ESTIMATING TRAVEL TIME FOR UN-SIGNALIZED TWO LANE HIGHWAYS IN SRI LANKA

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Degree of Master of Science

Department of Civil Engineering

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Thesis submitted in partial fulfilment of the requirements for the degree Master of Science in Civil Engineering

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Declaration

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Abstract

Estimating Travel Time for Un-signalized Two Lane Highways in Sri Lanka

Reliable travel time estimation of a given route is important in transport planning. Travel time estimation is an important parameter in effective transport planning, quality maintenance, and traffic management. Even though several models are available worldwide for travel time estimation from simple road network to a complex transport network, local availability of such methods are lacking mainly due to the inadequacy of research, data and resources. Travel time along a particular route is associated with several factors including land use type, geography, weather, road condition, traffic flow, road geometry. One or a combination of these factors can cause variation in travel time and the effect from each parameter can change with the land use activities in the area.

The objective of this research is to develop a relationship to estimate the travel time for road links to monitor the travel time and of two lane highways without signalized intersections in Sri Lankan context, by assessing the correlation between land use type and the travel time along the road.

Two lane road sections of three national highways in Sri Lanka; Peliyagoda-Puttalam road (A03), Colombo-Kandy road (A01), Ambepussa-Trincomalee road (A06) were considered for this study to associate the different land use types, different vertical and horizontal alignments and its correlation with vehicle travel times. Continuous travel time data along the roads was collected during daytime using GPS (Global Positioning System) data loggers. Road was sectioned according to the land use type. Multivariate stepwise regression was used to develop the relationship between the land use type and the travel time. Land use data showed significant positive correlation with the travel time data. One travel time estimation model for three leg un-signalized intersections and four models for travel time estimation for different four land use types, commercial, residential present on both side, residential present on one side and cultivation for the stretch of the road were successfully developed with model fit more than 69% and Mean Absolute Percentage Error (MAPE) of more than 38%.

Key words: *Two Lane Highways, Travel Time Estimation, Land Use Type, Transport Planning*

Dedication

To my loving parents and my husband

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List of Abbreviation

Abbreviation	Description
AI	Artificial Intelligence
ANN	Artificial Neural Network
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
C	Cultivation Length
CEP	Circular Error Probable
CL	Commercial Length
DMI	Distance Measuring Instrument
DW	Durban Watson
GPS	Global Positioning System
H	No of Houses
I	Number of Important Places
LOS	Level of Service
MAPE	Mean Absolute Percentage Error
RMSQ	Root Mean Squared Error
SMV	Support Vector Machine
TD	Travel Distance

1 INRODUCTION

1.1 Background

Reliable estimation of travel time on a given route is an essential part of effective transport planning. Due to the formation of built environments worldwide, the necessity of effective transportation has increased and valued. Many development activities automatically taken place along with transportation since the beginning of civilization. From the simple transport related issue to the major activities travel time has been one major factor or outcome and many studies have been carried out and are ongoing to capture this valued parameter. Accurate estimates of expected travel time is required for route and trip planning, estimation of benefits of transport projects, quality maintenance of road networks, risk mitigation evaluations and for the traffic system operations. Many methods are used in travel time estimation worldwide but it is not yet available to the transport planners, engineers, policy makers in Sri Lanka.

Travel time along a particular route is associated with several qualitative factors such as land use type, geography, weather, time, road condition, driver performance, traveler's choice and quantitative factors such as traffic flow, road geometry. One or a combination of these factors can cause variation in travel time and the effect from each parameter may change from place to place depending on the magnitude and nature each parameter involves. Due to this reason travel time estimation is yet in primary stages in Sri Lanka and lot of research will require to build up an accurate system.

The simplest method of travel time estimation is to use the average speed and the travel distance. Operating speed (85^{th} percentile speed) is also used to calculate the travel time which is more representative (Manual of uniform traffic control devices, 2008). Due to the increase in traffic demand, deficiencies in roadway features and land use development along the roads it is not accurate enough to use the average speed or operating speed. Different organizations do research to build travel time estimation models worldwide. But the effect of the parameters that is used for model development is not universal and not applicable for different regions of the world.

Adaptation of a prevailing method will at lease require a calibration to represent Sri Lankan context. Currently many countries are moving towards real time travel time estimation methods which are mainly using statistical approaches (Nahar & Sultana, 2014). These models use present traffic data and some models use present traffic flow data as well as the historical traffic data which is more promising even with a higher cost. Even though it is becoming crucial to adopt a travel time estimation method for the planning purposes in Sri Lanka, real time travel time estimation is not currently possible due to high capital cost, resources and lack of research tools.

In this research the effect from the built environment on the travel time has been assessed. For an example two geometrically identical road with same weather conditions, segments having different land use type can have two different travel times due to differences in trip generation patterns, accessibility levels and we experience this simple example every day. Out of many different perspectives, the effect due to land use type was used in this research to estimate the travel time. The method particular organization or road user can use for travel time estimation will depend on the accuracy required and capacity of resources, time and money they could allocate. This research has been carried out as an initial input for developing more accurate travel time estimation model for Sri Lanka.

1.2 Objective of the study

The main objective of this research is to develop a relationship to estimate the travel time for two lane highways without signalized intersection in Sri Lankan context, by assessing the correlation between land use type and the travel time along the road.

1.3 Scope of work

The study is focused on the relationship between land use type and the time taken to travel along a route. This research was implemented as a foundation to build up a travel time estimation model. The study was done only for two lane road segments without signalized intersections. The study contains macro level,

- Travel time estimation model for un-signalized three legged major intersections (Intersections where the A or B class roads intersects)

- Travel time estimation model for the stretch of the road (Road sections other than major intersections)

considering the land use types residential, commercial, presence of agriculture, bare lands, water bodies and the accessibility levels. In this research, the correlation between daily travel patterns (including morning, afternoon and evening traffic conditions) without any seasonal or occasional traffic variations (travel time in weekends or at holidays) of the area and land use type is considered.

2 LITERATURE REVIEW

2.1 Factors affecting the travel time

Roadway and other physical factors, vehicle and driver are three main considerations for a safe and reliable travel. Travel time will depend on the condition of them. These three factors belong to three entire different areas and their behavior is also entirely different and time dependent. Their performance will decide the final travel time of a journey. Since this research is on two lane highways without signal intersections the literature is based on that.

Two lane highway is an undivided roadway with two lanes serving the traffic in each direction. Additional space is not provided for vehicles to pass and when the geometric restrictions increase the possibility of passing of vehicle decreases causing platooning of vehicles. Due to this reason two lane highways can be considered as interrupted flows. When the traffic volume increases the platoon volume increases causing increase in delays and increase in travel time.

Capacity is a governing factor in a road because not only traffic flow will decide the capacity but other disturbances such as geometric deficiencies, weather conditions, geography and road condition can reduce the capacity from the ideal condition (Highway capacity manual, 2000).

Travel time depends on several factors and they can be mainly divided in to two, Qualitative factors and Quantitative factors and some of them are listed in Table 2.1. Quantification of travel time is complex due to high variability and the association with each other. Next few paragraphs will contain literature on factors affect travel time.

Table 2.1: Factors Affecting Travel Time

Quantitative factors	Qualitative factors
Traffic flow	Weather
Road geometry	Time of travel (Morning, Evening etc.)
Roadway condition	Driver performance,

Land use type	Travelers choice on travel mode, route selection, speed

Traffic flow, speed and density are vastly used parameters in travel time prediction/estimation. It is in the senses that increase in flow cause reduction of speed resulting increase in travel time. Several reasons could cause to increase in traffic flow including but not limited to inadequate public transport facility, lack of infrastructure development compared to the population growth, new trip attraction. Greensheild model demonstrate the relationship between traffic flow, speed and the vehicle density for traffic under uninterrupted flow conditions and speed and density are linearly related. Traffic volume vs. Speed graph is illustrated in Figure 2.1 and flow is usually indicated per hour basis (Hall, 2001). According to the graph it could be seen how the speed changes with the increase of flow. When the density increases, the flow increases up to the saturation point and after that the flow starts to reduce. The optimum efficient point road serves at its full capacity is the portion of the curve starting from the maximum speed up to the inflection point. After that the vehicle speed reduces and the flow tends to reduce. Most of the travel time prediction models are based on the traffic flow theory where traffic flows described by using mathematical and statistical ideas which helps to understand and express the properties of traffic flow (Liu H. , 2008) (Chu, Oh, & Recker, 2005). At present shock wave concepts are used together with traffic flow theories in studies (Izadpanah, 2010). The idea behind this is shock wave is created due to a change in flow rate density of traffic. This is transferred along the travel routes creating vehicle queues and delays and they increases (accumulate) when the distance increases from the starting point of the shock.

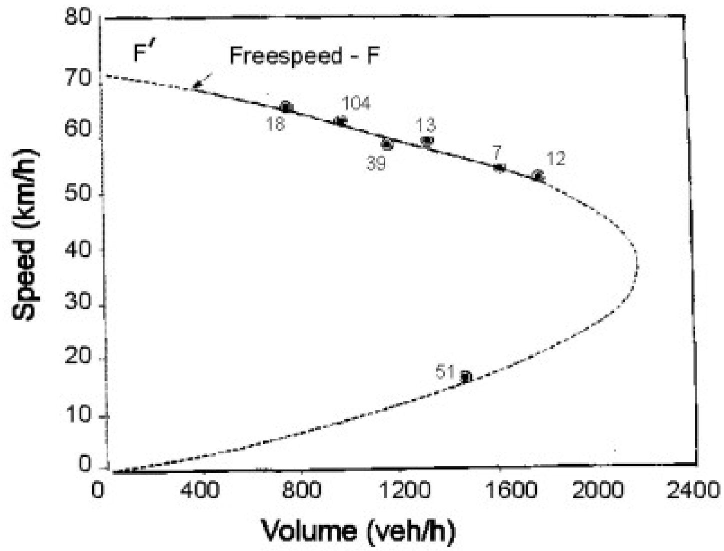

Figure 2.1: Greenshield Speed – Flow Curve (1935)

Source: http://www.fhwa.dot.gov/publications/research/operations/tft/chap2.pdf

Visited date: 2015.05.22

Highway classification based on the major geometric features (freeways, highways local streets etc.) is most helpful one for highway location and design procedures. Generally trip contains main movement, transition, distribution, collection, access, and termination. The policies for highway planning and design are made such that the road can serve according the purpose it's been constructed (ex: for the major movement of traffic, access to residential areas). Figure 2.2 exhibits the relationship between the road classification and their functionality. Roads have to design depending on the functionality requirement for them to be economically viable.

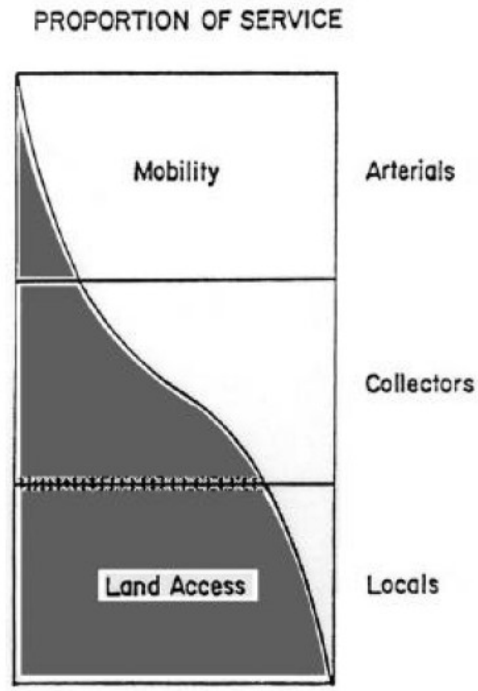

Figure 2.2: Functional classification of roads

Source: (A policy on Geometric Design of Highways & Streets, 2001)

Selection of geometric features such as lane width, number of lanes, and provision for shoulder, minimum curve radius, and maximum grade will depend on the design speed and traffic of the route (A policy on Geometric Design of Highways & Streets, 2001).

Roads consist of tangent segments, horizontal curved sections, crests and sags. The behavior of a horizontal curve, crest or a sag is different from tangent sections. For a safe driving sufficient stopping sight distance should be provided to allow the driver sufficient brake reaction time to bring the vehicle a stop (Project Development & Design Guide, 2006). Change in the horizontal alignment automatically cause speed reduction due to the difficulties in clear sight visibility and difficulty in maneuver. Yet the interaction between the horizontal curve design elements and the traffic performance measures are still not perfectly found. The research carried out by the Shawky & Hashim (2010) used the traffic data collected from mid-tangent and mid-curve points with various horizontal alignment characteristics and the relationships were built between the follower density, flow rate, horizontal alignment characteristics (curve radius, tangent length), and average speed. The study showed that the horizontal alignment characteristics, especially the curve radius have a significant effect on the follower density. Decrease in the radius causes to increase the follower density and the threshold of curve radius on traffic performance is radius falling between 400m -450m (Shawky & Hashim , 2010).

