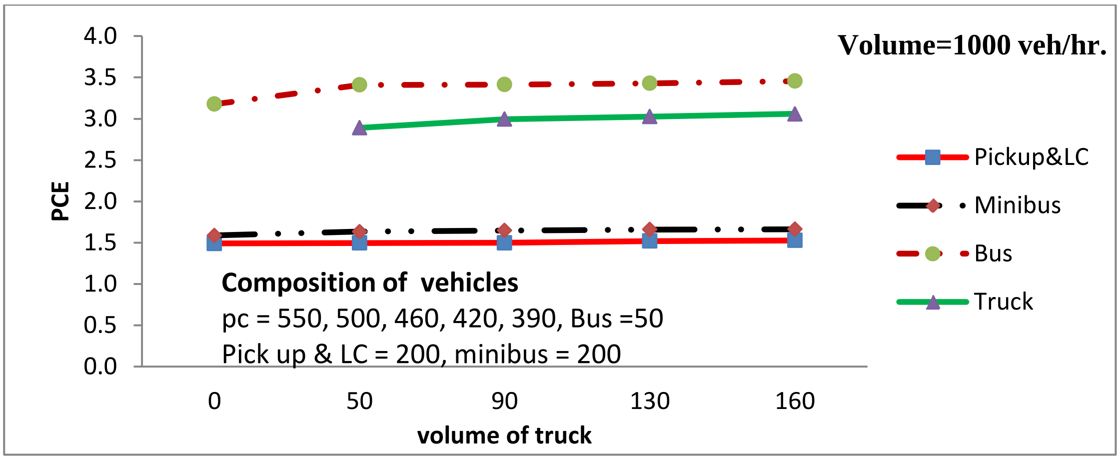

Figure 4-20 Effect of percentage of truck on PCE

III. Effect of minibus on PCE

The impact of minibus proportion on the PCE of other vehicle types is associated with the amount of minibus present in the traffic stream. That is, for small proportion of minibus on the traffic stream the PCE is increased but gradually increment of proportion of minibus results a decrease in PCE of the vehicles as shown in **Figure 4-21**; this is related with small number of minibus occupy the available small size space formed on the traffic stream by computing with other small size vehicles as a result they restrict the flow rate of bus and truck at a higher rate and pickup and land-cruiser at small rate. However, gradual increment of the minibus proportion on the traffic stream results a decrease in PCE this is due to the fact that minibuses have relatively high speed and small size and high proportion of small size vehicles are formed in the traffic stream and the speed restriction decreases.

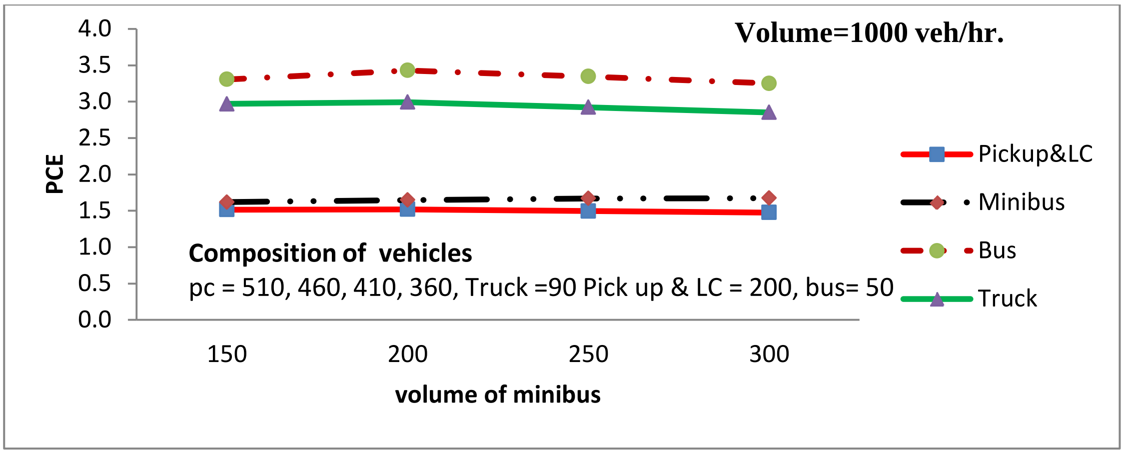

Figure 4-21 Effect of percentage of minibus on PCE

IV. Effect of pickup and land cruiser on PCE

The PCE of every vehicle increases (from 1.5 to 1.54 for LC and pickup, 1.6 to 1.69 for minibus, 3.2 to 3.7 for bus, 2. 8 to 3.41 for truck) as the proportion of pickup and land-cruiser increases (from 100 veh/hr to 250 veh/hr) keeping the total volume of the traffic stream constant as shown in **Figure 4-22**. This condition is associated with two factors; for minibus, pickup and land cruiser this is associated with the computation to use any space formed in the facility between them and this result indicates most of the time pickup and land cruiser vehicle class wins as a result the minibus PCE is relatively high compared with them. For truck and bus they restrict the movement by overtaking the space of this vehicle groups on the traffic stream as their proportion is increased; this is because pickup and land cruiser have small projected area and high relative speed than truck and bus this able them to take any space formed in the traffic stream which agrees with the study by [4].

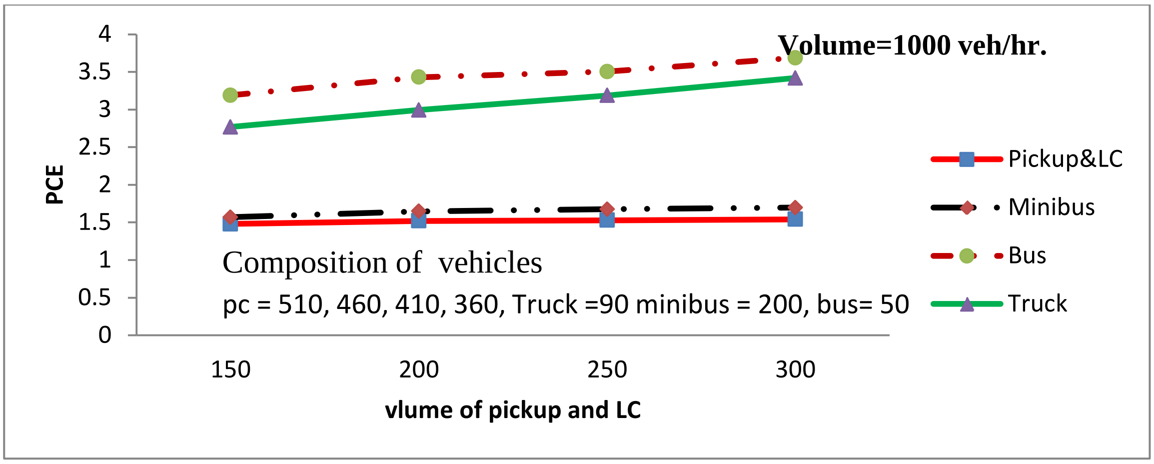

Figure 4-22 Effect percentage of pickup and land cruiser on PCE

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This study investigates the change in travel speed and PCE of every vehicle types; for every possible combination of traffic volume and composition that are observed in Addis Ababa considering Adiss Abab ring road as a case study. To do this artificial neural network modeling technique for predicting the average travel speed of every vehicle types at different composition and volume scenarios was utilized. The speed model is then used for PCE estimation. MAT LAB is used to construct the model. The optimum number of neurons on the hidden layer and the best training and transfer function are chosen from possible combinations using their R^2 value. A model with 12 numbers of hidden neurons trained using Levenberg–Marquardt back propagation using Tan-sigmoid as a transfer function shows better approximation and utilized.

To check the performance of the model developed the model output speed values are compared with the collected speed data. It was observed that the model predicted speed data has a good agreement with the collected speed data.

The passenger car equivalence was also estimated using **Equation 2-1** and a high value for bus, truck, and minibus, pickup. Land cruiser respectively was estimated for different volume and composition variations observed in the ring road.

The methodology developed here can be used for future prediction of travel speed and PCE of any vehicle on no access urban arterial roads.

5.2 Recommendation

From the outputs of the study, recommendation made and possible areas of extension for this research are indicated below.

The study conducted on traffic speed and PCE under different flow and composition conditions founds that PCE is dynamic in nature and depend on the observed volume and composition scenario of the traffic stream. PCE factor developed by this research is expected to provide more accurate results of our condition than those used by international manuals.

The investigation can be utilized by transport planners, road traffic management agency, and traffic engineers who are responsible for planning, design, operation and maintenance of urban highway corresponding to nearby traffic conditions.

For future study the influences of pavement condition, geometry of road and other factors on average travel speed and PCE are recommended to be studied.

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APPENDIX

Appendix A Sample of extracted spot speed data

Table A-1 Spot speed data

Length of Section						205.4m					
No	Vehicle type	Entry Time(Sec)			Entry Time second	Exit Time(sec)			Exit Time second	Speed (m/s)	Speed (km/s)
		minute	second	milli sec.		minute	second	milli sec.			
1	pc	0	9	370	9.37	0	19	736	19.74	19.8	71.333
2	Truck	0	14	420	14.42	0	29	391	29.39	13.7	49.391
3	Pc	0	17	522	17.522	0	30	677	30.68	15.6	56.210
4	Minibus	0	20	813	20.813	0	32	311	32.31	17.9	64.310
5	Pc	0	21	258	21.258	0	35	67	35.07	14.9	53.5
6	LC	0	22	594	22.594	0	34	365	34.37	17.4	62.8
7	Truck	0	22	851	22.851	0	37	1	37.00	14.5	52.3
8	Truck	0	31	640	31.64	0	45	172	45.17	15.2	54.6
9	Pick up	0	32	791	32.791	0	44	495	44.50	17.5	63.2
10	Pick up	0	33	213	33.213	0	45	449	45.45	16.8	60.4
11	Truck	0	35	837	35.837	0	48	243	48.24	16.6	59.6
12	Minibus	0	38	892	38.892	0	50	162	50.16	18.2	65.6
13	Bus	0	39	321	39.321	0	52	694	52.69	15.4	55.3
14	Pc	0	42	28	42.028	0	52	694	52.69	19.3	69.3
15	Pc	0	43	73	43.073	0	55	461	55.46	16.6	59.7
16	Minibus	0	45	423	45.423	0	57	890	57.89	16.5	59.3
17	LC	0	52	876	52.876	1	1	130	61.13	24.9	89.6
18	Taxi	1	4	34	64.034	1	17	936	77.94	14.8	53.2
19	Pick up	1	4	894	64.894	1	13	508	73.51	23.8	85.8
20	Pick up	1	5	70	65.07	1	14	500	74.50	21.8	78.4
21	Pc	1	17	219	77.219	1	27	807	87.81	19.4	69.8
22	LC	1	18	480	78.48	1	29	328	89.33	18.9	68.2
23	Pick up	1	19	685	79.685	1	30	39	90.04	19.8	71.4
24	Mini bus	1	20	442	80.442	1	30	651	90.65	20.1	72.4
25	Truck	1	22	833	82.833	1	47	944	107.94	8.2	29.4
26	Truck	1	26	5	86.005	1	43	13	103.01	12.1	43.5
27	Pc	1	27	768	87.768	1	43	13	103.01	13.5	48.5
28	Minibus	1	28	304	88.304	1	43	901	103.90	13.2	47.4
29	LC	1	30	236	90.236	1	45	618	105.62	13.4	48.1
30	Truck	1	32	243	92.243	1	49	130	109.13	12.2	43.8
31	Minibus	1	40	991	100.991	1	52	420	112.42	18.0	64.7
32	Minibus	1	44	478	104.478	1	56	522	116.52	17.1	61.4