The vertical alignment should use smooth grade line with gradual changes, consistent with the type of highway and character of terrain. Grades with break points and short tangent lengths should be avoided (Project Development & Design Guide, 2006).

The general practice is to minimize the changes in the horizontal or vertical alignment as much as possible and if present they have to be gradual changes since the safety and the performance are affected significantly. The Geometric consistency of rural two lane highways are measured to assess the convenience of the road for the driving and in most cases consistency is measured by analyzing the operating speed (usually 85^{th} percentile speed), at tangents and curves (Faden & Elefteriadou, 2000) (Praticò & Giunta, 2010).

2.1.1 Land Use

Land use is defined in many perspectives worldwide. In this research the term “Land use type” indicates the natural or modified (built environment) land cover. For an example natural land use types includes forests, marshy areas, natural water bodies, planes etc. and the built environment indicates all the modified land cover including cultivations, residential areas, commercial areas etc. Land use and transportation are interacting subjects where one affects on the other since these factors have the ability of traffic generation as well as attraction. This will depend on their combination with each other and there inter and intra relationship are being studied worldwide to solve transportation & land use necessities (Litman, 2015).

Time scale of analysis is a main consideration in land use and transport related studies since these two areas changes with the time. As described in the previous paragraph transport planning causes changes in land use and land use cause changes in transport planning. For an example due to widening of roads road side structures can be demolished and new structures will be built. Once a single story residential unit, can be renovated in to a multi-story residential and commercial building. Due to this reason this type of research requires periodic updates. There can be community changes over time and solution exist 50 years ago may not be practical today.

Another governing factor is the geography of the area. Certain geographic features attract certain land use features and travel pattern changes according to them. For an example commercial activities are high closer to a harbor and the majority of the transport can be freight transport (in land) and the surrounding communities develop by abstracting the characteristics of the area.

Table 2.2 shows some land use factors and its effect on transportation. One or combination of these factors can cause changes in travel characteristics. Due to this reason isolation of one character is difficult since others influence the nature significantly.

Land use pattern affects the accessibility and mobility. For an example in urban areas accessibility is high and several transport modes are available within a small area but average speeds are slow and costly. But in rural areas/ suburbs accessibility is low, transport modes are less but speeds are greater. It is difficult to argue which controls which, but provides sufficient proof that the land use and transport related parameters interrelated to each other.

Table 2.2 : Effect of Land Use on Transport

Factor	Definition	Mechanisms
Regional Accessibility	Location relative to regional centers, jobs or services	Reduce travel distances between regional destinations (homes, services and jobs)
Density	People, jobs or houses per unit of land area (acre, hectare, square mile or kilometer)	Reduce travel distances between local destinations (homes, services and jobs). Increases the portion of destinations within walking and cycling distances.

Factor	Definition	Mechanisms
Mix	Proximity of different land uses (residential, commercial, institutional, etc.). Sometimes described as jobs/housing balance, the ratio of jobs and residents in an area.	Reduces travel distances between local destinations (homes, services and jobs). Increases the portion of destinations within walking and cycling distances.
Centeredness (centricity)	Portion of jobs, commercial and other activities in major activity centers.	Provides agglomeration efficiencies and increases public transit service efficiency.
Connectivity	Degree that roads and paths are connected and allow direct travel between destinations.	Reduces travel distances. Reduces congestion delays. Increase the portion of destinations within walking and cycling distances.
Roadway design and management	Scales and design of streets, to control traffic speeds, support different modes, and enhance the street environment.	Improve waling, cycling and public transit travel. May improve local environments so people stay in their neighborhoods more.
Parking supply & management	Number of parking spaces per building unit or hectare, and the degree to which they are priced and regulated for efficiency.	Increased parking supply disperses destinations, reduces walkability, and reduces the cost of driving.
Active transport conditions	Quantity and quality of sidewalks crosswalks, paths, bike lanes, bike parking, pedestrian security and amenities.	Improves pedestrian and bicycle travel, and therefore public transit access. Encourages more local activities.
Transit accessibility	The degree to which destinations are accessible by higher quality	Improves transit access and supports other accessibility

Factor	Definition	Mechanisms
	public transit	improvements.
Site design	The layout and design of buildings and parking facilities.	Improves pedestrian access.
Mobility Management	Various strategies that encourage use of alternative modes.	Improves and encourages use of alternative modes

Source: (Litman, 2015)

- Land Use in Sri Lanka-

  According to the Economic & Social Statistics of Sri Lanka 2014 published by the Central bank the gross land area is 65,610 km^2 and the inland excluding water is 62,705km^2. The population in Sri Lanka is 20,483,000 in year 2013 and the composition of population is given in Table 2.3. According to the statistics, heights percentage GDP by sector holds for Services with a value of 58.1%, secondly 31.1% for industry and lowest is for agriculture sector with a value of 10.8%. Majority of the population of 77.3% lives in rural areas while 18.3% lives in urban areas and 4.4% residence in estate. The main economic hub in the country is Colombo and all the developments are centered around the Capital (Economic and Social Statistics of Sri Lanka 2014, 2014).

  The land cover in Sri Lanka can be mainly categorized in to Residential, Commercial (retail, industrial etc.) Agricultural, Recreational, Religious, and Natural (water bodies, Marshy areas, forests etc.). These land use types have specific characteristics which are important in transportation but it is very tricky because land use characteristics are more often associated with socio economic characteristics thus difficult in establishing precise/universal travel characteristics (Stead, 2001).

  Figure 2.2, 2.3 and 2.4 shows thee maps Pettah, Jaffna and Habarana (forest area) with approximately same scale. These three figures illustrate typical differences in travel characteristics (accessibility) and they are partly visible from the demographic differences in the map (population densities, land use mix, transport network, scatter in the land). Many reasons will cause for these variation in community in the land such as job market, living standards etc. But these areas inherit certain land use features for example urban areas are denser compared to other areas. Table 2.3 illustrates more on this argument.

Figure 2.3: Map of Pettah, Sri Lanka, 2016 May

Source: Google Maps, 2016

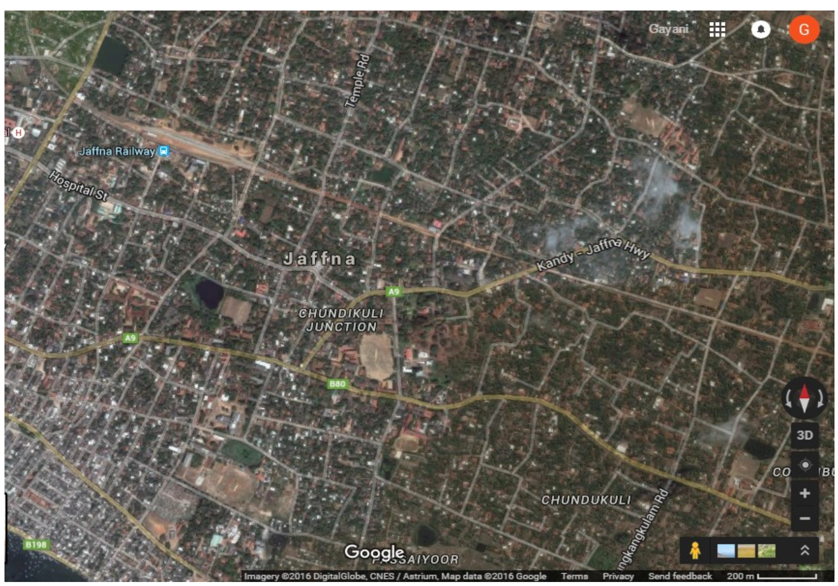

Figure 2.4: Map of Jaffna, Sri Lanka, May 2016

Source: Google Maps, 2016

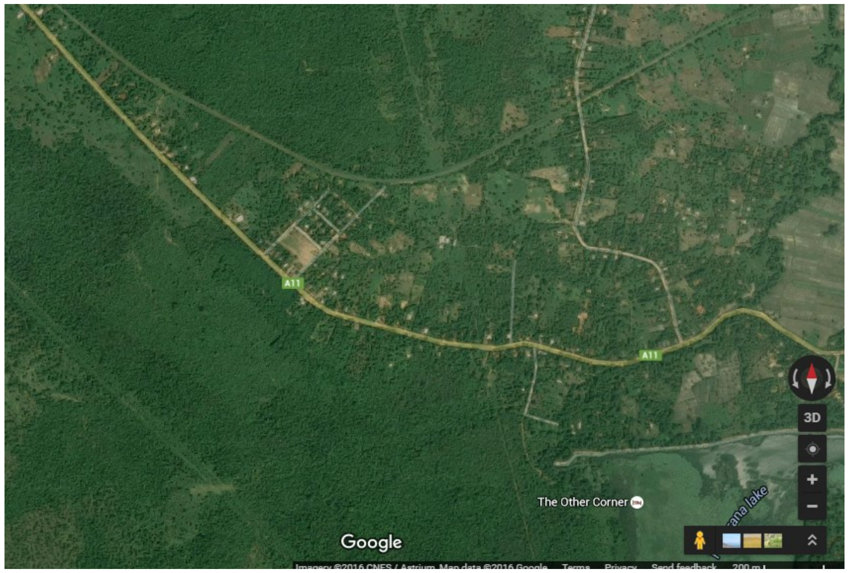

Figure 2.5: Map of Habarana Forest, Sri Lanka, May 2016

Source: Google Maps, 2016

Table 2.3 : Land Use Features

Feature	Urban	Suburb	Rural
Public service nearby	Many	Few	Very few
Jobs nearby	Many	Few	Very few
Distance to major activity centers (downtown or major mall)	Close	Medium	Far
Road type	Low speed grid	Low speed cul-de-sacs and higher speed arterials	Higher speed roads and highways
Road & path connectivity	Well connected	Poorly connected	Poorly connected
Parking	Sometimes limited	Abundant	Abundant
Sidewalks along streets	Usually	Sometimes	Seldom
Local transit service	Very good	Moderate	Moderate to poor

Feature	Urban	Suburb	Rural
quality			
Site/building orientation	Pedestrian oriented	Automobile oriented	Automobile oriented
Mobility management	High to moderate	Moderate to low	Low

Source: (Litman, 2015)

- Road network structure of Sri Lanka

There are two types of road structures available in Sri Lanka toll roads and Non toll roads. In this research only the non-tolls roads are considered. The main non toll road network consists of inter intra provincial roads, inter provincial roads and local roads. These roads are categorized in to 5 categories and they are A, B, C, D and E class roads. A class roads are main arterials or long distance routes for moving traffic between different parts of the country and B class roads are the feeders for A class roads. C class roads are considered to be the collectors/distributors for/from A and B class roads and D and E class roads act as the local roads. (Road Development Authority, 2016). A class roads again categorized in to AA, AB and AC. The total road lengths are given in Table 2.4

Table 2.4: Details of the Main roads of Sri Lanka

Road Type	Description	Road Length(km)
A class roads	Trunk roads which are for high performance roads that don't meet the requirement for motorway.	4217.42
AA		3720.31
AB		466.92
AC		30.19
B class roads	These are the primary intra provincial arterial roads and are the next most important roads in the country's system.	7992.94
Total A class and B class Roads		12210.36

Source: (Road Development Authority, 2016)

The majority of the roads are two lane roads (without center medians) with soft shoulder. The desirable lane width varies from 3.1m to 3.7m and the desirable shoulder width varies from 1.8m to 3.0m. Recently due to the traffic growth the many roads have undergone widening to four lanes at town areas. Because of that many major junctions in the country are four lane. Hot mix asphalt or concrete is used as the surface construction material and for low traffic situations, presently interlocking block paving, concreting and hot mix asphalting is used.

Land use impacts can be evaluated in many ways and the level of analysis can vary according to the outcome required. Evaluation can be done by,

- Analysis of a single land use factor
- Regression analysis of various land use factors (allows to measure relative magnitude of each factor)
- Regression analysis of land use factors and demographic factors
- Regression analysis of land use, demographic and preference factors (Litman, 2015)

The main thing to be mindful in analyzing land use factors is there behavior can change according to the scale of analysis because factor used in one study may not be appropriate for another's scope. In some cases combination of factors can be more meaningful than using separately. Usually the basic meaning of using land use indicators is they reflect travel behavior of the particular region (Bento, Cropper, Mobarak, & Vinha, 2003).