No	Vehicle type	Entry Time(Sec)			Entry Time second	Exit Time(sec)			Exit Time second	Speed (m/s)	Speed (km/s)
		minute	second	milli sec.		minute	second	milli sec.			
33	Taxi	1	46	178	106.178	1	57	134	117.13	18.7	67.5
34	Truck	1	51	190	111.19	2	11	115	131.12	10.3	37.1
35	Minibus	1	51	784	111.784	2	2	476	122.48	19.2	69.2
36	pick up	1	52	640	112.64	2	4	314	124.31	17.6	63.3
37	pick up	1	55	76	115.076	2	7	811	127.81	16.1	58.1
38	Truck	2	1	401	121.401	2	20	709	140.71	10.6	38.3
39	LC	2	3	502	123.502	2	16	991	136.99	15.2	54.8
40	Minibus	2	4	515	124.515	2	17	634	137.63	15.7	56.4
41	Truck	2	6	715	126.715	2	19	606	139.61	15.9	57.4
42	pick up	2	7	492	127.492	2	22	246	142.25	13.9	50.1
43	Truck	2	16	10	136.01	2	33	601	153.60	11.7	42.0
44	pc	2	17	846	137.846	2	31	115	151.12	15.5	55.7
45	pc	2	19	502	139.502	2	32	373	152.37	16.0	57.5
46	pc	2	19	864	139.864	2	33	906	153.91	14.6	52.7
47	Minibus	2	23	268	143.268	2	37	943	157.94	14.0	50.4
48	pick up	2	27	692	147.692	2	43	257	163.26	13.2	47.5
49	Taxi	2	29	934	149.934	2	46	760	166.76	12.2	43.9
50	LC	2	33	695	153.695	2	47	141	167.14	15.3	55.0
51	LC	2	36	980	156.98	2	50	378	170.38	15.3	55.2
52	Taxi	2	42	174	162.174	2	52	71	172.07	20.8	74.7
53	pc	2	44	820	164.82	2	54	691	174.69	20.8	74.9
54	pc	2	46	958	166.958	3	2	593	182.59	13.1	47.3
55	Minibus	2	46	958	166.958	2	58	432	178.43	17.9	64.4
56	Truck	2	52	868	172.868	3	7	841	187.84	13.7	49.4
57	LC	2	57	518	177.518	3	12	986	192.99	13.3	47.8
58	Truck	3	3	280	183.28	3	17	31	197.03	14.9	53.8
59	Minibus	3	11	253	191.253	3	22	861	202.86	17.7	63.7
60	LC	3	12	788	192.788	3	23	861	203.86	18.5	66.8
61	Bus	3	30	558	210.558	3	46	931	226.93	12.5	45.2
62	Truck	3	40	978	220.978	3	52	182	232.18	18.3	66.0
63	Truck	3	41	944	221.944	3	58	935	238.94	12.1	43.5
64	LC	3	43	804	223.804	3	54	775	234.78	18.7	67.4
65	Bus	3	43	804	223.804	3	56	748	236.75	15.9	57.1
66	pc	3	46	906	226.906	3	59	500	239.50	16.3	58.7
67	motor	3	47	203	227.203	3	57	600	237.60	19.8	71.1
68	LC	3	51	361	231.361	4	4	742	244.74	15.4	55.3
69	Bus	3	53	904	233.904	4	9	244	249.24	13.4	48.2
70	Truck	3	55	308	235.308	4	7	518	247.52	16.8	60.6
71	Minibus	3	57	654	237.654	4	11	212	251.21	15.1	54.5
72	pc	4	2	11	242.011	4	14	977	254.98	15.8	57.0
73	Minibus	4	8	471	248.471	4	18	484	258.48	20.5	73.8

No	Vehicle type	Entry Time(Sec)			Entry Time second	Exit Time(sec)			Exit Time second	Speed (m/s)	Speed (km/s)
		minute	second	milli sec.		minute	second	milli sec.			
74	Truck	4	9	24	249.024	4	23	774	263.77	13.9	50.1
75	motor	4	10	898	250.898	4	20	800	260.80	20.7	74.7
76	motor	4	12	804	252.804	4	24	778	264.78	17.2	61.8
77	Truck	4	16	99	256.099	4	35	603	275.60	10.5	37.9
78	pick up	4	17	531	257.531	4	29	386	269.39	17.3	62.4
79	pc	4	23	166	263.166	4	36	437	276.44	15.5	55.7
80	pc	4	25	416	265.416	4	38	437	278.44	15.8	56.8
81	LC	4	26	790	266.79	4	39	729	279.73	15.9	57.1
82	LC	4	27	923	267.923	4	40	716	280.72	16.1	57.8
83	Truck	4	30	460	270.46	4	47	624	287.62	12.0	43.1
84	pc	4	32	2	272.002	4	44	534	284.53	16.4	59.0
85	pc	4	33	852	273.852	4	47	600	287.60	14.9	53.8
86	pick up	4	36	41	276.041	4	50	898	290.90	13.8	49.8
87	Truck	4	37	130	277.13	4	53	686	293.69	12.4	44.7
88	Minibus	4	37	130	277.13	4	52	400	292.40	13.5	48.4
89	Minibus	4	41	738	281.738	4	54	431	294.43	16.2	58.3
90	Truck	4	42	428	282.428	4	56	918	296.92	14.2	51.0
91	Truck	4	46	228	286.228	5	0	784	300.78	14.1	50.8
92	pc	4	46	228	286.228	4	59	274	299.27	15.7	56.7
93	LC	4	48	428	288.428	5	2	400	302.40	14.7	52.9
94	LC	4	49	496	289.496	5	2	93	302.09	16.3	58.7
95	pc	4	49	864	289.864	5	2	820	302.82	15.9	57.1
96	Taxi	4	53	353	293.353	5	7	314	307.31	14.7	53.0
97	Minibus	4	53	708	293.708	5	6	722	306.72	15.8	56.8
98	Truck	4	56	722	296.722	5	12	243	312.24	13.2	47.6
99	truck	5	1	533	301.533	5	16	985	316.99	13.3	47.9
100	Taxi	5	2	467	302.467	5	16	600	316.60	14.5	52.3
101	truck	5	3	905	303.905	5	19	49	319.05	13.6	48.8
102	motor	5	4	706	304.706	5	16	600	316.60	17.3	62.2
103	Minibus	5	5	401	305.401	5	18	585	318.59	15.6	56.1
104	pc	5	6	643	306.643	5	20	777	320.78	14.5	52.3
105	LC	5	8	799	308.799	5	22	709	322.71	14.8	53.2
106	pc	5	9	664	309.664	5	21	149	321.15	17.9	64.4
107	truck	5	11	85	311.085	5	24	883	324.88	14.9	53.6
108	truck	5	11	676	311.676	5	28	989	328.99	11.9	42.7
109	Bus	5	14	116	314.116	5	27	47	327.05	15.9	57.2
110	pc	5	20	779	320.779	5	32	783	332.78	17.1	61.6
111	pc	5	24	353	324.353	5	39	534	339.53	13.5	48.7
112	pc	5	26	850	326.85	5	44	7	344.01	12.0	43.1
113	pick up	5	45	297	345.297	5	55	22	355.02	21.1	76.0

Appendix B Sample of calculated ATS and flow data

Table A-2 5-minute ATS and flow data

Passenger car		pickup and LC		Minibus		Bus		Truck	
0-5 minute		0-5 minute		0-5 minute		0-5 minute		0-5 minute	
pc	71.3	LC	62.8	Minibus	64.3	Bus	55.3	Truck	49.4
Pc	56.2	Pick up	63.2	Minibus	65.6	Bus	45.2	Truck	52.3
Pc	53.5	Pick up	60.4	Minibus	59.3	Bus	57.1	Truck	54.6
Pc	69.3	LC	89.6	Mini bus	72.4	Bus	48.2	Truck	59.6
Pc	59.7	Pick up	85.8	Minibus	47.4	Bus	57.2	Truck	29.4
Taxi	53.2	Pick up	78.4	Minibus	64.7	**No**	**5**	Truck	43.5
Pc	69.8	LC	68.2	Minibus	61.4	**ATS**	**52.59**	Truck	43.8
Pc	48.5	Pick up	71.4	Minibus	69.2	**Flow**	**60**	Truck	37.1
Taxi	67.5	LC	48.1	Minibus	56.4			Truck	38.3
pc	55.7	pick up	63.3	Minibus	50.4			Truck	57.4
pc	57.5	pick up	58.1	Minibus	64.4			Truck	42.0
pc	52.7	LC	54.8	Minibus	63.7			Truck	49.4
Taxi	43.9	pick up	50.1	Minibus	54.5			Truck	53.8
Taxi	74.7	pick up	47.5	Minibus	73.8			Truck	66.0
pc	74.9	LC	55.0	Minibus	48.4			Truck	43.5
pc	47.3	LC	55.2	Minibus	58.3			Truck	60.6
pc	58.7	LC	47.8	Minibus	56.8			Truck	50.1
pc	57.0	LC	66.8	Minibus	56.1			Truck	37.9
pc	55.7	LC	67.4	**No**	**18**			Truck	43.1
pc	56.8	LC	55.3	**ATS**	**60.40**			Truck	44.7
pc	59.0	pick up	62.4	**Flow**	**216**			Truck	51.0
pc	53.8	LC	57.1					Truck	50.8
pc	56.7	LC	57.8					Truck	47.6
pc	57.1	pick up	49.8					truck	47.9
Taxi	53.0	LC	52.9					truck	48.8
Taxi	52.3	LC	58.7					truck	53.6
pc	52.3	LC	53.2					truck	42.7
pc	64.4	pick up	76.0					**No**	**27**
pc	61.6	**No**	**28**					**ATS**	**48.11**
pc	48.7	**ATS**	**61.27**					**Flow**	**324**
pc	43.1	**Flow**	**336**						
No	**31**								
ATS	**57.16**								
Flow	**372**								

Appendix C Calculated flow data (vehicle/hr.)