2.1.2 Weather

Adverse weather such as rainfall, mist, precipitation reduces the capacities and operating speeds on roadways, resulting in congestion and productivity loss. Nearly all traffic engineering guidance and methods used to estimate highway capacity assume clear weather. Most of the researches have been carried out to investigate the effect of adverse weather conditions on traffic flow, capacity and speed (operating speed, free flow speed).

Kahatib, Shannon, & Kitchener (2000) studied the effect of advers weather(wind speed and direction, air temperature, relative humidity, roadway surface condition, and the type and amount of precipitation) on free flow speed and the analysis was done compared to the base conditions (no precipitation, dry road way, visibility greater than 0.37, wind speed less than 16km/h). According to the results the visibility had a lesser effect on speed while wind speed higher than 32km/h and the wet road surface had 4.5km/h speed reduction. For heavy rain the speed reduction was more than 30 km/h. (Kahatib, Shannon, & Kitchener, 2000).

However the research carried on the effect on capacity and operating speed by considering the rain (more than 6.35 mm/hour), and low visibility (less than 402 m) showed capacity reductions of 10%–17% and 12 % and speed reductions of 4%–7% and 10%–12%, respectively (Agarwal, Maze, & Souleyrette, 2005)

2.2 Travel time estimation approaches

Travel time estimation methods are mainly divided in to two sections they are direct methods and indirect methods. Direct methods are the methods used to calculate travel time using travel time data, in this type of analysis travel time is collected during the data collection and analysis those data to predict the travel time. Sometimes algorithms are used in this analyses (Celikoglu, 2011) (Kwong, Kavaler, Rajagopal, & Varaiya, 2009). Indirect methods use travel time estimation using traffic dependent parameters such as velocity, occupancy, volume data etc.

2.2.1 Extrapolation method

Extrapolation methods are used to estimate the average travel time for short distances (link length less than 0.8km (805 m) for the application which doesn't require higher accuracy (Turner, Eisele, & Holdener, 1998). This is the direct method of calculating travel time after collection of data and this method is usually used when spot speeds are collected at limited points along the road as shown in Figure 2.6.

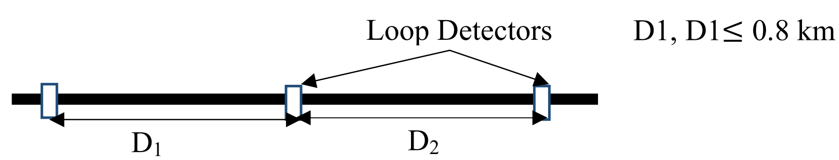

Figure 2.6: Sensors Located on the Road

Even though literature on validation of the extrapolation is less but the accuracy can be checked using probe vehicle and test vehicles. A simple equation for spot speed is given as,

$$Spot\ Speed = \frac{Volume}{Lane\ Occupancy \times g}$$

Where, g is the speed correction factor (based upon assumed vehicle length, detector configuration, and traffic conditions) (Turner, Eisele, & Holdener, 1998). The Chicago Traffic Systems Centre assumes a vehicle length of 6.55 m (21.5 ft.) (Liu & Haines, 1996). Several techniques are used to calculate the spot speed based on the outcome requires. For an example half distance method, the segment is selected by taking half of each distances (D1 and D2 as shown in Figure 2.6) considering that the detector is applicable to half the distance both side and in the minimum speed approach method the minimum spot speed tracked by the two loops situated either side of the segment is chosen to be the spot speed of the segment (Vanajakshi, 2004). Extrapolation methods were used with other methods such as regression techniques to measure the accuracy levels (Sisiopiku, Rouphai, & Santiago, 1994) or to improve the performances of the extrapolation techniques (Ferrier & James, 1999).

2.2.2 Time series analysis

Time series analysis is mostly used in transportation studies (Durango-Cohen, 2007). The basis of this method is to forecast the travel time using previously observed values. This method is usually adopted when a particular agency data base has historical data collected. This can be used to predict travel time for different times or occasions such as peak, off peak, seasonal variations, holidays, week days etc. Figure 2.7 shows traffic variations in different seasons. Several techniques are used for time series analysis and vector regression approach is one method. Direct data or indirect data could be used for the analysis to predict but most widely used is the direct method where travel time on different scales is used. The main advantage of using time series analysis is the possibility of identification of patterns of travel time data (Applied Business Statistics, 2004) in the time scale and the provision of micro scale data analysis.

Support Vector Machine (SVM) is a time series analysis technique use in the travel time prediction approaches. Vanajakshi carried out an analysis to estimate and predict travel time using the loop detector data and three models were developed using SVM technique, artificial neural network (ANN) and theoretical methods. Even though both ANN and SVM showed good performance compared to theoretical method at transitions and congested conditions, SVM performed well when trained data showed high variation (Vanajakshi, 2004). The advantage of support vector machine is that it has greater generalization ability due to the risk mitigation method used. It is feasible and perform well for traffic data analysis (Wu, Wei, Su, Chang, & Ho , 2003; Wu, Ho, & Lee, Travel-time Prediction with Support Vector Regression, 2004; Vanajakshi, 2004).

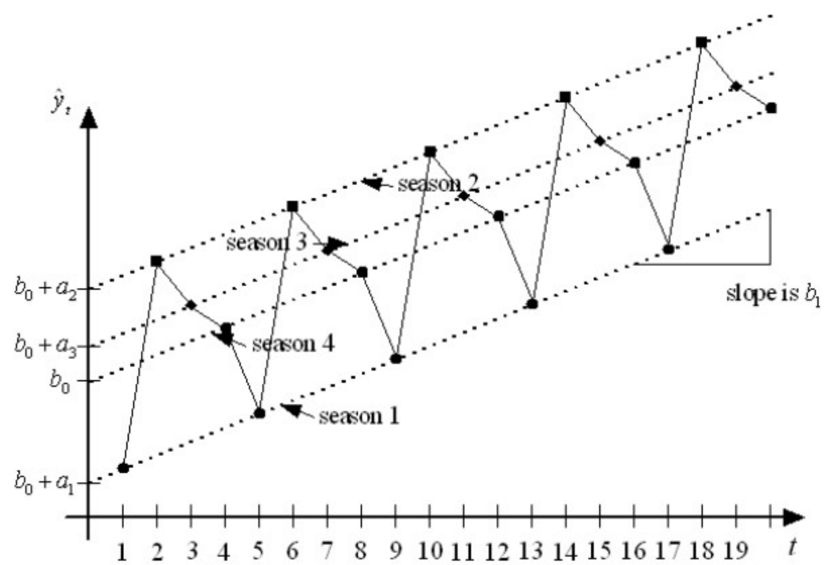

Figure 2.7: Seasonal variation over time

Source: (Applied Business Statistics, 2004)

An interesting phenomenon was found in a study done by Jones, Geng, Nikovski, & Hirita, 2013 which basically used a support vector machine for the analysis. That is geo spatial inference. The concept behind geo spatial inference is when there are no probe vehicle data available for a particular link, travel time data available for the connecting links are used. The assumption is when a certain link get congested the connecting link also tend to congest. Further study used shows predictors using only historical data reduces the accuracy when unexpected congestion occur and current travel time used method perform well in congestions. (Jones, Geng, Nikovski, & Hirata, 2013)

2.2.3 Artificial neural networks (ANN)

Artificial Intelligence (AI) is used in many areas in transportation sector for interpretation, analysis, diagnosis, monitoring, prediction, planning, design, control, advising and interaction (Wild, 1994). Neural network is a popular technique in AI and it is used in many fields such as science, phycology, management, engineering etc. Neural networks are statically models build by tuning parameters according to the objectives of the study. The major advantage of the ANN is the capability of pattern matching, classification, adaptive filtering, target tracking, modeling, estimation, prediction etc. (Kisgyorgy & Rilette, 2002; Vanajakshi, 2004; Hellinga, Izadpanah, Takada, & Fu, 2008)

Travel time prediction model proposed by Zheng & Zuylen is a three layer ANN model where travel time data, positions and speeds collected using probe vehicles were taken for modelling (Zheng & Zuylen, 2013). The data model was compared with an analytical model using Root Mean Square Error (RMSE) and the ANN model performed well. Similar research was done using the ANN modelling (directly ANN predict the travel time) and the model was compared with a basic model (which calculate travel time using actual data), indirect method (speed is calculated using ANN and use that to calculate the travel time) to check performance (Kisgyorgy & Rilette, 2002).

Many data sources used in ANN modeling including plate recognition surveys (Hellinga, Izadpanah, Takada, & Fu, 2008), traffic detectors (Kisgyorgy & Rilette, 2002), microwave radar sensors and many models have proven a good capacity in travel time prediction (Celikoglu, 2011). Although the neural based models are robust than regression models, it is more convenient to use regression modeling in linear relationships (Li & McDonald, 2002 cited Zheng & Zuylen, 2012).

2.2.4 Statistical approach

Even though there are several travel time prediction and estimation models available most of these techniques are based on statistical methods (Kwong, Kavaler, Rajagopal, & Varaiya, 2009; Zheng & Zuylen, 2013; Vanajakshi, 2004; Rice & Zwet, 2004). Statistical techniques are used both in model development and model validation process. Most of the travel time estimation models are based on statistical approaches (Kwong, Kavaler, Rajagopal, & Varaiya, 2009; Dion & Rakha, forthcoming). Mean travel time is a widely used estimator among transport researches as well as road user and in many real time travel time prediction methods use the mean travel time due to its explanatory power together with variation/deviation to understand the nature of road segments (Kwong, Kavaler, Rajagopal, & Varaiya, 2009; Qiang, Qian, & Lixin, 2011). Mean travel time has the capability of reflecting the different traffic conditions (free flow, traffic jam, congestion) (Qiang, Qian, & Lixin, 2011). Relative travel time prediction errors were used as a measure of performance and were based on speed predictions at freeway detector stations. Statistical analysis was conducted to identify the parameters with a statistically significant effect on the model's performance. K-nearest neighborhood method is another statistical method used in travel time prediction. The concept of this is to use only the data closer to the explanatory parameter for prediction. Unlike regression modeling this allows to predict using the neighborhood characteristics (Gibbens & Saacti, 2006; Meng, Shao, Wong, Wang, & LI, 2015).

Regression analysis is the most commonly used statistical method in data analyzing. Regression analysis can be categorized in to two linear regression (Kwong, Kavaler, Rajagopal, & Varaiya, 2009) and nonlinear regression (Blandin, Ghaoui, & Bayen, 2009). Linear regression is the most used analyzing method compared to nonlinear regression. Even in many other travel time prediction models other than pure mathematical models uses the regression up to a certain extent for statistical analyzing (Nahar & Sultana, 2014). Several researches have used regression models starting from the simple linear regression models to different modified regression models such as Bayesian support vector regression (Gopi, et al., 2013), Kernel regression (Blandin, Ghaoui, & Bayen, 2009) up to hybrid model to enhance the predictive capability and improve the accuracy of the models.

Travel time is depend on several traffic and non-traffic factors and regression models provides the capability of working with different kind of data (Logendran & Wang, 2008)(direct, indirect, categorical, time dependent) providing a platform to filter and analyze for decision making.

Traffic flow data (flow and occupancy) with historical data was used in the travel time prediction model developed by Kwong et al. In the analysis linear regression with a stepwise variable selection and tree based more advanced method was used and cross validation was used to validate the results. The analysis was done for free way road segment and the method was capable of predicting near future up to 20 minutes. (Kwong, Kavaler, Rajagopal, & Varaiya, 2009). Model proposed by Izadpanah is using both travel time estimation and travel time prediction for final prediction. In the model average travel time is estimate for segments using the data collected by probe vehicle at the initial stage. When a shock wave is detected due to a difference in the flow in the road segment the estimated travel time was adjusted by two phase linear regression. Performance was checked by testing using simulated signalized intersection. Finally, a linear regression model is applied to find propagation speed and spatial and temporal extent of each shockwave. The results showed that the proposed methodology is able to detect shockwaves and predict travel time even with a small sample of vehicles (Izadpanah, 2010).

Incorporation of several explanatory Factors for accurate travel time prediction can be carried out by using a regression trees. Regression tree is a model constructed partitioning by which the data are consecutively split along the explanatory variables. Each explanatory variable is evaluated sequentially, and the variable which results the largest deviance in the response variable is selected. This method is adoptable in the absence of actual travel time data and by predicting the Vehicle speed eventually travel time data could be estimate. (Logendran & Wang, 2008) Proposed a regression tree based travel time prediction model to accompany the free flow travel time and travel time near capacity. Thirteen explanatory variables were used to build the model including four categories of variable types: traffic flow (speed, volume, occupancy), incident related (start time of the incident, duration, number of fatalities, incident type, affected lanes etc.), weather data (rain fall, snow fall, low visibility), and time of day. Model performed well in speed prediction as well as travel time estimation.