Table A-3 Input data

Original input						Transferred input				
No	PC	pickup &LC	Minibus	Bus	Truck	PC	pickup &LC	Minibus	Bus	Truck
1	264	228	120	12	60	-0.72632	0	-0.48387	-1	-0.75
2	264	60	72	36	84	-0.72632	-0.77778	-0.74194	-0.81818	-0.625
3	336	72	108	24	72	-0.6	-0.72222	-0.54839	-0.90909	-0.6875
4	420	240	288	60	168	-0.45263	0.055556	0.419355	-0.63636	-0.1875
5	612	228	180	60	192	-0.11579	0	-0.16129	-0.63636	-0.0625
6	444	288	204	24	204	-0.41053	0.277778	-0.03226	-0.90909	0
7	372	336	216	60	324	-0.53684	0.5	0.032258	-0.63636	0.625
8	444	168	144	24	288	-0.41053	-0.27778	-0.35484	-0.90909	0.4375
9	252	192	108	12	288	-0.74737	-0.16667	-0.54839	-1	0.4375
10	240	132	60	12	60	-0.76842	-0.44444	-0.80645	-1	-0.75
11	216	192	132	72	36	-0.81053	-0.16667	-0.41935	-0.54545	-0.875
12	168	132	36	60	48	-0.89474	-0.44444	-0.93548	-0.63636	-0.8125
13	912	312	216	12	288	0.410526	0.388889	0.032258	-1	0.4375
14	600	348	228	24	312	-0.13684	0.555556	0.096774	-0.90909	0.5625
15	504	240	228	276	300	-0.30526	0.055556	0.096774	1	0.5
16	336	276	180	12	252	-0.6	0.222222	-0.16129	-1	0.25
17	168	96	48	12	288	-0.89474	-0.61111	-0.87097	-1	0.4375
18	396	264	168	12	336	-0.49474	0.166667	-0.22581	-1	0.6875
19	132	192	60	24	84	-0.95789	-0.16667	-0.80645	-0.90909	-0.625
20	216	180	84	96	24	-0.81053	-0.22222	-0.67742	-0.36364	-0.9375
21	240	84	24	48	12	-0.76842	-0.66667	-1	-0.72727	-1
22	552	288	144	12	288	-0.22105	0.277778	-0.35484	-1	0.4375
23	696	288	252	12	288	0.031579	0.277778	0.225806	-1	0.4375
24	456	408	156	48	240	-0.38947	0.833333	-0.29032	-0.72727	0.1875
25	324	216	180	24	276	-0.62105	-0.05556	-0.16129	-0.90909	0.375
26	288	168	96	24	276	-0.68421	-0.27778	-0.6129	-0.90909	0.375
27	312	132	120	12	204	-0.64211	-0.44444	-0.48387	-1	0
28	204	72	192	48	48	-0.83158	-0.72222	-0.09677	-0.72727	-0.8125
29	180	72	156	24	48	-0.87368	-0.72222	-0.29032	-0.90909	-0.8125
30	204	36	132	36	24	-0.83158	-0.88889	-0.41935	-0.81818	-0.9375
31	324	84	144	24	24	-0.62105	-0.66667	-0.35484	-0.90909	-0.9375
32	156	84	168	36	24	-0.91579	-0.66667	-0.22581	-0.81818	-0.9375
33	144	108	192	12	12	-0.93684	-0.55556	-0.09677	-1	-1
34	156	192	132	24	12	-0.91579	-0.16667	-0.41935	-0.90909	-1
35	132	36	192	36	12	-0.95789	-0.88889	-0.09677	-0.81818	-1
36	264	72	132	36	24	-0.72632	-0.72222	-0.41935	-0.81818	-0.9375
37	648	324	336	108	48	-0.05263	0.444444	0.677419	-0.27273	-0.8125

Original input						Transferred input				
No	PC	pickup &LC	Minibus	Bus	Truck	PC	pickup &LC	Minibus	Bus	Truck
38	432	180	264	60	72	-0.43158	-0.22222	0.290323	-0.63636	-0.6875
39	360	216	264	48	12	-0.55789	-0.05556	0.290323	-0.72727	-1
40	504	252	192	60	48	-0.30526	0.111111	-0.09677	-0.63636	-0.8125
41	528	156	204	72	396	-0.26316	-0.33333	-0.03226	-0.54545	1
42	420	180	204	72	24	-0.45263	-0.22222	-0.03226	-0.54545	-0.9375
43	396	132	180	36	60	-0.49474	-0.44444	-0.16129	-0.81818	-0.75
44	504	252	192	24	48	-0.30526	0.111111	-0.09677	-0.90909	-0.8125
45	336	228	180	36	36	-0.6	0	-0.16129	-0.81818	-0.875
46	792	372	360	96	12	0.2	0.666667	0.806452	-0.36364	-1
47	840	192	192	24	24	0.284211	-0.16667	-0.09677	-0.90909	-0.9375
48	540	252	168	180	48	-0.24211	0.111111	-0.22581	0.272727	-0.8125
49	672	240	312	60	60	-0.01053	0.055556	0.548387	-0.63636	-0.75
50	1212	300	324	120	12	0.936842	0.333333	0.612903	-0.18182	-1
51	1128	408	264	72	12	0.789474	0.833333	0.290323	-0.54545	-1
52	552	216	168	72	12	-0.22105	-0.05556	-0.22581	-0.54545	-1
53	480	288	144	36	36	-0.34737	0.277778	-0.35484	-0.81818	-0.875
54	888	276	324	24	12	0.368421	0.222222	0.612903	-0.90909	-1
55	324	156	180	36	36	-0.62105	-0.33333	-0.16129	-0.81818	-0.875
56	360	120	324	24	36	-0.55789	-0.5	0.612903	-0.90909	-0.875
57	300	144	216	12	24	-0.66316	-0.38889	0.032258	-1	-0.9375
58	372	156	156	24	24	-0.53684	-0.33333	-0.29032	-0.90909	-0.9375
59	216	96	192	24	36	-0.81053	-0.61111	-0.09677	-0.90909	-0.875
60	300	96	192	12	60	-0.66316	-0.61111	-0.09677	-1	-0.75
61	384	180	180	12	48	-0.51579	-0.22222	-0.16129	-1	-0.8125
62	288	120	192	24	24	-0.68421	-0.5	-0.09677	-0.90909	-0.9375
63	276	96	120	24	12	-0.70526	-0.61111	-0.48387	-0.90909	-1
64	828	408	396	132	72	0.263158	0.833333	1	-0.09091	-0.6875
65	876	228	228	60	48	0.347368	0	0.096774	-0.63636	-0.8125
66	576	288	204	216	60	-0.17895	0.277778	-0.03226	0.545455	-0.75
67	708	276	348	96	84	0.052632	0.222222	0.741935	-0.36364	-0.625
68	1248	336	360	156	96	1	0.5	0.806452	0.090909	-0.5625
69	1164	444	300	108	48	0.852632	1	0.483871	-0.27273	-0.8125
70	588	252	204	108	48	-0.15789	0.111111	-0.03226	-0.27273	-0.8125
71	516	324	180	72	48	-0.28421	0.444444	-0.16129	-0.54545	-0.8125
72	924	312	360	60	72	0.431579	0.388889	0.806452	-0.63636	-0.6875
73	264	228	120	12	60	-0.72632	0	-0.48387	-1	-0.75
74	264	60	72	36	84	-0.72632	-0.77778	-0.74194	-0.81818	-0.625
75	336	72	108	24	72	-0.6	-0.72222	-0.54839	-0.90909	-0.6875
76	240	132	60	12	60	-0.76842	-0.44444	-0.80645	-1	-0.75
77	216	192	132	12	36	-0.81053	-0.16667	-0.41935	-1	-0.875

	Original input					Transferred input				
No	PC	pickup &LC	Minibus	Bus	Truck	PC	pickup &LC	Minibus	Bus	Truck
78	168	132	36	12	48	-0.89474	-0.44444	-0.93548	-1	-0.8125
79	132	192	60	24	84	-0.95789	-0.16667	-0.80645	-0.90909	-0.625
80	216	180	84	32	24	-0.81053	-0.22222	-0.67742	-0.84848	-0.9375
81	240	84	24	36	12	-0.76842	-0.66667	-1	-0.81818	-1
82	252	132	72	24	72	-0.74737	-0.44444	-0.74194	-0.90909	-0.6875
83	312	108	132	60	132	-0.64211	-0.55556	-0.41935	-0.63636	-0.375
84	216	144	132	12	96	-0.81053	-0.38889	-0.41935	-1	-0.5625
85	264	144	96	36	120	-0.72632	-0.38889	-0.6129	-0.81818	-0.4375
86	204	120	144	12	108	-0.83158	-0.5	-0.35484	-1	-0.5
87	360	144	144	12	120	-0.55789	-0.38889	-0.35484	-1	-0.4375
88	396	84	156	60	132	-0.49474	-0.66667	-0.29032	-0.63636	-0.375
89	228	120	204	12	132	-0.78947	-0.5	-0.03226	-1	-0.375
90	420	60	60	36	24	-0.45263	-0.77778	-0.80645	-0.81818	-0.9375
91	180	48	168	24	24	-0.87368	-0.83333	-0.22581	-0.90909	-0.9375
92	156	48	132	24	24	-0.91579	-0.83333	-0.41935	-0.90909	-0.9375
93	180	12	108	36	24	-0.87368	-1	-0.54839	-0.81818	-0.9375
94	300	60	120	24	24	-0.66316	-0.77778	-0.48387	-0.90909	-0.9375
95	132	60	144	36	12	-0.95789	-0.77778	-0.35484	-0.81818	-1
96	120	84	168	12	12	-0.97895	-0.66667	-0.22581	-1	-1
97	132	168	108	24	36	-0.95789	-0.27778	-0.54839	-0.90909	-0.875
98	108	12	168	36	36	-1	-1	-0.22581	-0.81818	-0.875
99	240	48	108	36	12	-0.76842	-0.83333	-0.54839	-0.81818	-1
100	756	336	324	96	24	0.136842	0.5	0.612903	-0.36364	-0.9375
101	804	156	156	24	48	0.221053	-0.33333	-0.29032	-0.90909	-0.8125
102	504	216	132	144	60	-0.30526	-0.05556	-0.41935	0	-0.75
103	636	204	276	60	12	-0.07368	-0.11111	0.354839	-0.63636	-1
104	1212	300	324	120	12	0.936842	0.333333	0.612903	-0.18182	-1
105	1128	408	264	72	12	0.789474	0.833333	0.290323	-0.54545	-1
106	552	216	168	72	36	-0.22105	-0.05556	-0.22581	-0.54545	-0.875
107	480	288	144	36	96	-0.34737	0.277778	-0.35484	-0.81818	-0.5625
108	888	276	324	24	24	0.368421	0.222222	0.612903	-0.90909	-0.9375
109	540	120	120	84	84	-0.24211	-0.5	-0.48387	-0.45455	-0.625
110	432	156	204	72	96	-0.43158	-0.33333	-0.03226	-0.54545	-0.5625
111	444	144	168	96	72	-0.41053	-0.38889	-0.22581	-0.36364	-0.6875
112	372	168	276	96	84	-0.53684	-0.27778	0.354839	-0.36364	-0.625
113	348	144	288	156	72	-0.57895	-0.38889	0.419355	0.090909	-0.6875
114	312	156	264	144	84	-0.64211	-0.33333	0.290323	0	-0.625
115	312	192	228	156	84	-0.64211	-0.16667	0.096774	0.090909	-0.625
116	372	144	276	84	84	-0.53684	-0.38889	0.354839	-0.45455	-0.625
117	324	168	240	144	84	-0.62105	-0.27778	0.16129	0	-0.625