Support vector regressions is widely used in the time series analysis and have a prediction capability with higher accuracy, but the main disadvantage the method does not provide information on associated uncertainty. The method proposed by Gopi et al. proposed to use Bayesian support vector regression to incorporate uncertainty (Gopi, et al., 2013).

Regression models are built to predict the travel time as well as check the performances of newly experimented models by comparing the results (Nahar & Sultana, 2014). In some cases hybrid models can be seen in the literature where part of the model is built using regression modeling/statistical modeling. Other than the discussed information, statistical approaches are used in validation and evaluation of built models (Gibbens & Saacti, 2006).

- Basic terms in regression analysis -There are mainly two types of regression, simple regression and multiple regression. Single linear regression uses when there is only one explanatory variable while multiple linear regression is used when there are two or more explanatory variables to be analyzed. Correlation describes the strength of the linear relationship between each variable. It varies between -1 to +1 where minus sign indicates a negative correlation and plus sign indicates the positive correlation and closer the value to one stronger the correlation between the two variables. Correlation provides an indication to the user how fair data is used in a linear relationship. Another important parameter found in the regression is R square value. R square is called as the co efficient of determination usually called as the goodness of fit and it describe the percentage explained variance by the equation. The predictive capacity of the data should not solely depend on the coefficient of variation due to over fitting of data which reduces the actual prediction capability of the model. The validity of the coefficients of the model is checked by standard error of estimate, t statistic and its p-value. Standard error of the estimate indicates the uncertainty of estimating the dependent variable with the regression model and the acceptance of the coefficient varies according to the accuracy each study required.

- Linear regression assumption

  Error values should be statistically independent, normally distributed and homoscedasticity for acceptance of the model. Durban Watson (DW) value is used to check the randomness of the residuals of a regression and it test whether there is an auto correlation in the error term using hypothesis testing.

- Sampling is essential to ensure accuracy, reliability and be representative of the population because a sample with poor representative capability of sample can lead to wrong predictions. There are several types of sampling techniques available such as simple random sampling, systematic sampling, stratified sampling, multistage sampling, multiphase sampling, cluster sampling etc. and the method to be used in a particular study will differ according to the characteristics of the data set as well as the objective of the study.

I. Random sampling- every member of the data has the equally chance to be selected

II. Stratified random sampling –in this method data is separated in to mutually exclusive sets and then draw simple random sampling from each set

III. Systematic sampling- selection of data according to an order is defined as systematic sampling. The most popular technique of this method is equal probability method in which the sampling starts by selecting a random data and then every K^{th} element is selected where K is the sampling element.

IV. Cluster sampling- it is the simple random sampling of groups or clusters of elements. Usually this method is good when it is costly to develop complete population members.

There are two types of errors encounter when samples are collected from the population, sampling error and non-sampling error. Sampling error is the error encountered due to the difference of sample estimate to the population estimate and this could be reduced by increasing the sample size. Non sampling error is considered as the error occurred during the data acquisition or during sampling. This can be very serious since the predictions can be entirely wrong and increasing the sample size will not minimize the error.

In this study statistical approach was used for analysis and multivariate stepwise regression was used for model development. Systematic sampling was used in sample preparation and K-fold cross validation was used to validate the results.

2.3 Travel time data collection methods

Generally data can be collected from direct observation, experimental or through surveys and the method chosen for a particular study will depend on the availability, required accuracy and the cost. Travel time information is considered as one of the important factor in transportation due to the vast usage in several sectors. In some papers data collection is categorized as site based, vehicle based, sensor based (Lee, Tseng, & Tsai, 2009) by how the data is collected from.

- Site based- usually data such as license plate characteristics, arrival times are collected from the vehicles using stationary observation points situated in the route and different Automatic Vehicle Identification (AVI) methods used to capture them. The initial cost is high in this method since there is a high installation cost involve. But this type of method is appropriate for urban traffic flow measurements. If data is to be collected in several locations and this type of method is not appropriate if the data collection plan change spatially over time (Lee, Tseng, & Tsai, 2009).
- Vehicle based- data is collected from probe vehicles or from the fleet. Different techniques including Global Positioning System (GPS) (Bouchier, 2004), mobile communication methods etc. uses for data storage and collection. This method appropriate if continuous data is to be collected. But if the sample size is very large or if the long term data collection is required this type may not be economical.
- Sensor based- data is collected using stationary sensors such as loop detectors, acoustic sensors, radio beacons etc. In this method vehicle is identified by the change of a wave phase, amplitude or frequency at the points of interest in a particular route. This method is economical to be used if large sample is to be

collected but the accuracy is low since there can be complications in vehicle identification.

In much literature the data collection techniques could be found (Mathew, 2014; Turner, Eisele, & Holdener, 1998). They are,

- Vehicle techniques- the test vehicle equipped with distance tracking system mainly an electronic distance measuring instrument (DMI) or GPS receivers and travel time measuring system. These are usually called active test vehicles since they are used to collect data. In the primary stage clip board and a stop watch is used to measure the travel time or GPS receiver could be used. GPS based travel time measurements are accurate and the initial cost is low. But data storage difficulties could arise and both human errors and instrumental errors can include in the data.
- License plate matching technique- License plate matching is used in consecutive check points. There are four basic methods that the data could be collected.
  - Manual method- Data collected manually by observer at each check point via pen and paper or audio recorders
  - Portable computer – use portable computers which automatically provide an arrival time stamp
  - Video with Manual Transcription- license plates in the fields are recorded using video cameras and manually data collected using the video clips by human.
  - Video with Character Recognition- license plates in the field are collected using video and the data of the license plate (licence plate number, arrival time, check point etc.) automatically by the license plate recognition.
- ITS probe vehicle techniques- this is usually used in real travel time data collection approaches. They are usually called as passive test vehicles since they are in the traffic stream for purposes other than data collection. However they are being used in real time travel time data collection. Probe vehicle is a vehicle equipped with tracking technology (Cetin, List, & Zhou, 2005) to collect the travel time. Normally three major components traffic centers, probe vehicle, mobile communication network (Probe Vehicle System Concept, ©1993,1995).

The probe vehicles transmits the current traffic condition using an electronic communication device to the data collection sign posts and the data including location, instantaneous speed etc. are gathered in electronic format. There are three driving styles (Turner, Eisele, & Holdener, 1998) usually used by probe vehicles to collect data they are,

- Average car method – the probe vehicle tries to capture the average traffic speed and drive
- Floating car method – driver "floats" with the traffic by attempting to safely pass as many vehicles as pass the probe vehicle
- Maximum car method – the probe vehicle drives according to the speed limits given in particular sections as much as possible

There are 5 main techniques used and a comparison of the techniques used in the ITS probe vehicle identification is shown in Table 2.5

- Signpost-Based Automatic Vehicle Location (AVL) - Probe vehicles communicate with transmitters mounted on the sign posts
- Automatic vehicle identification(AVI)- probe vehicles are equipped with electronics tags and they identified by transceivers located at road side
- Ground based radio navigation- this is similar to GPS. data are collected by the communication between probe vehicle and the radio tower
- Cellular geo location- in this method the vehicles are detected by the telephone call transmission.
- GPS- the GPS signals are used to determine the location of the vehicle and send the information to the control centre.

- Emerging and non-traditional techniques (Mathew, 2014) using techniques such as image matching algorithms the point parameters such as volume, lane occupancy, vehicle headway used to estimate the travel time.

Several methods are adopted in studies to travel time data collection. All these methods have limitations and advantages therefore the method used will vary according to the purpose. In this case study the continuous travel time data logging should be done continuously along the profile and GPS tracking system is more convenient in that aspect.

Table 2.5 : Comparison of ITS Probe Vehicle Systems/Techniques

Technique	Cost				Data Accuracy	Constraints	Driver Recruitment
	Capital	Installation	Data Collection[1]	Data Reduction			
Signpost- Base Automatic Vehicle Location(AVL)	High	High	Low	High	Low*	No. of signpost sites, transit routes, and probes	None- uses transit vehicles
Automatic Vehicle Identification(AVI)	High	High	Low	Low	High	No. of antenna sites and tag distribution	Required- but can use toll patrons
Ground Based Radio Navigation	Low	Low	Low	Low	Moderate	No. of probes & sizes of service area	Required
Cellular Geolocation	High	High	Low	Moderate	Low	No. of cell users and cell towers	None – uses current cellular users
Global Positioning System (GPS)	Low	Low	Low	Moderate	High*	No. of Probes	Required : Also instrumented vehicles can be used

Notes: * Unless passenger vehicles are included in the study, samples are composed of transit or commercial vehicles.

Source: (Turner, Eisele, & Holdener, 1998)

3 METHODOLOGY AND DATA COLLECTION

Vehicle transportation is a similar phenomenon as water transportation. Water is collected from the catchment and transported from streams to rivers and finally fall to the sea, same as that different land use types generate trips and these trips are attracted to trip attraction areas through roads. The model which uses land use data usually incorporates the qualities of the catchment of the particular road. The main advantage of the proposed method is that the sensitivity of the estimate increases since the model is based on the characteristics of the catchment (both trip generation and attraction areas).Two types of data was collected for the development of the model, travel time data along the road and land use data and the road section type (whether an intersection or stretch of the road).

3.1 Methodology

The effect from the land use type on the travel time is checked by assessing the relationship of the land use parameters with travel time. The methodology that was followed is given in Figure 3.1.

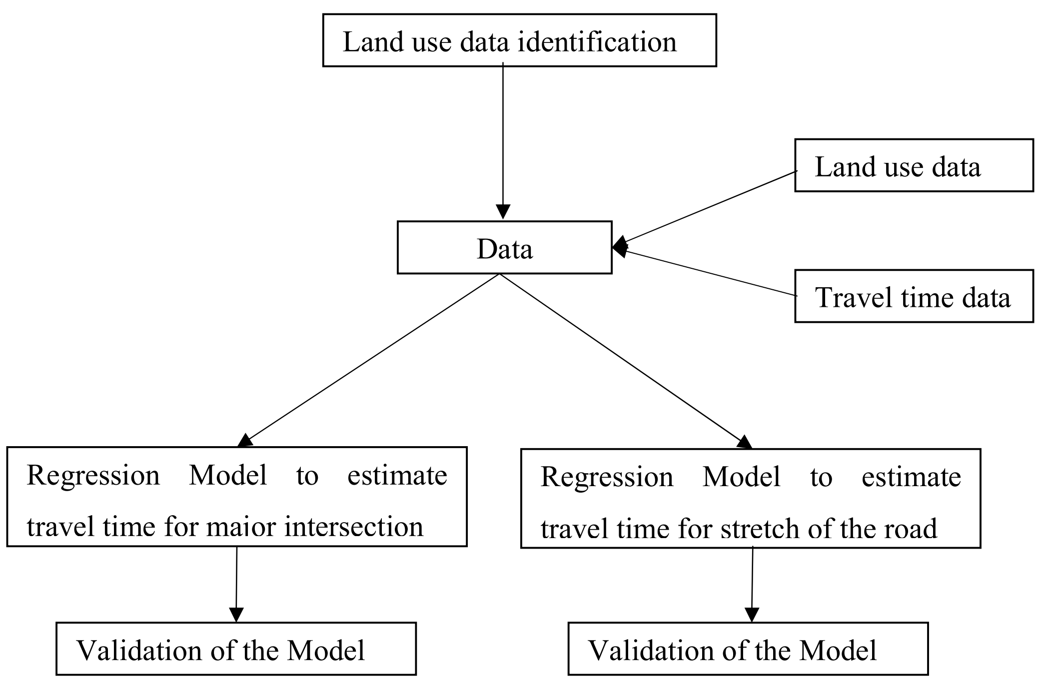

Figure 3.1: Methodology of travel time estimation model

3.2 Route selection

There are 36 non toll "A" class national highways fulfilling the main transportation requirements in Sri Lanka and majority from the total length are two lane roads. Routes were selected to represent majority of features available in the two lane un-signalized highways in Sri Lanka as mentioned in Table 3.1. Three main national highways, Ambepussa Trincomalee (A6) road, Colombo Kandy (A1) road and Peliyagoda Puttalam (A3) road was selected for the study to accommodate the features listed in Table 3.1.

It is difficult to find un-signalized two lane road segments throughout the road in major national highways. Therefore the only the two lane un-signalized road segments were taken for the analysis. There are two types of land use developments available along the roadside band type land use development and ring type land use development.