Original input						Transferred input				
No	PC	pickup &LC	Minibus	Bus	Truck	PC	pickup &LC	Minibus	Bus	Truck
118	456	132	204	72	84	-0.38947	-0.44444	-0.03226	-0.54545	-0.625
119	420	156	180	84	84	-0.45263	-0.33333	-0.16129	-0.45455	-0.625
120	444	168	180	96	84	-0.41053	-0.27778	-0.16129	-0.36364	-0.625
121	372	180	180	72	120	-0.53684	-0.22222	-0.16129	-0.54545	-0.4375
122	384	120	228	84	96	-0.51579	-0.5	0.096774	-0.45455	-0.5625
123	276	180	240	144	84	-0.70526	-0.22222	0.16129	0	-0.625
124	360	168	216	144	72	-0.55789	-0.27778	0.032258	0	-0.6875
125	348	300	264	72	84	-0.57895	0.333333	0.290323	-0.54545	-0.625
126	384	144	216	156	96	-0.51579	-0.38889	0.032258	0.090909	-0.5625
127	408	180	156	108	84	-0.47368	-0.22222	-0.29032	-0.27273	-0.625
128	240	84	252	156	84	-0.76842	-0.66667	0.225806	0.090909	-0.625
129	552	144	120	72	108	-0.22105	-0.38889	-0.48387	-0.54545	-0.5
130	372	180	180	72	120	-0.53684	-0.22222	-0.16129	-0.54545	-0.4375
131	504	132	120	84	96	-0.30526	-0.44444	-0.48387	-0.45455	-0.5625
132	564	132	156	72	84	-0.2	-0.44444	-0.29032	-0.54545	-0.625
133	420	192	168	72	84	-0.45263	-0.16667	-0.22581	-0.54545	-0.625
134	516	144	168	72	72	-0.28421	-0.38889	-0.22581	-0.54545	-0.6875
135	432	156	168	72	108	-0.43158	-0.33333	-0.22581	-0.54545	-0.5

Appendix D Calculated speed data (km/hr.)

Table A-4 Output data

Original output						Transferred output				
No	PC	pickup &LC	Minibus	Bus	Truck	PC	pickup &LC	Minibus	Bus	Truck
1	89.4	89.0	89.9	87.9	82.7	0.956386	0.947569	0.970473	0.938131	0.806077
2	88.6	88.7	87.2	86.2	80.0	0.932545	0.935668	0.88535	0.887006	0.724771
3	85.2	90.3	89.4	82.4	81.4	0.825545	0.987843	0.955414	0.769455	0.767584
4	33.6	33.8	33.9	31.9	31.0	-0.78193	-0.82952	-0.8121	-0.79274	-0.7737
5	31.5	30.6	29.1	30.9	28	-0.84735	-0.93245	-0.96497	-0.82367	-0.86544
6	29.0	28.7	29.9	27.2	27.9	-0.92523	-0.99357	-0.93949	-0.93813	-0.8685
7	57.6	61.3	60.4	52.6	48.1	-0.03385	0.055037	0.031847	-0.15239	-0.25076
8	58.6	57.1	63.1	60.3	53.8	-0.00312	-0.08006	0.117834	0.085802	-0.07645
9	59.9	57.7	64.1	60.2	54.7	0.037383	-0.06076	0.149682	0.082708	-0.04893
10	84.7	85.7	85.8	82.8	72.8	0.810032	0.839881	0.840764	0.781829	0.505843
11	85.2	86.7	80.9	30.7	70.4	0.825545	0.872047	0.684713	-0.82986	0.431193
12	84.1	82.5	87.2	28.8	73.6	0.791277	0.736951	0.88535	-0.88864	0.529052
13	76.6	33	33.9	30.4	31.7	0.557632	-0.85525	-0.8121	-0.83914	-0.75229

Original output						Transferred output				
No	PC	pickup &LC	Minibus	Bus	Truck	PC	pickup &LC	Minibus	Bus	Truck
14	28.9	29.5	29.5	52.1	29.1	-0.92835	-0.96783	-0.95223	-0.16786	-0.8318
15	29.4	28.7	30.5	54.6	27.9	-0.91277	-0.99357	-0.92038	-0.09052	-0.8685
16	57.8	61.1	62.3	55.5	53.0	-0.02804	0.048603	0.092357	-0.06268	-0.10092
17	60.1	60.7	60.4	87.4	52	0.043614	0.035737	0.031847	0.924128	-0.1315
18	67.9	66.6	59.6	89.1	55.7	0.286604	0.225515	0.006369	0.976716	-0.01835
19	90.7	89.2	90.8	87.4	81.0	0.996885	0.952461	1	0.924128	0.755352
20	90.8	90.0	90.0	31.5	89.0	1	0.978194	0.974522	-0.80511	1
21	90.1	89.6	89.5	29.2	88.2	0.978193	0.965327	0.958599	-0.87626	0.975535
22	35.4	32.1	32.6	29.1	30.8	-0.72586	-0.8842	-0.8535	-0.87936	-0.77982
23	29.1	28.5	29.3	47.9	27.7	-0.92212	-1	-0.9586	-0.29779	-0.87462
24	29.2	29.8	30	55.5	27.1	-0.919	-0.95818	-0.93631	-0.06268	-0.89297
25	54.9	54.0	51.2	69.8	46.5	-0.11838	-0.17977	-0.26115	0.37968	-0.29969
26	56.6	65.8	61.6	82.4	49.1	-0.06542	0.199783	0.070064	0.769455	-0.22018
27	86.7	85.8	85.7	87.4	66.5	0.872274	0.843098	0.83758	0.924128	0.311927
28	80.9	87.5	85.7	74.3	73.3	0.691589	0.897779	0.83758	0.518885	0.519878
29	87.0	84.8	82.2	72	74.4	0.88162	0.810932	0.726115	0.447736	0.553517
30	89.6	87.7	87.9	77.9	53.6	0.962617	0.904212	0.907643	0.63025	-0.08257
31	80.6	81.7	86.7	78.7	68.1	0.682243	0.711218	0.869427	0.654997	0.360856
32	76.7	81.2	83.6	78.7	81.5	0.560748	0.695135	0.770701	0.654997	0.770642
33	86.7	85.1	86.5	74.9	84.5	0.872274	0.820581	0.863057	0.537446	0.862385
34	77.0	88.1	81	68.9	69.5	0.570093	0.917079	0.687898	0.351839	0.40367
35	86.0	86.7	86.7	80.2	85.1	0.850467	0.872047	0.869427	0.701399	0.880734
36	87.7	79.0	80.9	73.7	54.8	0.903427	0.62437	0.684713	0.500325	-0.04587
37	57	58.2	57.3	55.3	56	-0.05296	-0.04468	-0.06688	-0.06887	-0.00917
38	57.5	56.5	56	51.9	52.1	-0.03738	-0.09936	-0.10828	-0.17405	-0.12844
39	53.9	54.3	54	50.4	54.2	-0.14953	-0.17012	-0.17197	-0.22045	-0.06422
40	57	59.7	60.7	54.3	51.9	-0.05296	0.003571	0.041401	-0.09981	-0.13456
41	56.7	57.1	55.2	53.9	58.7	-0.06231	-0.08006	-0.13376	-0.11218	0.073394
42	56.8	54.8	56.4	56.4	58.5	-0.05919	-0.15404	-0.09554	-0.03484	0.067278
43	56.9	55.1	54.7	53	51.4	-0.05607	-0.14439	-0.14968	-0.14002	-0.14985
44	57.5	55.6	52.9	52.6	52.2	-0.03738	-0.12831	-0.20701	-0.15239	-0.12538
45	56.1	54.8	54.3	48.6	33.2	-0.081	-0.15404	-0.16242	-0.27613	-0.70642
46	36.1	35.8	36.4	34.9	32.9	-0.70405	-0.76519	-0.73248	-0.69994	-0.7156
47	36.1	36.3	36.8	30.4	28.6	-0.70405	-0.74911	-0.71975	-0.83914	-0.84709
48	36.3	36.3	33.2	25.7	28.3	-0.69782	-0.74911	-0.83439	-0.98453	-0.85627
49	37.5	37.9	36.9	25.4	26.1	-0.66044	-0.69764	-0.71656	-0.99381	-0.92355
50	33.0	32.5	33.3	29.7	25.4	-0.80062	-0.87134	-0.83121	-0.86079	-0.94495
51	53.9	37.5	36.2	26.8	31.4	-0.14953	-0.71051	-0.73885	-0.9505	-0.76147
52	26.6	38.9	36.6	37.4	29.5	-1	-0.66548	-0.72611	-0.6226	-0.81957
53	36.2	36.2	33	25.2	29.4	-0.70093	-0.75232	-0.84076	-1	-0.82263