Table 3.1: Features considered for route selection

	Features	Ambepussa Trincomalee (A6) road	Peliyagoda Puttalam (A3) road	Colombo Kandy (A1) road
Total length of the road (km)		198	97	109
Topography	Level terrain	X	X	
	Hilly terrain	X		X
	Rolling terrain			X
	Straight road segments	X	X	X
	Curved segments	X		X
Land use features	Residential	X	X	X
	Agricultural lands	X	X	X
	Forests/bare lands	X	X	X
	Water bodies (Rivers/Sea)	X	X	X

	Features	Ambepussa Trincomalee (A6) road	Peliyagoda Puttalam (A3) road	Colombo Kandy (A1) road
	Commercial areas	X	X	X
	Important places (Schools, Religious places and Hospital)	X	X	X
Transportation related features	Presence of major intersections where main arterials intersect	X	X	X
	Presence of Access roads(where minor roads intersect)	X	X	X

3.3 Data collection

3.3.1 Sectioning the roads

Selected roads were segmented considering the accessibility and the land use type along the road. According to that there are two main sets.

- Major intersections- This is where the road intersects with a main road (A class or B class road). At an intersection, the traffic flow changes due to addition or reduction of traffic from the connecting road. Due to this reason and due to the change in the geometry (the intersection alone cause some delay compared to stretch of the road), the intersection behaves separately from the stretch of a road. Therefore intersections need to be analyzed separately. The maximum intersection length was taken as 1km (maximum 500m either side). Majority of the intersections in the selected roads are three leg intersections and very few intersections were four leg intersections without signal intersections. Some three leg and four leg major intersections were signalized intersections. Signalized sections were not analyzed in this research and they were dropped out. Traffic behavior of three leg and four leg intersections are different and due to this reason they have to be analyzed separately. Since inadequacy of data in four leg intersections travel time estimation model for the three leg intersections was carried out in this study.

- Stretch of the road- the stretch of a road was sectioned according to the land use type present. In this study only the main land use types, commercial development, residential area, agricultural area, forests/bare lands, water bodies(river/sea)and important places (hospitals, schools and religious places) of the particular segment was used for the analysis and mix development was not considered. The maximum length of a section was taken as 1500m. Colombo-Kandy road (A1) was segmented to 95 sections , Peliyagoda-Puttalam road (A3) was segmented to 165 road sections and the Ambepussa-Trincomalee (A6) road was segment was sectioned to 308 road sections.

3.3.2 Travel time data collection

The travel time varies with time of the day due to the fluctuations in the traffic flow. In this study the travel time estimation was done for the peak period traffic as an initial step. There are three main traffic peaks occur during a normal day. That is in the morning, mid-day and in the evening. Continuous speed and travel time data were collected along the three routes during the day time and the trips were selected so that peak traffic is covered as much as possible. During the process of data collection instructions were given to drivers to drive according to the road alignment to capture the exact horizontal alignment (to strictly follow the lane markings). The travel plan used is given in Table 3.2.

Table 3.2: Travel plan for three routes

Origin	Destination	Date(dd/mm/yy)	Trip number	Start time
Peliyagoda	Negambo	13-May-13	1	11.00am
		14-May-13	2	6.00 am
		14-May-13	3	4.00 pm
Negambo	Peliyagoda	13-May-13	4	6.00am
		13-May-13	5	4.00 pm
		14-May-13	6	11 .00 am
Ambepussa	Kandy	07-Jun-13	7	3.00pm
		06-Jun-13	8	5.00 pm

Origin	Destination	Date(dd/mm/yy)	Trip number	Start time
Kandy	Ambepussa	07-Jun-13	10	4.00 pm
		06-Jun-13	11	6.00 pm
		06-Jun-13	12	12.00 noon
		14-Jun-13	13	11.00am
Ambepussa	Kurunegala	05-Jun-13	14	7.00 am
		02-Apr-13	15	5.30 pm
		10-May-13	16	12.00 noon
Kurunegala	Ambepussa	05-Jun-13	17	12.00 noon
		02-Apr-13	18	6.30 pm
		10-May-13	19	7.00am
		10-May-13	20	5.00pm
Kurunegala	Dambulla	15-May-13	21	8.30 am
		15-May-13	22	6.30 pm
Dambulla	Kurunegala	16-May-13	23	6.45 am
		16-May-13	24	4.45 pm
		15-May-13	25	11.45 am
Dambulla	Trincomalee	29-May-13	26	7.00 am
		29-May-13	27	5.00 pm
		30-May-13	28	12.00 noon
Trincomalee	Dambulla	29-May-13	29	12.00 noon
		30-May-13	30	7.00 am

Continuous travel time was logged in every one second using the GPS data logger and a sample of the speed data logged in the GPS is shown in Table 3.3. The data logger has the capability of capturing the location coordinates, date, time and the instantaneous speed. The accuracy of the GPS data logger is less than 3m with a 50% of CEP (Circular Error Probable).

Table 3.3: Sample of the data logged in the GPS data logger

Index	RCR	Local date	Local Time	ms	Y	X	Height (m)	Speed (km/h)	Distance (m)
272	T	2013/05/09	07:00:46	0	7.321922	80.62453	357.566	20.550	4.83
273	T	2013/05/09	07:00:47	0	7.321887	80.62448	357.340	21.711	6.18
274	T	2013/05/09	07:00:48	0	7.321859	80.62443	357.398	22.165	6.11
275	T	2013/05/09	07:00:49	0	7.321835	80.62438	357.010	24.722	6.69

Index	RCR	Local date	Local Time	ms	Y	X	Height (m)	Speed (km/h)	Distance (m)
276	T	2013/05/09	07:00:50	0	7.321811	80.62431	356.491	28.754	7.73

3.3.3 Land use data collection

Comprehensive land use data base is required for travel time estimation model in the targeted roads, by considering the land use type as well as accessibility. The major roads start and end from a main commercial and industrial developments areas such as Colombo city, Kurunegala city and Dambulla city.

There are two main ways that the land use development was taken place around the roads. They are band development and the ring development. Band development is that the land use development taken place along or parallel to the road as a strip. In this kind of development there is a place available for new development to take place and the area is not saturated with the existing development. Figure 3.1

Figure 3.1 : Band development in Colombo Batticaloa Highway

Source: Google maps, February 2015

The ring development is the development take place around the road or intersections in a ring shape. This type of development is complex compared to band development and it could be seen in highly congested urban areas. Example for the ring development is shown in Figure 3.2.

Several parameters were used to capture the land use of a particular section. All together four land use data categories were used in analysis Commercial, Residential, Cultivation and Important places. Agricultural lands, forests, bare lands and water bodies were considered in to cultivation land use type due to low disturbance to the traffic flow compared to other land use types. Presence of schools, hospital and religious places were considered as important places in the study.

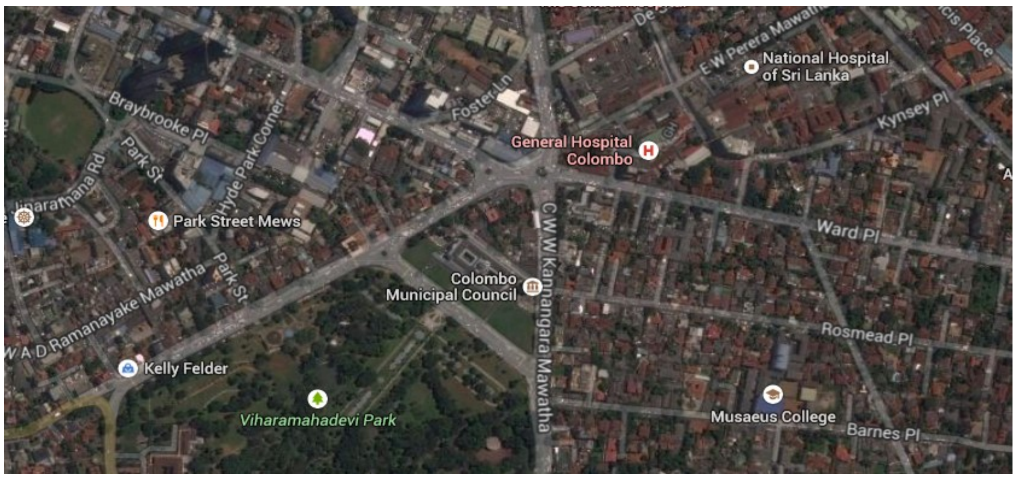

Figure 3.2: Band development in Colombo 07

Source: Google maps, February 2015

The land use parameters considered in the travel time estimation for major intersection is given in Table 3.4 and Figure 3.3. Table 3.5 describes the land use parameters considered for the stretch of a road and the sketch of the road is given in Figure 3.4 for the reference. All the land use data was collected in a 50m buffer zone either sides of the road. For the major intersections, data was collected up to the length that the commercial development is available and when the continuous commercial development is available more than 1km then data was collected only up to 1km. The intersection length of each intersection was represented using the parameter "Travel distance (TD)", the total commercial development present was represented using the parameter "Commercial length (CL)".

Table 3.4: Parameters considered in the major intersection

Parameter	Measuring Unit
Commercial length(CL)	meters
Travel distance along the road(TD)	meters

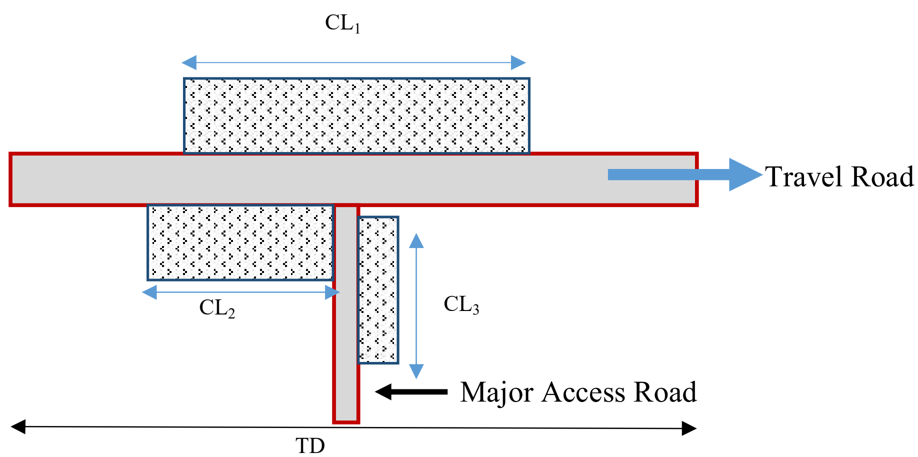

Figure 3.3: Sketch of a major intersection

According to the Figure 3.4,

The total commercial development of the major intersection (CL) = $CL_1+CL_2+CL_3$

For the travel time estimation of a stretch of the road, the road sectioning was done considering the land use type. The section length was represented using the parameter "Travel distance (TD)", the land use types present in each section was indicated using the parameters indicated in Table 3.5 and sketch of a road section is given in Figure 3.4. In this model "No. of Access roads" indicates the number of minor access (Access roads other than major A, B class roads) roads connecting to the main road section.

Table 3.5: Parameters considered for the stretch of the road

Parameter	Measuring Unit
Commercial length(CL)	meters
Cultivation length along the road(B)	meters
Houses	numbers
Travel distance along the road(TD)	meters
Important places	numbers
Access roads	numbers

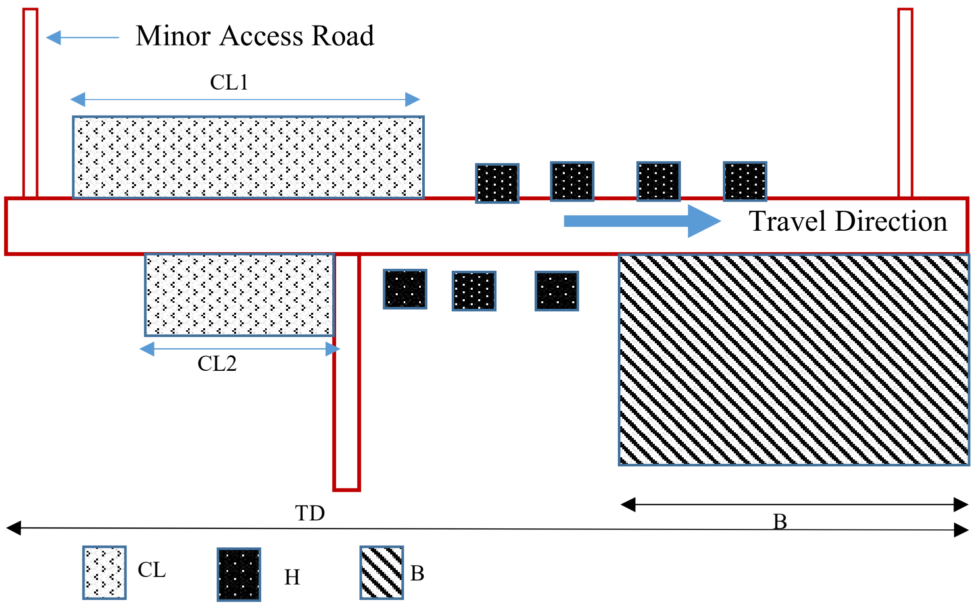

Figure 3.4: Stretch of the road

Land use data was collected using the Google earth software: US department of state geographer, © 2009 GeoBasis-DE/BKG: Data SIO, NOAA, U.S Navy, NGA, GEBCO.

3.3.4 Data Reduction

Ones the travel time data was collected, all the data was fed separately to the ARC GIS 10.1 map and checked the continuity of the data as shown in Figure 3.5. When data losses were identified, those data was filtered from the main data base.

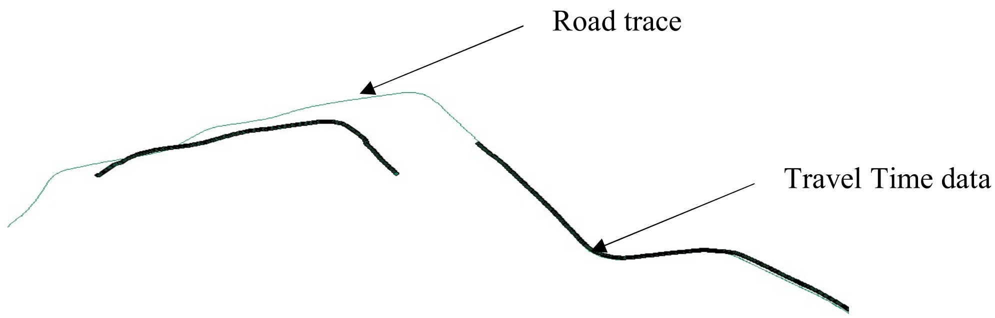

Figure 3.5 : 7th of June 2013, 3pm trip from Ambepussa to Kandy

4 ANALYSIS AND RESULTS

The travel time estimation model is developed under two main categories as described in section 3.3.3 and the analysis and the results of the model are described in this chapter.

4.1 Travel time estimation for three leg un-signalized major intersection in two lane highways

Travel time and land use data was collected for 75 un-signalized three leg major intersections and altogether there was 386 data points to build up the regression model.

4.1.1 Sensitivity of the minimum buffer distance for intersections

The general procedure for the identification of the major intersection length was to get the section up to the length of the commercial development (up to the maximum length of 1km). Even though commercial development is present more than 1km (500m maximum distance from the intersection to one side) at some intersections, only up to 1km length was taken considering that the effect of intersection will be less after that.

At an intersection travel time will be high compared to a normal road section due to the change in geometry. This effect can be isolated and identified when there is no effect from the land use. In order to identify the minimum length to be considered at intersections a sensitivity analysis was done for intersections where no commercial development is present.

90 sample points were used for the sensitivity analysis and travel time and speed for 40m, 50m, 80m, 100m, 200m intersection lengths were collected for all 90 sample points and error pointes were identified and filtered by plotting the box plots, GIS maps and excel data files. The box plots after corrections for each intersection length is given in Figure 4.1. Vertical axis of each graph in Figure 4.1 indicates the travel time in seconds.

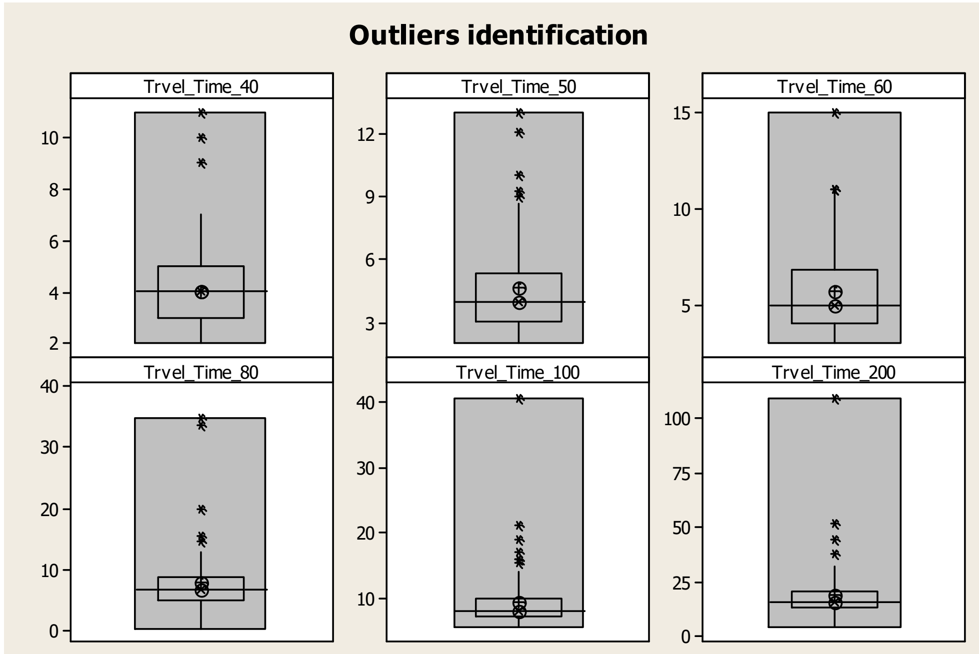

Figure 4.1: Box plots of travel time(s) for intersection lengths of 40m, 50m, 60m, 80m, and 100m

The scatter plot for data of Figure 4.1 is given in Figure 4.2 and the general statistic are given in Table 4.1

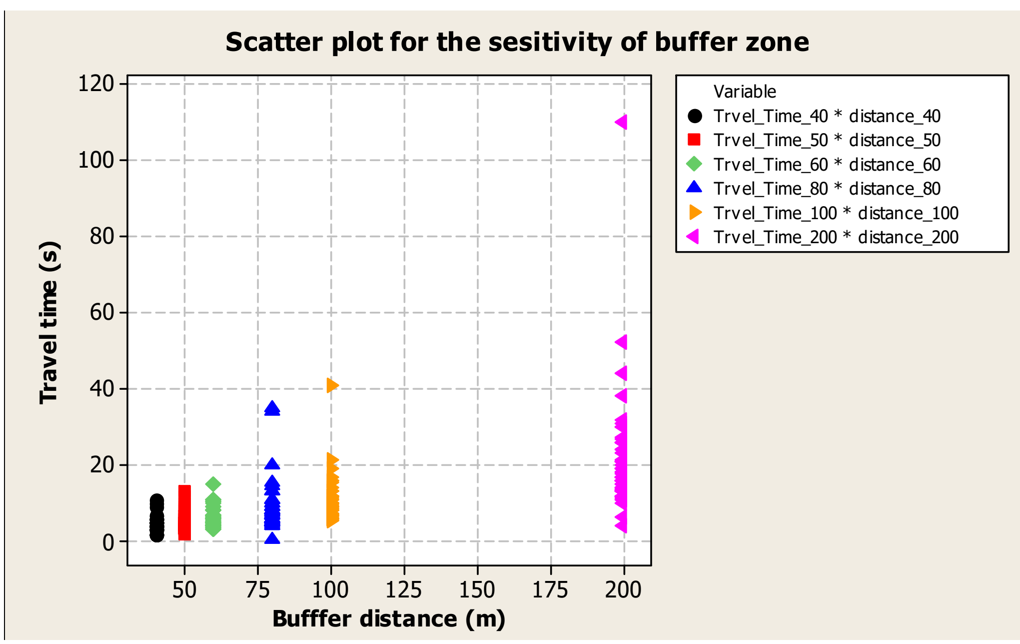

Figure 4.2: Scatter plot for the sensitivity of buffer zone

Table 4.1: Statistics on sensitivity of buffer zone

Buffer Distance (m)	N	Mean Travel Time(s)	Standard Deviation	Variance	Coefficient of Variation
40	91	4	1.63	2.63	40.16
50	86	4	2.03	4.38	44.65
60	85	5	2.49	5.01	39.15
80	85	7	5.07	25.74	64.5
100	84	9	4.69	22.01	49.59
200	79	19	12.91	166.64	66.44

Coefficient of variation was used to compare the different intersection length and from the graph and the statistics it could be seen that the coefficient of variation was tend to decrease when the minimum buffer is 60m and when inspecting the travel time thoroughly using the GIS maps it was observed that the alignment variations has a great effect on speed reduction. Travel time data showed that intersections geometry cause great increase in travel time and Figure 4.3 shows the travel time map of an intersection and the location map is given in Figure 4.4.

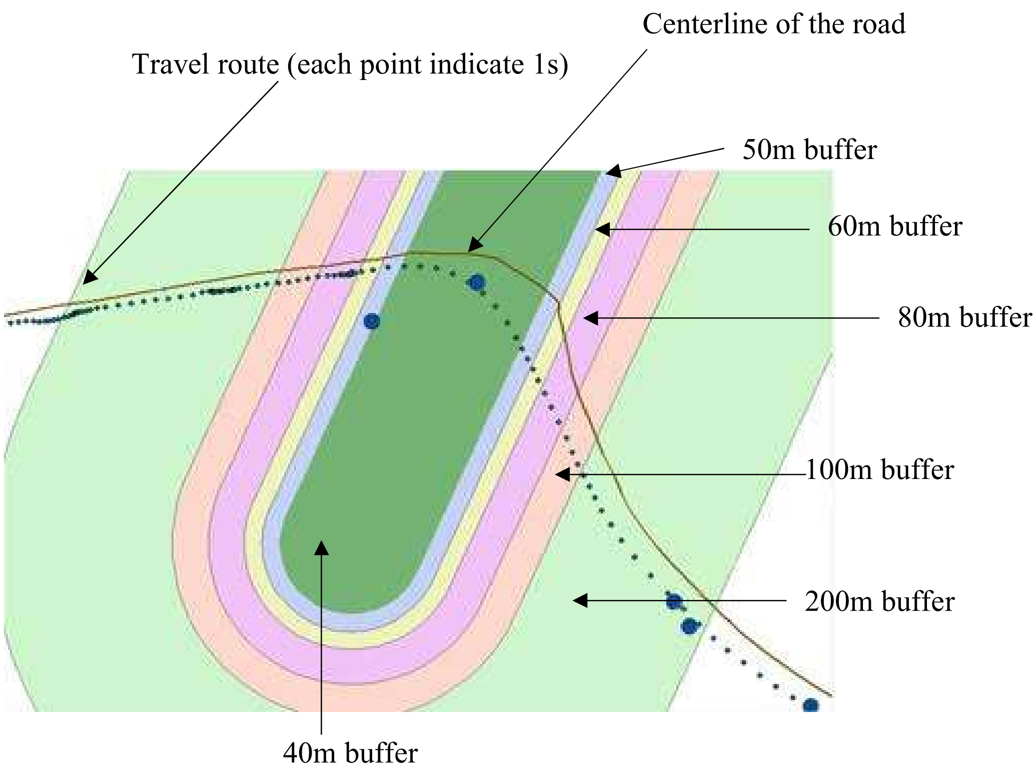

Figure 4.3: Travel time map of an intersection

Figure 4.4: Location map of the intersection shown in Figure 4.3

Source: Google maps, February 2015

The results obtained from the analysis showed that the selection of minimum buffer length for intersections with no commercial length present should be taken considering the geometric features of the particular intersection.

In the travel time estimation model for the intersections with no commercial development, minimum intersection length for the intersections in straight road segments were was taken as 60m.

4.1.2 Regression model of un-signalized three leg major intersections to estimate the travel time

The regression models were developed using the stepwise regression and for the validation purpose K-fold cross validation was used. All sample points collected for travel time estimation for un-signalized three leg intersections was divided into 5 sets using systematic sampling.

As indicated in Figure 4.5 using 4 training sets(set 1,2,4,5) one model was developed and remaining set[test set (set 3)] was used for validation. In the next step previously used test set (set 3) and three other sets(set 1,2,5)sets is included to build the model and remaining set is used as test set (set 4). Likewise all together 5 models were developed until every set become test set at one time. Training sets were used to build the model and the test set was used to validate the model. Number of data used for the train set and the test is given in Table 4.2.