Original output						Transferred output				
No	PC	pickup &LC	Minibus	Bus	Truck	PC	pickup &LC	Minibus	Bus	Truck
54	31.4	32.2	33	28.8	25.4	-0.85047	-0.88099	-0.84076	-0.88864	-0.94495
55	65.06	66.39	66.39	56.02	55.59	0.19798	0.218835	0.222536	-0.04657	-0.0216
56	58.48	59.39	62.07	60.66	57.97	-0.00698	-0.00631	0.085015	0.097092	0.051115
57	58.42	61.52	59.01	62.50	56.23	-0.00865	0.061986	-0.01239	0.153889	-0.00206
58	70.58	60.07	49.87	58.11	46.87	0.369976	0.015558	-0.30365	0.017932	-0.28828
59	60.07	61.89	60.73	53.24	50.36	0.042623	0.073941	0.042224	-0.13253	-0.18177
60	64.33	60.61	64.29	55.92	58.87	0.175297	0.032789	0.155753	-0.04966	0.078497
61	58.94	65.30	64.62	55.92	53.65	0.007335	0.18373	0.166097	-0.04966	-0.08112
62	58.77	57.89	60.41	55.54	55.38	0.002314	-0.0545	0.032145	-0.06143	-0.0282
63	57.92	58.57	56.11	47.51	50.62	-0.02443	-0.03273	-0.10471	-0.30987	-0.17372
64	33.60	33.30	33.90	32.40	30.70	-0.78193	-0.8456	-0.8121	-0.77727	-0.78287
65	33.60	33.80	34.30	27.90	30.40	-0.78193	-0.82952	-0.79936	-0.91648	-0.79205
66	33.80	32.80	30.70	27.20	26.10	-0.7757	-0.86169	-0.91401	-0.93813	-0.92355
67	35.00	35.40	34.40	32.90	35.80	-0.73832	-0.77806	-0.79618	-0.7618	-0.62691
68	34.50	33.00	31.80	27.20	23.60	-0.75389	-0.85525	-0.87898	-0.93813	-1
69	34.40	33.00	31.70	28.30	27.90	-0.75701	-0.85525	-0.88217	-0.9041	-0.8685
70	33.10	32.40	30.10	27.90	26.90	-0.79751	-0.87455	-0.93312	-0.91648	-0.89908
71	33.70	33.70	30.50	28.70	27.00	-0.77882	-0.83274	-0.92038	-0.89173	-0.89602
72	34.90	33.70	30.50	26.30	25.90	-0.74143	-0.83274	-0.92038	-0.96597	-0.92966
73	85.40	86.05	86.87	89.85	79.66	0.831776	0.851072	0.874932	1	0.714334
74	85.63	90.68	89.20	88.20	77.00	0.839087	1	0.949045	0.948875	0.633028
75	87.20	88.30	86.40	89.40	78.40	0.88785	0.923512	0.859873	0.985997	0.675841
76	81.70	82.70	82.80	89.80	69.84	0.716574	0.743384	0.745223	0.99837	0.4141
77	82.20	83.70	77.90	89.40	67.40	0.732087	0.775549	0.589172	0.985997	0.33945
78	81.10	79.50	84.20	86.10	70.60	0.697819	0.640453	0.789809	0.883913	0.437309
79	90.70	86.20	87.80	89.40	78.00	0.996885	0.855964	0.904459	0.985997	0.663609
80	90.80	87.00	88.00	63.60	86.00	1	0.881696	0.910828	0.187886	0.908257
81	85.10	86.60	86.50	88.20	85.20	0.82243	0.86883	0.863057	0.948875	0.883792
82	70.29	70.148	71.70	72.62	52	0.360966	0.339639	0.391783	0.466884	-0.1315
83	69.02	75.30	62.59	62.30	55.3	0.321371	0.505486	0.101656	0.147764	-0.02962
84	71.43	58.64	81.36	57.58	52.9	0.396451	-0.03055	0.699215	0.001804	-0.1053
85	68.03	58.64	69.91	60.77	50.7	0.29059	-0.03055	0.334771	0.100322	-0.17111
86	64.53	67.38	65.08	48.97	49.0	0.181751	0.250657	0.181037	-0.26473	-0.22364
87	79.59	67.12	56.76	62.30	53.2	0.65091	0.242094	-0.08406	0.147764	-0.09397
88	59.44	72.18	59.93	57.58	55.8	0.022944	0.405129	0.016784	0.001804	-0.01587
89	65.67	75.21	72.38	60.77	61.2	0.216993	0.502421	0.413503	0.100322	0.148539
90	74.75	78.68	79.62	48.97	74.3	0.500045	0.613991	0.643878	-0.26473	0.550459
91	81.90	88.50	86.70	75.3	75.4	0.722741	0.929945	0.869427	0.54982	0.584098
92	88.00	85.80	83.20	73.0	74.6	0.912773	0.843098	0.757962	0.47867	0.559633
93	85.60	88.70	88.90	78.9	69.1	0.838006	0.936378	0.93949	0.661184	0.391437

	Original output					Transferred output				
No	PC	pickup &LC	Minibus	Bus	Truck	PC	pickup &LC	Minibus	Bus	Truck
94	81.60	82.70	87.70	79.7	72.5	0.713396	0.743384	0.901274	0.685932	0.495413
95	87.70	82.20	84.60	79.7	75.5	0.903427	0.727301	0.802548	0.685932	0.587156
96	87.70	86.10	87.50	75.9	70.5	0.903427	0.852747	0.894904	0.568381	0.434251
97	88.00	89.10	82.00	69.9	71.1	0.912773	0.949244	0.719745	0.382773	0.452599
98	87.00	87.70	87.70	81.2	32.2	0.88162	0.904212	0.901274	0.732334	-0.737
99	88.70	80.00	81.90	73.7	31.9	0.934579	0.656536	0.716561	0.500325	-0.74618
100	35.10	34.80	35.40	33.9	37.6	-0.7352	-0.79736	-0.76433	-0.73087	-0.57187
101	35.10	35.30	35.80	29.4	37.3	-0.7352	-0.78127	-0.75159	-0.87007	-0.58104
102	35.30	35.30	32.20	30.7	31.1	-0.72897	-0.78127	-0.86624	-0.82986	-0.77064
103	36.50	36.90	35.90	34.4	25.4	-0.69159	-0.72981	-0.74841	-0.7154	-0.94495
104	38.00	37.50	38.30	34.7	26.4	-0.64486	-0.71051	-0.67197	-0.70612	-0.91437
105	38.90	32.50	34.20	31.8	34.5	-0.61682	-0.87134	-0.80255	-0.79583	-0.66667
106	37.60	33.90	37.60	32.4	34.4	-0.65732	-0.8263	-0.69427	-0.77727	-0.66972
107	31.20	31.20	28.00	30.2	52.9	-0.8567	-0.91315	-1	-0.84533	-0.1053
108	36.40	37.20	38.00	33.80	74.60	-0.6947	-0.72016	-0.68153	-0.73396	0.559633
109	54.76	57.14	69.55	54.12	42.60	-0.12286	-0.07865	0.323222	-0.10533	-0.41881
110	51.87	58.81	51.68	45.07	43.36	-0.21291	-0.02503	-0.24589	-0.38541	-0.39573
111	52.12	48.78	51.42	43.93	42.52	-0.2049	-0.34767	-0.25408	-0.42075	-0.42154
112	49.48	47.97	48.32	50.84	56.91	-0.28709	-0.37378	-0.35297	-0.20678	0.018647
113	55.39	51.92	48.52	45.11	44.12	-0.10321	-0.24654	-0.34654	-0.38404	-0.37241
114	56.50	55.90	52.95	53.85	47.75	-0.06868	-0.1186	-0.20543	-0.11361	-0.26152
115	57.99	53.49	55.18	50.67	48.39	-0.02223	-0.19616	-0.13426	-0.21198	-0.24183
116	52.56	50.52	50.12	50.01	47.83	-0.19121	-0.29166	-0.2955	-0.23259	-0.25903
117	53.15	50.75	49.50	42.66	39.87	-0.17274	-0.28446	-0.31539	-0.46001	-0.50234
118	57.94	63.43	62.95	57.82	60.21	-0.02378	0.123446	0.11306	0.008956	0.119528
119	56.15	64.27	62.82	73.99	61.00	-0.07938	0.1507	0.108813	0.509218	0.143702
120	52.87	50.92	48.29	48.34	40.32	-0.18163	-0.2788	-0.35385	-0.28431	-0.48863
121	45.54	45.65	46.04	33.67	36.56	-0.40982	-0.44847	-0.42532	-0.73813	-0.60379
122	40.92	50.01	38.06	30.81	28.05	-0.5538	-0.30799	-0.67961	-0.82647	-0.86403
123	50.85	48.17	44.57	35.03	27.69	-0.24451	-0.36743	-0.47226	-0.69593	-0.87498
124	47.43	42.34	40.96	35.02	30.09	-0.3511	-0.55478	-0.58726	-0.69622	-0.80152
125	49.99	37.71	35.55	30.49	25.18	-0.27137	-0.7036	-0.75963	-0.83626	-0.95161
126	56.45	53.53	40.83	40.29	38.32	-0.07002	-0.19499	-0.5914	-0.5331	-0.54986
127	49.81	51.38	52.18	46.88	40.49	-0.27692	-0.26421	-0.23006	-0.32928	-0.48338
128	59.28	54.73	41.81	44.21	41.23	0.018047	-0.15634	-0.5602	-0.41193	-0.461
129	47.77	50.27	42.73	47.93	42.96	-0.34055	-0.29989	-0.53081	-0.29683	-0.40787
130	45.06	43.30	48.30	40.12	44.09	-0.42498	-0.5239	-0.35348	-0.53844	-0.37334
131	53.24	57.04	53.45	49.68	49.12	-0.17008	-0.08203	-0.1894	-0.24273	-0.21964
132	55.66	59.54	57.76	56.90	38.23	-0.09477	-0.00153	-0.05223	-0.01926	-0.55269
133	55.49	56.07	54.89	39.99	39.59	-0.09985	-0.11319	-0.1437	-0.54238	-0.51111

Original output						Transferred output				
No	PC	pickup &LC	Minibus	Bus	Truck	PC	pickup &LC	Minibus	Bus	Truck
134	59.26	59.39	57.48	39.88	41.38	0.0175	-0.00628	-0.06113	-0.54601	-0.45635
135	55.84	55.86	51.23	42.10	41.60	-0.08922	-0.12001	-0.26017	-0.47731	-0.44944

Appendix E Checking consistency and adequacy of data

Table A-5 Checking adequacy and consistency of data

Section 1				Section 2			
Data points	Time interval (minute)	No of vehicle in the study	Minimum No of vehicle required for ATS calculation	Data points	Time interval (minute)	No of vehicle in the study	Minimum No of vehicle required for ATS calculation
1	5	97	97	1	5	98	97
2	5	99	97	2	5	98	97
3	5	100	97	3	5	99	97
4	5	98	97	4	5	100	97
5	5	106	97	5	5	101	97
6	5	97	97	6	5	101	97
7	5	109	97	7	5	100	97
8	5	97	97	8	5	107	97
9	5	97	97	9	5	98	97
10	5	99	97	10	5	122	97
11	5	98	97	11	5	97	97
12	5	98	97	12	5	100	97
13	5	145	97	13	5	98	97
14	5	126	97	14	5	113	97
15	5	129	97	15	5	75	97
16	5	99	97	16	5	106	97
17	5	98	97	17	5	102	97
18	5	98	97	18	5	108	97
19	5	97	97	19	5	136	97
20	5	100	97	20	5	106	97
21	5	98	97	21	5	99	97
22	5	107	97	22	5	112	97
23	5	128	97	23	5	164	97
24	5	109	97	24	5	157	97
25	5	99	97	25	5	105	97
26	5	97	97	26	5	97	97
27	5	97	97	27	5	127	97
Section 3				Section 4			

Data points	Time interval (minute)	No of vehicle in the study	Minimum No of vehicle required for ATS calculation	Data points	Time interval (minute)	No of vehicle in the study	Minimum No of vehicle required for ATS calculation
1	5	99	97	1	5	99	97
2	5	103	97	2	5	107	97
3	5	98	97	3	5	100	97
4	5	100	97	4	5	99	97
5	5	98	97	5	5	98	97
6	5	100	97	6	5	105	97
7	5	106	97	7	5	104	97
8	5	99	97	8	5	101	97
9	5	100	97	9	5	100	97
10	5	153	97	10	5	97	97
11	5	120	97	11	5	101	97
12	5	112	97	12	5	97	97
13	5	126	97	13	5	99	97
14	5	183	97	14	5	97	97
15	5	172	97	15	5	99	97
16	5	100	97	16	5	99	97
17	5	107	97	17	5	99	97
18	5	144	97	18	5	97	97
19	5	98	97	19	5	128	97
20	5	99	97	20	5	99	97
21	5	100	97	21	5	109	97
22	5	97	97	22	5	99	97
23	5	98	97	23	5	164	97
24	5	98	97	24	5	157	97
25	5	98	97	25	5	97	97
26	5	97	97	26	5	101	97
27	5	97	97	27	5	100	97

Section 5			
Data points	Time interval (minute)	No of vehicle in the study area	Minimum No of vehicle required for ATS calculation
1	5	99	97
2	5	100	97
3	5	107	97
4	5	102	97
5	5	110	97
6	5	109	97
7	5	102	97
8	5	97	97
9	5	99	97
10	5	98	97
11	5	98	97
12	5	99	97
13	5	101	97
14	5	97	97
15	5	97	97
16	5	98	97

Data points	Time interval (minute)	No of vehicle in the study area	Minimum No of vehicle required for ATS calculation
17	5	102	97
18	5	99	97
19	5	98	97
20	5	100	97
21	5	100	97
22	5	100	97
23	5	99	97
24	5	97	97
25	5	99	97
26	5	105	97
27	5	100	97

Appendix F Model estimate speed data

Table A-6 Model estimate output

No	PC	pickup &LC	Minibus	Bus	Truck
1	82.1281	81.5248	83.1222	88.9839	70.0063
2	85.9268	86.6032	86.636	82.1728	71.7792
3	86.1444	87.2395	87.2525	84.9934	78.0553
4	38.7327	39.9424	37.5528	36.983	36.1486
5	28.9703	30.5424	30.026	27.9363	27.6809
6	34.561	35.272	33.6976	31.7352	30.4086
7	54.0841	54.9871	52.0122	68.2836	42.5312
8	53.4844	56.7196	55.0437	65.3964	53.8657
9	50.1648	51.937	49.5172	64.6277	40.1467
10	83.3215	82.7661	84.775	89.6027	71.9052
11	82.6511	83.3535	79.0638	33.776	66.806
12	89.2225	89.6671	87.1965	26.0367	83.7163
13	75.3712	33.4418	33.6714	33.6646	33.6266
14	30.0209	30.4913	29.8528	37.2054	27.3459
15	34.2373	34.9857	35.8939	52.6615	29.726
16	57.7557	58.3361	55.4526	56.6153	45.335
17	56.9869	61.0629	59.222	83.3109	49.0145
18	63.3312	64.5657	61.5741	87.7246	55.7356
19	86.886	87.1025	86.5243	88.2527	79.1135
20	90.4421	90.5029	89.7998	25.43	87.9473
21	87.9206	88.5597	86.0197	31.6573	78.3387
22	33.851	33.2346	32.5621	32.5022	31.0347
23	31.4218	30.8523	30.32	48.6163	29.5477
24	40.0809	38.9106	37.1036	32.6901	28.9171
25	55.7732	57.4254	54.6532	62.0026	45.9865
26	63.6696	66.6417	63.6043	70.9538	54.251

No	PC	pickup &LC	Minibus	Bus	Truck
27	77.5091	80.1255	78.2551	79.8724	71.5431
28	75.6636	76.5002	75.2614	68.8641	62.9094
29	82.0119	82.4972	81.9801	75.5303	69.2794
30	85.4849	85.9436	86.0449	78.2308	68.5707
31	69.997	71.08	70.4097	63.8237	55.6163
32	81.8791	82.1573	81.6793	74.6251	69.2018
33	80.0884	80.569	79.7965	74.1288	69.2832
34	86.2757	86.7507	85.0676	62.3415	76.9579
35	84.0979	84.7569	84.4875	78.6125	72.3513
36	76.4576	76.8159	76.4376	66.6866	58.0549
37	57.1495	57.3103	56.956	52.0918	54.628
38	54.7315	55.6857	53.381	51.3681	50.9907
39	67.8153	68.5817	67.0574	64.3521	61.9448
40	48.3984	47.6966	46.666	41.8501	40.2111
41	57.8871	57.9327	54.3597	89.8475	58.0443
42	56.9088	56.6683	55.2993	50.7477	48.1732
43	62.9944	63.7774	62.6186	58.9479	55.7244
44	53.3277	52.6806	51.8054	47.4967	46.3004
45	52.1728	51.411	49.7073	43.7983	41.0454
46	34.8125	34.9368	35.2584	30.3491	33.2354
47	36.0749	35.6249	37.3606	30.7424	31.5267
48	38.7262	38.7837	35.2721	26.1896	29.7593
49	33.4963	33.9407	34.1198	29.6647	32.35
50	34.6757	35.1505	36.5874	31.9001	35.563
51	38.7704	32.2798	32.9764	28.2387	32.5734
52	39.4464	39.0378	38.3394	33.5309	32.5823
53	39.1186	38.3772	37.1839	32.4487	30.5609
54	33.9336	33.9781	34.8675	31.39	36.8423
55	59.4586	59.3076	57.773	53.2651	49.7297
56	53.2552	55.2134	51.8677	51.1933	50.303
57	65.8261	66.6262	64.9117	62.3087	59.5556
58	55.6112	55.2654	53.92	49.6263	45.9078
59	71.6945	72.4357	70.9227	65.8766	61.1352
60	62.1619	63.5468	61.3938	58.1098	53.8524
61	60.8098	60.9667	59.5917	56.6138	53.5105
62	65.6046	66.1068	64.6428	60.717	57.0427
63	69.605	69.3302	68.4542	58.9954	51.6224
64	31.7952	32.4144	32.5355	28.3411	30.2223
65	32.2567	33.1261	33.9108	30.1225	32.2932
66	40.5628	40.5869	36.7353	26.5241	31.1648
67	30.7141	31.6164	31.4498	27.698	28.9575
68	33.106	34.0311	35.0305	31.9316	37.1081

No	PC	pickup &LC	Minibus	Bus	Truck
69	31.7008	30.9056	31.1499	27.4509	29.7684
70	39.8946	39.4285	38.8764	34.0948	33.4649
71	39.5989	39.0144	37.604	31.5193	31.0555
72	29.9958	30.9543	31.1355	27.6855	30.1374
73	82.1281	81.5248	83.1222	88.9839	70.0063
74	85.9268	86.6032	86.636	82.1728	71.7792
75	86.1444	87.2395	87.2525	84.9934	78.0553
76	83.3215	82.7661	84.775	89.6027	71.9052
77	80.8386	80.4615	80.9277	84.561	66.5919
78	87.4963	87.5947	87.6126	89.3762	80.7676
79	86.886	87.1025	86.5243	88.2527	79.1135
80	87.9481	88.3587	86.9463	66.2982	81.1786
81	87.9367	88.4212	87.1363	68.6903	79.4414
82	75.3014	74.2365	74.9221	79.2639	55.0203
83	71.2097	71.8316	70.126	62.3299	54.9464
84	70.7357	70.6095	69.0933	64.8909	53.3775
85	67.1612	66.2674	64.8728	55.8174	46.4847
86	67.6383	68.0849	65.5225	59.5285	51.5534
87	64.5275	66.5372	64.1469	64.4559	58.0842
88	63.0485	66.4683	64.9023	61.1552	51.6335
89	66.2663	67.8517	64.6413	62.0417	56.0107
90	74.1467	77.2461	77.5071	70.6331	50.5252
91	83.8197	84.4497	84.2524	78.1133	71.4668
92	84.1655	84.4677	84.3691	76.671	68.9541
93	86.7704	87.1778	87.3812	78.8107	66.2127
94	79.4504	80.7503	80.6533	73.405	61.5807
95	82.2434	82.3798	81.9866	72.3672	66.5258
96	82.776	83.0937	82.6581	76.5429	71.1821
97	83.341	83.5839	81.9346	71.3549	69.6703
98	85.0695	85.745	85.5566	78.2785	69.0537
99	81.8799	82.3058	82.2958	70.298	58.8192
100	34.6185	34.7602	35.0041	30.2025	32.619
101	37.3858	37.042	39.4555	30.5881	29.7267
102	32.9545	33.2468	31.8788	26.4428	26.3785
103	41.2275	41.0927	41.6293	35.8763	39.5444
104	34.6757	35.1505	36.5874	31.9001	35.563
105	38.7704	32.2798	32.9764	28.2387	32.5734
106	39.8655	39.488	38.9251	34.4125	33.4421
107	41.1199	40.1454	39.2794	35.5818	32.5157
108	34.253	34.1788	35.1165	31.6499	37.3578
109	51.6731	54.1205	54.9239	49.8211	41.9486
110	51.4718	51.7898	50.1836	46.7036	45.4459