From five models best fitted model was selected using Root Mean Squared Error (RMSE) and Mean Absolute Percentage Error (MAPE) and the coefficient of determination (R^2 value)

- Mean Squared Error (MSE) = $(1/n) * \Sigma(yi - fi)^2$
- Root Mean Squared Error (RMSE) = $[(1/n) * \Sigma(yi - fi)^2]^{0.5}$
- Mean Absolute Percentage Error (MAPE) = $(\frac{1}{n} \sum | \frac{yi-fi}{yi} |) \times 100$

  Where,

  yi =Observed value   n = sample size

  fi = Predicted value

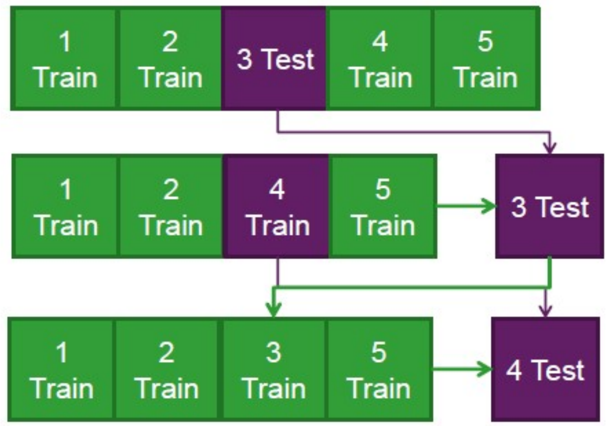

Figure 4.5: Method of test set and training set selection for model development

Table 4.2: Number of data points used: Travel time estimation for major intersections

Number of data points	Train set	Test set
Model 1	307	78
Model 2	307	78
Model 3	305	80
Model 4	310	75
Model 5	311	74

Correlation Matrix: Commercial, Travel time(s), Distance (m) – Model 2

	Commercial length	Travel time(s)
Travel time(s)	0.755 0.000	
Travel Distance (m)	0.813 0.000	0.829 0.000

Cell Contents: Pearson correlation
P-Value

Correlation matrix of Commercial length(m), Travel time (s) and Travel Distance (m) for model 2 is given above and according to the correlation matrix of the variables used in the second model it could be seen that the travel time has a linear relationship with the commercial length and the travel distance. Further, scatter plots of the commercial length vs. travel time shown in Figure 4.6 and the travel distance vs. travel time shown in Figure 4.7 confirms the linearity of the relationship.

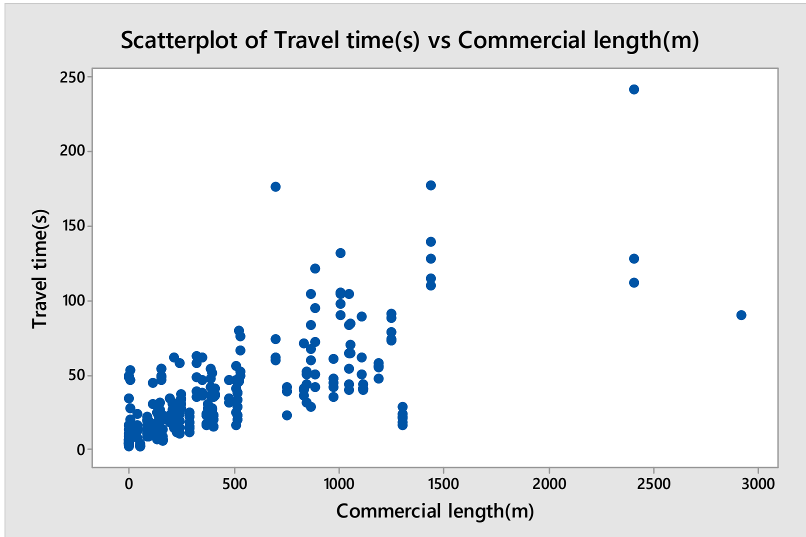

Figure 4.6: Commercial length (m) Vs. Travel time(s)

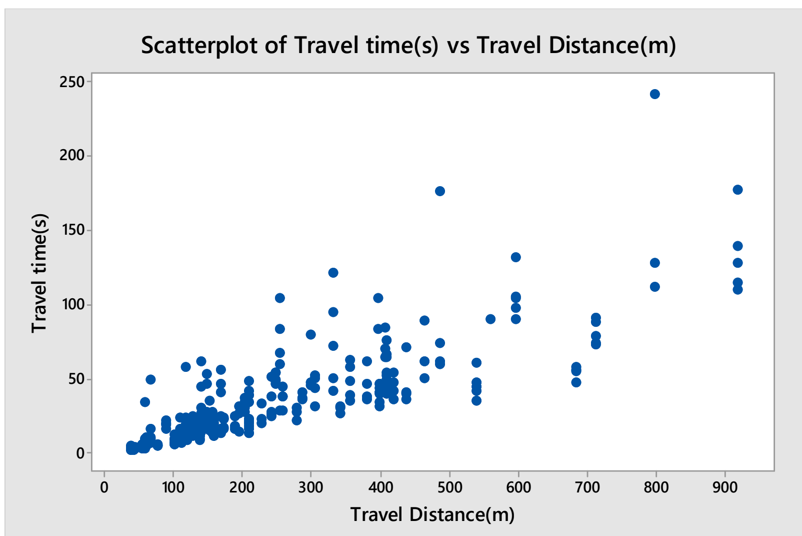

Figure 4.7: Travel distance (m) Vs. Travel time(s)

Five travel time estimation models were developed using the multivariate stepwise regression and MSE, RMSE and MAPE valued were calculated by applying the equation in to the test data set. The summary of each model is given in Table 4.3

Table 4.3: Summary of the travel time estimation model for major intersections

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Standard error R-squared R-squared(adjusted) R-squared(predicted)	18.5 s 68.5% 68.32% 67.3%	17.6 s 70.6% 70.45% 69.33%	19 s 64.5% 64.1% 63.3%	19.6 s 65.2% 65% 64%	19.7 s 6% 68.32% 64.16%
Durbin-Watson Statistic	1.92	1.88	1.81	1.86	1.85
Validation					
RMSE (seconds)	20.4	23	19	15.1	16.12
MAPE	45%	38%	51%	52%	49%

The regression was carried out using around 300 data points and according to the results shown in table 4.3 all 5 models have a comparatively an acceptable R squared value indicating the that the independent variables, travel distance along the road and the commercial development present have a strong explanatory power of the dependent variable, travel time. Durban Watson (DW) value provides an indication of the randomness of the residuals. If the DW value is closer to 2 then the residuals are random and all 5 models satisfy the randomness. Please refer Figure A.1 in the Appendix A for further clarifications of the randomness of residuals.

Root mean squared error is higher in the second model and the error as a percentage of observed value y_i is lowest in the second model and the cross validation results of the model 2 is given in Table A.2 ,Appendix A for further reference. Cross validation provides the capability of measuring the predictively and from the validation results given in Table 4.3 second model has a higher predictive capability.

According to the results obtained from the Table 4.3 it could be evident that the model 2 was able to capture nearly 70% of the observed variability with a DW value of 1.88 and MAPE value of 38%. The equation of the model two is shown in equation 4.1 and the regression model summary is attached in Table A.1, Appendix

A. Thus it can be concluded that the model 2 is the best fitted model to explain the relationship between travel time and commercial involvement of major intersections and the equation is given by,

$$Travel\ time(s) = 0.84 + 0.01636 \times CL\ + 0.10784 \times\ TD$$

Where CL=Commercial Length (m)

TD= Travel Distance (m)

4.2 Travel time estimation for the stretch of the road in two lane highways

Travel time estimation for road sections other than major intersections is discussed in this sub section. Travel time and land use data was collected for 568 road sections and altogether there was around 2700 data points to build up the travel time estimation models for the road segments having commercial, residential and agricultural land use types. Land use type including the agricultural, forests, water bodies, bare lands were considered as a one land use type since the trip generation and attractions are very low in those and here after all of them will be called as cultivation.

The regression models were developed using the stepwise regression and for the validation purpose K-fold cross validation was used. At the initial stage different combinations (all land use types together and separately) were considered to select the best way to use the land use types for model development. It was observed that the effect of commercial development dominant compared to other land use types (see section 4.2.1 for more clarification). Both side residential, one side residential (other side cultivation) and cultivation were taken as three cases since the predictive capability increases. In each case the data was divided in to 5 sets using systematic sampling and 5 models were developed from them. Each model has 4 sets as the train set to build the model and the other set was used as the test set. Linear relationship was considered for model developed and in each model travel time is taken as dependent variable and land use variables and travel distance were taken as independent variables. For each land use model, number of data used for train set and the test set is given in Table 4.5, 4.8, 4.11, 4.14. Best model was selected using RMSE, MAPE and the coefficient of determination (R^2 value).

4.2.1 Travel time estimation model when the land use type is commercial development

The road sections containing the land use type commercial were filtered from the data set and data was divided in to 5 samples. Among the four land use types, commercial development has the major impact on the travel time as shown in Table 4.4. According the correlation matrix commercial development and travel distance showed a good positive linear correlation with the travel time while residential and cultivation land use types showed poor correlation. Further, scatter plots of the commercial length vs. travel time shown in Figure 4.8 confirms the linearity of the relationship.

Total 614 sample points were used for the analysis. Maximum section length is 1200m and the minimum length was 200m. Data consist of Residential Density from 0 to 152 houses/km, No. of Important places from 0 to 5, No. of Access roads from 0 to 14 and Commercial Development percentage from 15% to 100% per section.

Table 4.4: Correlation of land use parameters with travel time: Stretch of the road-Commercial development

	Travel time(s)
Travel Distance (m)	0.729 0.000
Commercial length(m)	0.655 0.000
Residential	0.126 0.014
No of Access roads	0.336 0.000
No of Important places	0.496 0.000
Cultivation (m)	-0.147 0.012
Cell Contents	Pearson correlation P-Value

Table 4.5: Number of data points: Travel time estimation for road stretch-Commercial development

Number of data points	Train set	Test set
Model 1	393	94
Model 2	377	110
Model 3	397	90
Model 4	391	96
Model 5	390	97

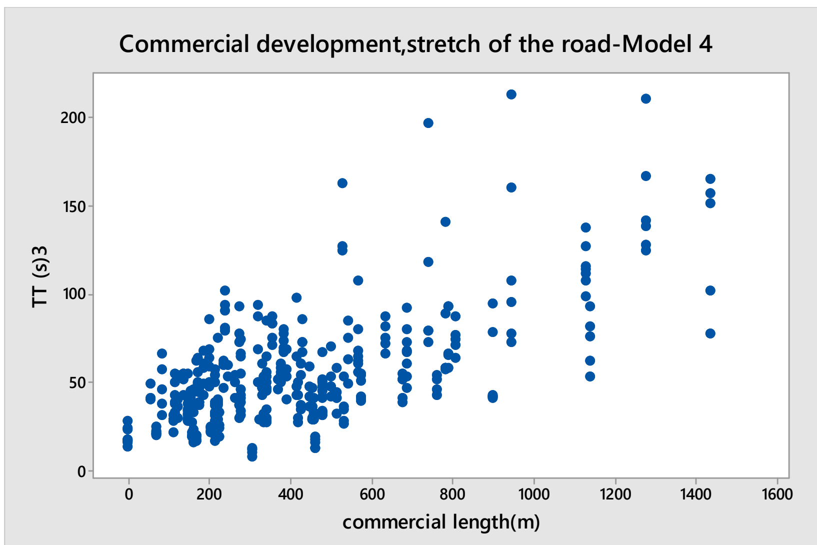

Figure 4.8: Scatter plot- stretch of the road: commercial development

Five travel time estimation models were developed using the multivariate stepwise regression and MSE, RMSE and MAPE valued were calculated by applying the equation in to the test data set. The summary of each model is given in Table 4.6 and according to the model summary the all the models showed a significant explanatory power of the dependent variable and the accuracy of the model have increased compared to the travel time for major intersection. The average speed of the data set is 35.7 km/h (See Appendix B, Figure B.1)

Table 4.6: Summary of 5 models -Stretch of the road: Commercial development

	Model 1	Model 2	Model 3	Model 4	Model 5
R-squared	68.79%	69.6%	68.21%	69.31%	71.9%
Durbin-Watson Statistic	1.65	1.65	1.71	1.67	1.58
Validation					
MSE	199	279	310	229	553
RMSE	14.12	16.7	17.6	15.1	23.5
MAPE	24%	23%	25%	23.6%	23%

The explanatory power and the accuracy of the five models are approximately the same. Model 5 has the highest R squared value of 71% while the highest accuracy was achieved by the model 4 and the randomness of the five models are at an acceptable level (See Appendix B, Figure B.2). DW value is closer to 2 then the residuals are random and all 5 models satisfy the randomness.

According to the results obtained from the Table 4.3 it is evident that the model 4 is able to capture nearly 69% of the observed variability with a DW value of 1.67 and MAPE value of 23.6%.