No	PC	pickup &LC	Minibus	Bus	Truck
111	49.5284	49.0565	48.1166	42.7598	40.0157
112	47.9605	48.9936	46.0508	44.9651	43.588
113	53.5429	54.331	51.6447	49.8048	47.4676
114	46.4344	46.8988	44.3029	42.1407	39.6322
115	51.1075	50.4326	48.372	41.9387	38.972
116	47.5209	48.7319	45.738	44.6829	43.5679
117	49.53	49.4671	47.2612	43.6975	40.6258
118	56.6952	57.3532	56.4944	51.3759	49.6987
119	52.6292	52.3581	51.0929	46.561	44.0301
120	49.7053	49.2248	48.1015	43.4238	41.1403
121	47.0513	47.0476	44.8771	41.1443	38.3834
122	49.1448	50.0273	47.6641	44.7211	42.7849
123	51.3038	51.0337	48.5816	43.3144	39.8394
124	51.2126	50.6496	48.9693	43.9835	40.8872
125	41.8127	42.2311	39.8903	37.6974	35.4269
126	51.1343	50.8584	49.1459	44.871	41.6494
127	44.9164	43.9645	42.7381	37.0044	34.2431
128	53.4712	54.1103	51.1381	46.9369	42.8246
129	46.0376	47.9685	48.4684	46.5963	42.2734
130	47.0513	47.0476	44.8771	41.1443	38.3834
131	51.083	52.6487	52.4866	49.5982	43.2108
132	53.0066	55.6322	56.7979	52.4125	47.6812
133	49.0984	48.4838	47.2051	42.6075	39.907
134	53.1086	54.081	54.0109	49.7867	47.0751
135	49.6495	49.6712	48.367	44.4926	42.3247

Appendix G Model estimated error

Table A-7 Model estimated error

	Error					Error^2				
No	PC	pickup &LC	Minibus	Bus	Truck	PC	pickup &LC	Minibus	Bus	Truck
1	7.271918	7.523171	6.750799	-1.1309	0.65275	52.88079	56.59811	45.57329	1.278939	0.426082
2	2.7082	2.07478	0.563956	4.027202	8.220788	7.334346	4.304713	0.318047	16.21835	67.58136
3	-0.94436	3.060486	2.147475	-2.59339	3.344667	0.891815	9.366576	4.611649	6.725666	11.1868
4	-5.1327	-6.14243	-3.65279	-5.08301	-5.14861	26.34465	37.72944	13.34285	25.83699	26.50823
5	2.529677	0.057585	-0.92601	2.963659	0.319135	6.399266	0.003316	0.857493	8.783275	0.101847
6	-5.56095	-6.57204	-3.79764	-4.53516	-2.50855	30.9242	43.19166	14.4221	20.56771	6.292834
7	3.52892	6.312889	8.387754	-0.68362	5.5688	12.45328	39.85257	70.35442	0.467331	31.01153
8	5.115638	0.380438	8.05634	-5.09641	-0.06571	26.16975	0.144733	64.90462	25.9734	0.004317
9	9.735154	5.763043	0.582842	-4.4277	0.553345	94.77322	33.21267	0.339705	19.60449	0.30619

	Error					Error^2				
No	PC	Pickup and LC	Minibus	Bus	Truck	PC	Pickup and LC	Minibus	Bus	Truck
10	1.380526	2.933929	1.025013	-6.80271	0.935788	1.905852	8.607937	1.050651	46.2769	0.875699
11	2.548935	3.346504	1.8362	-3.07605	3.593961	6.497068	11.19909	3.371632	9.462073	12.91656
12	-5.12246	-7.16713	0.003488	2.763276	-10.1163	26.23958	51.36779	1.22E-05	7.635694	102.3396
13	1.228841	-0.44183	0.228612	-3.26456	-1.92664	1.51005	0.195218	0.052263	10.65734	3.711941
14	-1.12091	-0.99126	-0.3528	0.894589	1.754099	1.256435	0.982605	0.124468	0.800289	3.076864
15	-4.83731	-6.28568	-5.39391	1.938485	-1.82595	23.39955	39.50977	29.09422	3.757723	3.334111
16	0.044281	2.763886	6.847395	-1.11534	7.665006	0.001961	7.639067	46.88682	1.243993	58.75231
17	3.113115	-0.36288	1.178008	4.089064	2.985453	9.691482	0.131684	1.387704	16.72045	8.912928
18	4.568802	2.034263	-1.97415	1.375378	-0.03564	20.87396	4.138226	3.897264	1.891666	0.00127
19	3.813955	2.097549	4.275688	-0.85274	1.886473	14.54625	4.399711	18.28151	0.727167	3.558779
20	0.357922	-0.50287	0.200219	6.070014	1.052673	0.128108	0.252877	0.040088	36.84507	1.10812
21	2.179427	1.040281	3.480254	-2.45729	9.861317	4.749901	1.082185	12.11217	6.038277	97.24557
22	1.549	-1.13462	0.037921	-3.40222	-0.23472	2.3994	1.28737	0.001438	11.5751	0.055095
23	-2.32179	-2.35228	-1.01998	-0.71632	-1.84767	5.390688	5.533243	1.040359	0.513116	3.413884
24	-0.88085	-9.11064	-7.10361	0.80989	-1.81709	0.7759	83.00377	50.46122	0.655922	3.301829
25	-0.87318	-3.4254	-3.45323	7.797388	0.513459	0.762438	11.73337	11.92478	60.79926	0.26364
26	-7.06958	-0.84171	-2.00429	0.446232	-5.15099	49.97896	0.708471	4.017191	0.199123	26.53272
27	9.190896	5.674484	7.444915	7.527577	-5.04313	84.47257	32.19976	55.42676	56.66442	25.43317
28	5.236411	0.999751	0.43865	5.435948	0.390582	27.42	0.999503	0.192413	29.54953	0.152554
29	4.988085	2.302766	0.21994	-3.53027	5.120573	24.88099	5.30273	0.048374	12.46281	26.22027
30	4.115122	1.756444	1.855136	-0.33076	-0.97073	16.93423	3.085097	3.441529	0.109405	0.942326
31	0.603031	10.62005	0.290317	0.876277	0.483721	0.363646	112.7854	0.084284	0.767862	0.233986
32	-5.17907	-0.95735	1.920704	4.074922	0.298161	26.82279	0.916519	3.689103	16.60499	0.0889
33	6.611552	4.531041	6.703469	0.771183	0.21676	43.71262	20.53033	44.9365	0.594723	0.046985
34	-9.27569	1.349267	-4.06763	6.558463	-7.45788	86.03836	1.820522	16.54558	43.01344	55.62
35	1.902086	1.943107	2.212478	1.587549	0.748739	3.617931	3.775664	4.895057	2.520311	0.560609
36	0.242367	2.184072	4.462401	7.013431	-3.25488	0.058742	4.770172	19.91302	49.18822	10.59421
37	-0.14952	0.889652	0.344033	3.208248	1.372006	0.022358	0.791482	0.118359	10.29285	1.8824
38	2.768475	0.814328	2.619033	0.531855	1.109291	7.664453	0.663129	6.859331	0.28287	1.230525
39	-0.91534	-0.28168	-0.05741	-0.95208	-7.74484	0.837848	0.079346	0.003296	0.906448	59.98255
40	8.601615	0.003399	0.033992	0.44992	0.688949	73.98777	1.16E-05	0.001155	0.202428	0.474651
41	-1.18706	-0.83273	0.840337	-0.94748	0.655668	1.409119	0.693443	0.706167	0.897718	0.429901
42	-0.10885	-1.86835	1.100724	5.65234	10.32681	0.011848	3.490731	1.211592	31.94895	106.643
43	-6.0944	-8.67738	-7.9186	-5.94793	-4.32438	37.14166	75.29688	62.70425	35.37786	18.7003
44	4.17226	2.919423	1.094625	5.103337	5.899628	17.40776	8.52303	1.198205	26.04405	34.80561
45	3.927246	3.388974	4.592701	4.801675	-7.84542	15.42326	11.48515	21.0929	23.05608	61.55065
46	1.287543	0.863203	1.141599	4.550877	-0.33536	1.657767	0.74512	1.303248	20.71048	0.112466
47	0.025067	0.675117	-0.56056	-0.34236	-2.92666	0.000628	0.455783	0.314229	0.11721	8.565351
48	-2.42616	-2.48374	-2.07213	-0.48959	-1.45934	5.886264	6.168986	4.293706	0.2397	2.129666
49	4.00374	3.959346	2.780185	-4.26472	-6.24997	16.02993	15.67642	7.729429	18.1878	39.06207
50	-1.67574	-2.65048	-3.28745	-2.20009	-0.163	2.808121	7.025051	10.8073	4.840394	0.026568

	Error					Error^2				
No	PC	Pickup and LC	Minibus	Bus	Truck	PC	Pickup and LC	Minibus	Bus	Truck
51	0.129581	5.220207	3.22364	-1.43872	-1.17345	0.016791	27.25056	10.39185	2.069921	1.376984
52	-0.84641	-0.13782	-1.73945	3.869092	-3.08234	0.716411	0.018994	3.02568	14.96987	9.500802
53	-2.91856	-2.17724	-4.18388	-7.24872	-1.16087	8.517966	4.74039	17.50487	52.54395	1.347609
54	-2.53359	-1.77813	-1.86751	-2.59001	-0.44231	6.419083	3.161749	3.487585	6.708177	0.19564
55	5.596372	7.084421	8.615018	2.755908	5.864346	31.31938	50.18902	74.21854	7.595031	34.39056
56	5.220769	4.17957	0.201299	9.471715	7.667989	27.25642	17.46881	0.040521	89.71339	58.79805
57	-7.40413	-5.11017	-5.9007	0.192304	-3.3226	54.82115	26.11379	34.81821	0.036981	11.0397
58	0.964798	4.807618	-4.05505	8.47971	0.965178	0.930835	23.11319	16.44339	71.90548	0.93157
59	-0.62648	-10.5477	-0.19669	-0.63457	-0.77922	0.392472	111.2533	0.038688	0.402675	0.607185
60	2.165143	-2.93885	2.897188	-2.18879	5.014575	4.687843	8.63682	8.393697	4.790786	25.14597
61	-1.8748	4.334325	5.023289	-0.69284	0.136509	3.514885	18.78638	25.23343	0.480024	0.018635
62	-6.8306	-8.21177	-4.23382	-5.17605	-1.66475	46.65713	67.43312	17.92523	26.79145	2.771381
63	-0.68903	-0.75918	-0.34218	-0.48645	-1.00342	0.474756	0.576355	0.117086	0.236633	1.006852
64	1.804771	0.885561	1.364523	4.058878	0.477653	3.2572	0.784218	1.861923	16.47449	0.228153
65	1.3433	0.673948	0.389166	-2.22252	-1.89319	1.804455	0.454205	0.15145	4.939602	3.584178
66	-6.76276	-7.78689	-6.03526	0.675887	-5.06475	45.73491	60.6357	36.42436	0.456823	25.65172
67	4.285933	3.783562	2.950223	5.201958	6.842499	18.36922	14.31534	8.703818	27.06037	46.81979
68	1.393962	-1.03114	-3.23051	-4.73156	-0.50814	1.94313	1.063253	10.43623	22.38763	0.258205
69	2.699218	2.094353	0.550104	0.849068	-1.8684	7.285776	4.386313	0.302615	0.720917	3.4909
70	-6.79458	-7.02846	-8.77636	-6.19477	-6.56487	46.16631	49.3992	77.02456	38.37521	43.09751
71	-5.89885	-5.31442	-7.10399	-2.81931	-4.05547	34.79649	28.24302	50.46664	7.948482	16.44686
72	4.904175	2.745743	-0.63546	-1.3855	-4.23737	24.05093	7.539102	0.403806	1.919604	17.95534
73	3.271918	4.523171	3.750799	0.869098	9.65275	10.70545	20.45908	14.0685	0.755332	93.17558
74	-0.2918	4.07478	2.563956	6.027202	5.220788	0.085147	16.60383	6.573871	36.32716	27.25663
75	1.05564	1.060486	-0.85253	4.406611	0.344667	1.114377	1.124631	0.726799	19.41822	0.118796
76	-1.61947	-0.06607	-1.97499	0.197287	-2.06421	2.622696	0.004365	3.900574	0.038922	4.260971
77	1.361377	3.238501	-3.0277	4.839023	0.808145	1.853348	10.48789	9.166966	23.41615	0.653099
78	-6.39628	-8.09472	-3.4126	-3.27625	-0.16758	40.91238	65.52448	11.64587	10.73379	0.028084
79	3.813955	-0.90245	1.275688	1.147259	-1.11353	14.54625	0.814418	1.627381	1.316203	1.239943
80	2.851921	-1.35875	1.05366	-2.69824	4.821409	8.133454	1.846189	1.1102	7.280516	23.24598
81	-2.8367	-1.82122	-0.63631	0.50969	5.758576	8.046842	3.316832	0.40489	0.259784	33.1612
82	-5.01443	-4.08849	-3.22011	-6.64487	-3.02029	25.14448	16.71576	10.36909	44.15434	9.12218
83	-2.19367	3.472392	-7.53396	-0.02693	0.384558	4.812184	12.0575	56.76058	0.000725	0.147885
84	0.690277	-0.97054	0.261725	-7.3059	-0.5205	0.476483	0.941946	0.0685	53.37615	0.270921
85	0.866753	-7.62843	5.039205	4.951566	4.220306	0.75126	58.19292	25.39359	24.51801	17.81098
86	-3.10429	-0.70292	-0.43752	-0.56054	-2.56636	9.636641	0.494102	0.191421	0.314209	6.586219
87	0.066473	0.577774	-7.38588	-2.15291	-4.85722	0.004419	0.333823	54.55117	4.635033	23.5926
88	-3.61146	5.715695	-4.97531	-3.57018	4.147544	13.04265	32.66917	24.75369	12.74619	17.20212
89	-0.60126	7.35731	7.742732	-1.27265	5.146268	0.361514	54.13002	59.9499	1.61964	26.48407
90	0.604296	1.430937	2.110933	-0.6651	0.774758	0.365173	2.047579	4.456039	0.442353	0.60025
91	-1.91967	4.05034	2.447565	-2.8133	3.93315	3.685142	16.40526	5.990572	7.914672	15.46967

	Error					Error^2				
No	PC	Pickup and LC	Minibus	Bus	Truck	PC	Pickup and LC	Minibus	Bus	Truck
92	3.834494	1.332281	-1.16907	-3.67099	5.64591	14.70334	1.774972	1.366714	13.47614	31.87629
93	-1.17044	1.522249	1.518813	0.089306	2.887259	1.369924	2.317243	2.306794	0.007976	8.336265
94	2.14959	1.949693	7.046674	6.295003	0.919316	4.620736	3.801304	49.65562	39.62706	0.845141
95	5.456604	-0.17976	2.613371	7.332765	8.974186	29.77453	0.032313	6.829708	53.76944	80.53601
96	4.923994	3.006291	4.841894	-0.64287	-0.68212	24.24571	9.037788	23.44394	0.413278	0.465294
97	4.65903	5.51606	0.065447	-1.45486	1.429716	21.70656	30.42692	0.004283	2.116605	2.044089
98	1.930485	1.954973	2.143378	2.921541	-0.85371	3.726771	3.821919	4.594071	8.535402	0.728816
99	6.820055	-2.30579	-0.39581	3.401966	-0.9192	46.51315	5.316668	0.156663	11.57337	0.844935
100	0.481542	0.039786	0.39595	3.697519	4.981032	0.231883	0.001583	0.156776	13.67165	24.81068
101	-2.28576	-1.74204	-3.65549	-1.18815	7.573289	5.22468	3.034711	13.36261	1.411699	57.3547
102	2.345482	2.053247	0.32123	4.257151	4.721457	5.501286	4.215824	0.103189	18.12333	22.29216
103	-4.72748	-4.19275	-5.72927	-1.47625	-0.14442	22.34908	17.57912	32.82449	2.179315	0.020859
104	3.324255	2.349519	1.712554	2.799911	-9.163	11.05067	5.520239	2.932841	7.839499	83.96053
105	0.129581	0.220207	1.22364	3.561278	1.92655	0.016791	0.048491	1.497294	12.6827	3.711596
106	-2.26553	-5.58797	-1.32507	-2.01253	0.957914	5.132617	31.22538	1.755821	4.050286	0.9176
107	-9.91991	-8.94541	-0.27936	-5.38177	0.341328	98.40464	80.02037	0.078042	28.96345	0.116505
108	2.146969	3.021172	2.883538	2.150099	0.242183	4.609477	9.127481	8.314791	4.622925	0.058653
109	3.082864	3.023505	0.625094	4.299852	0.656407	9.504052	9.14158	0.390742	18.48872	0.43087
110	0.394222	7.021242	1.495439	-1.63559	-2.08588	0.155411	49.29783	2.236337	2.675151	4.350887
111	2.594613	-0.27653	3.305415	1.165226	2.500255	6.732015	0.076468	10.92577	1.357751	6.251277
112	1.524482	-1.02558	2.266197	5.876887	0.32198	2.324046	1.051816	5.13565	34.5378	0.103671
113	1.844091	-2.40701	-3.12575	-4.69276	-3.34564	3.400673	5.793705	9.770295	22.02195	11.19332
114	10.06063	9.003247	8.646067	0.713286	8.115841	101.2164	81.05846	74.75447	0.508776	65.86687
115	6.879536	3.058449	6.812035	8.735295	9.419993	47.32801	9.354112	46.40382	76.30538	88.73627
116	5.041135	1.790145	4.382985	5.325113	4.26206	25.41305	3.204618	19.21056	28.35683	18.16515
117	3.625021	1.278939	2.235767	-1.04149	-0.75276	13.14078	1.635686	4.998652	1.0847	0.566654
118	1.241759	6.073833	6.455643	6.440139	0.510278	1.541964	36.89145	41.67533	41.47539	0.260384
119	3.522826	0.915941	0.724126	0.426014	0.968863	12.4103	0.838947	0.524359	0.181488	0.938696
120	3.164653	1.696211	0.187525	4.912239	-0.81831	10.01503	2.87713	0.035166	24.13009	0.669628
121	-1.50629	-1.40058	1.167944	-7.47925	-1.82737	2.268916	1.961634	1.364094	55.93923	3.339282
122	-8.22175	-0.01333	-9.60412	-0.91107	-0.73892	67.59718	0.000178	92.23907	0.830045	0.546
123	-0.45278	-2.8677	-4.01058	-8.2854	-0.15142	0.205007	8.223721	16.08476	68.64785	0.022928
124	-3.78264	-8.30757	-8.00931	-8.96347	-0.79717	14.30839	69.01578	64.14902	80.34374	0.635478
125	8.176254	-4.51612	-4.34232	-7.20437	-0.24391	66.85113	20.39532	18.85576	51.90298	0.059491
126	5.317663	2.668605	-8.31589	-4.57803	-3.33043	28.27754	7.121455	69.15402	20.95833	11.09177
127	4.894593	7.410451	9.437932	0.877615	6.250851	23.95704	54.91478	89.07456	0.770208	39.07314
128	5.807785	0.618699	-9.32811	-2.72687	-1.59958	33.73036	0.382789	87.01371	7.435846	2.558648
129	1.730354	2.297544	-5.73644	1.334662	0.689588	2.994124	5.278707	32.9068	1.781324	0.475532
130	-1.99329	-3.74558	3.423944	-1.02425	5.70863	3.973213	14.0294	11.72339	1.049095	32.58845
131	2.156996	4.390256	0.966361	0.081762	5.907209	4.652632	19.27435	0.933854	0.006685	34.89512
132	2.651356	3.908835	0.96213	4.491471	-9.45422	7.029689	15.27899	0.925694	20.17331	89.3823

Error						Error^2				
No	PC	Pickup and LC	Minibus	Bus	Truck	PC	Pickup and LC	Minibus	Bus	Truck
133	6.396573	7.58624	7.682921	-2.61445	-0.31998	40.91615	57.55104	59.02728	6.83535	0.102389
134	6.153397	5.312986	3.470078	-9.91067	-5.6981	37.8643	28.22782	12.04144	98.22147	32.46834
135	6.186454	6.186837	2.864023	-2.39556	-0.72173	38.27221	38.27695	8.202625	5.738703	0.520898
					MSE	17.35988	17.49367	16.92036	16.80336	17.01936
					RMSE	4.166519	4.182544	4.113436	4.09919	4.125452