Regression equation for travel time estimation commercially developed road sections of the two lane highways of model four is given by,

$$Travel\ Time\ (s) = -1.4 + 0.08119 * TD + 0.03345 * CL + 6.77 * I$$

Where, Travel Distance (m) =TD

Commercial length (m) = CL

Important places (Number) =I

The equation can be used,

- When the sections having 100% commercial development or,
- When the road sections having Residential and Commercial land use types and the commercial density is more than 15% or,

When the road sections having only Commercial and Cultivation land use types and for travel distances more than 20m.

Commercial percentage of a section can be calculated by,

$$\text{Commercial percentage} = \frac{Commercial\ leng\quad (m)}{Travel\ Distance\ (m) x\ 2}\ x\ 100$$

The regression model summary is attached in Table B.1, Appendix B and the cross validation results for the model 4 is attached in Table B.2, Appendix B .Thus it can be concluded that the fitted model is the best fitted model to explain the relationship between travel time and commercial involvement for the stretch of the road. This model was developed considering a band commercial development along the road and the model may not provide accurate estimates for the roads with complex land use development.

4.2.2 Travel time estimation model when the land use type is residential

The effect on the travel time by the residential involvement in the area was estimated for the presence of the residential both side of the road and on one side only. During the analysis it was identified that unlike the effect of areas with commercial areas the effect is low in residential area. Effect on ravel time in residential areas in one side and the presence of residential area on either sides of the road was analyzed separately. Road segments with residential areas but cultivation percentage below 80% and commercial percentage below 15% are considered under the land use type residential.

- Both side residential

Travel time estimation for road segments having residential either side of the road was considered under these sections. The residential involvement was measured by taking the number of houses in a particular segment and according to Table 4.7, travel distance and number of houses showed significant positive correlation with travel time. The disturbance from the residential areas were taken for a 50m buffer either side of the road and around 1180 data points were collected to develop the regression model and to validate the results (see Table 4.8).
Maximum section length is 1450 m and the minimum length was 200m. Data consist of Residential Density from 18 to 171 houses/km, No. of Important places from 0 to

3, No. of Access roads from 0 to 15 and Commercial Development percentage from 0 to 15% per section.

Table 4.7: Correlation of land use parameters with travel time: Stretch of the road-residential one side

	Travel time(s)
Travel Distance (m)	0.813 0.000
Number of houses	0.613 0.000
Number of Access roads	0.383 0.000
Number of Important places	0.123 0.000

Table 4.8: Number of data points: Travel time estimation for stretch of the road-Residential both side

Number of data points	Train set	Test set
Model 1	915	271
Model 2	935	247
Model 3	971	229
Model 4	941	243
Model 5	980	202

The average speed of the road segments were increased up to 49km/h (see Figure C.1, Appendix C) which was 35km/h for the commercially developed areas. According to the regression and validation results shown in Table 4.9, the 1st model was able to capture nearly 77% of the observed variability with a Durban Watson value of 1.8 while the other four models showed around 65% with Durban Watson value around 1.55. But according to the validation results the model having highest R^2 was unable to achieve the highest predictive capability while the model 2 achieved the highest predicative capability and due to this reason model 2 was selected as the best model. The summary of the regression analysis is provided in Table C.1, Appendix C and see the Table C.2, Appendix C for cross validation results of the model two. Residual plots are attached in Figure C.2 and Appendix C for further information on the randomness of residuals.

Table 4.9: Model summary: Stretch of the road-residential both side

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
R-sq.(adj)	77.8%	64.8%	64.63%	66.8%	66.17%
Durbin-Watson Statistic	1.8	1.57	1.6	1.5	1.54
Validation					
MSE	194	154	142	143	184
RMSE	14	12.4	12	12	14
MAPE	20%	18%	21%	20%	22%

Travel time estimation equation for stretch of the road-both side residential of model 2 is given by,

$$Travel\ time\ (s) = 3.05 + 0.1644 \times H + 0.06131 \times TD + 4.157 \times I$$

Where, Number of houses within 50m buffer = H

Travel Distance (m) = TD

Number of Important Places within 50m buffer = I

The equation can be used for road sections when Commercial percentage is less than or equal to 15%, when cultivation percentage is less than or equal to 75 % and when residential units are present both side of the road. Maximum residential density used in the model is 170 houses/km and minimum residential density used in the model is 20 houses/km per section.

- One side residential

Travel time estimation for road segments having residential on one side and cultivation land use type on other side were only considered under these sections. The residential involvements was measured by taking the number of houses in a particular segment and according to Table 4.10, travel distance and number of houses showed significant positive correlation with travel time and the correlation of travel time with the travel distance relatively increased compared to road sections with commercial and both side residential. The disturbance from the residential areas were taken for a 50m buffer either side of the road and around 240 data points were collected to develop the regression model and to validate the results (see Table 4.11).

Maximum section length is 1200 m and the minimum length was 200m. Data consist of Residential Density from 10 to 76 houses/km, No. of Important places from 0 to 2, No. of Access roads from 0 to 11 and Commercial Development percentage from 0 to 15% per section.

Table 4.10: Correlation of land use parameters with travel time: Stretch of the road-residential one side

	Travel time(s)
Travel Distance (m)	0.871 0.000
Residential	0.535 0.000
No of Access roads	0.232 0.000
No of Important places	0.077 0.239
Cultivation (m)	0.664 0.000

Table 4.11: Number of data points: Travel time estimation for stretch of the road-Residential one side

Number of data points	Train set	Test set
Model 1	184	50
Model 2	191	46
Model 3	183	54
Model 4	189	48
Model 5	198	39

The average speed of the road segments is 50km/h (see Figure D.1, Appendix D) and according to the regression and validation results shown in Table 4.12, 4 models out of the 5 models was able to capture more than 75% of the observed variability with a Durban Watson value closer to 1.4 while the other model showed a R squared value of 70%. According to the validation results the 4th model was selected as the best model having highest predicative capability. The summary of the regression analysis is provided in Table D.1, Appendix D and the see the Table D.2, Appendix D for cross validation results of the model four. Residual plots are attached in figure D.2 and Appendix D for further information on the randomness of residuals.

Travel time estimation equation for stretch of the road-one side residential of model 4 is given by,

$$Travel\ time(s) = -2.04 + 0.07916 \times TD$$

Where, Travel Distance (m) =TD and TD >30m

The Durban Watson value is in acceptable range but the effect on travel time from the other parameters such as geometry, topography etc. than the land use type may increases due to the increase in speed. The equation can be used for road sections when Commercial percentage is less than or equal to 15%, when cultivation percentage is less than or equal to 80 % and when residential units are present in one side of the road. Maximum residential density used in the model is 70 houses/km and minimum residential density used in the model is 10 houses/km. All the values are given per section.

Table 4.12: Model summary: Stretch of the road-residential one side

	Model 1	Model 2	Model 3	Model 4	Model 5
R-squared(adjusted)	78%	75%	71%	76%	76%
Durbin-Watson Statistic	1.4	1.45	1.53	1.42	1.32
Validation					
MSE	152	59	115	70	90
RMSE	12.3	7.6	10.7	8.4	9.5
MAPE	19%	17%	17%	14%	20%

4.2.3 Travel time estimation model when the land use type is cultivation

The effect on the travel time on the road segments goes along cultivation areas were analyzed in this section. During the analysis it was identified that unlike the effect of areas with commercial areas and residential areas on travel time, the effect from the land use is not significant. Road segments with cultivation (Agricultural, forestry, bare lands, and presence of water bodies) were considered under the land use type cultivation.

Maximum length used for a section is 1300m and minimum section length is 200m.The cultivation involvement was measured by measuring the cultivation length along the road for a particular road segment and according to Table 4.13, travel distance (Figure E.1, Annex D) showed significant positive correlation with travel time and any land use parameter didn't showed a significant correlation to travel time. The disturbance from the residential areas were taken for a 50m buffer either side of the road and around 600 data points were collected to develop the regression model and to validate the results (see table 4.14).

Table 4.13: Correlation of land use parameters with travel time: Stretch of the road-Cultivation

	Travel time(s)
Travel Distance (m)	0.895 0.000
No of Access roads	0.176 0.000
Cultivation (m)	0.805 0.000

Table 4.14: Number of data points: Travel time estimation for stretch of the road - Cultivation

Number of data points	Train set	Test set
Model 1	484	129
Model 2	489	124
Model 3	491	121

Number of data points	Train set	Test set
Model 4	493	119
Model 5	493	119

The average speed of the road segments is 55km/h (see Figure E.3, Annex E) and according to the regression and validation results shown in Table 4.15, all the models were able to capture closer to 80% of the observed variability with a Durban Watson value closer to 1.75. According to the validation results all the models perform well but the 5th model was selected as the best model having highest predicative capability.

Travel time estimation equation for stretch of the road-Cultivation of model 5 is given by,

$$Travel\ time(s) = 7.569 + 0.05221 \times TD$$

Where Travel Distance (m) = TD

The summary of the regression analysis is provided in Table E.1, Appendix E and the see the Table E.2, Appendix E for cross validation results of the model four. Residual plots are attached in Figure E.1, Appendix E for further information on the randomness of residuals. The Durban Watson value is closer to two indicating the randomness of the residual but the effect on travel time from the other parameters due to the increase in speed.

The equation can be used,

- When the sections having 100% Cultivation land use type or,
- When the road sections having Both Side Residential and Cultivation land use types and the Cultivation land use type is more than 75% or,
- When the road sections having One Side Residential and Cultivation land use types and the Cultivation land use type is more than 80%

Table 4.15: Model summary: Stretch of the road-Cultivation

	Model 1	Model 2	Model 3	Model 4	Model 5
R-squared (adjusted)	80.4%	79.34%	79.44%	81.83%	80.13%
Durbin-Watson Statistic	1.77	1.76	1.76	1.63	1.76
Validation					
MSE	99	57	62	88.5	59
RMSE	10	7.56	7.9	9.4	7.7
MAPE	17%	18%	19%	19%	17.1%

5 DISCUSSION & CONCLUSION

The study was carried out to estimate travel time using land use types in two lane un-signalized roads. Basic land use data including commercial, residential and cultivation were used along with continuous travel time data. Complex land use details were not considered for the analysis and the land use data was collected from both sides of the road within a 50m buffer zone of three main highways [Peliyagoda-Puttalam Road (A3), Kandy Road (A1) and Ambepussa Trincomalee Road (A6)] roads. Daily travel time data for weekdays excluding travel data on normal holidays (Saturday, Sunday), seasonal variations and data covering morning, noon and evening peak times in travel time were used. Only day time travel time data was used in the research.

Data was mainly collected into two types of model development, Travel time estimation of intersections (where A or B class road intersect with the considered road) and travel time estimation for the stretch of the road. Further the stretch of the road was separated according to different land use types namely Commercial, Both Side Residential, One Side Residential and Cultivation. Average speeds for three roads according to the land use type can be summarized as shown in Table 5.1.

Table 5.1 : Average speeds for three roads according to the land use type

	A1 (km/h)	A3 (km/h)	A6 (km/h)	All Together (km/h)
Three Leg Intersections	18.9	38	34	31.5
Commercial	34	40	35	35.8
Both Side Residential	43	51	50	49
Residential One Side only	44	56	48	50
Cultivation	43	56	57	55

Table 5.1 shows that the average speed decreases causing an increase in travel time when travelling across more active areas (more trip generation/attraction areas). Also there are differences in speeds among three roads for each category. This is due to the magnitude of each land use parameter and due to geometric differences present on three roads.

The results obtain from the study is summarized in Table 5.2 and limiting values per section for each model are given in Table 5.3.

Table 5.2: Model Summary

Model	Parameters included in the equation	R^2 Value	DW Statistic	MAPE (%)
Three leg intersection	CL,TD	70.5	1.88	38
Commercial	CL,TD,I	69.3	1.67	23.6
Residential both side	H,TD,I	64.8	1.57	18
Residential one side only	TD	76	1.42	14
cultivation	TD	81	1.76	17

Where CL- Commercial Length

TD –Travel Distance

H- Number of Houses

I-Number of Important Places

All the models showed good explanatory power of travel time with a good predictive capability of travel time estimation. The model will perform well within the limiting values given in Table 5.3. The derived travel time estimation model can be useful to authorities, road designers, and town and country planners and for planning, design and research purposes. Further studies can be done for more accurate estimate of travel time and identification of traffic characteristics.

Table 5.3: Limiting Values of All models

	Section Length(m)	Commercial %	Residential density (Houses/km)	No of important places (No)	No of access roads (No)	Cultivation %
Three Leg Intersections	60-1000	0-100	-	-	-	0-100
Commercial	200-1200	Residential: >15%, Commercial and Cultivation:>0	0-152	0-5	0-14	-
Both Side Residential	200-1450	0-15	18-171	0-3	0-15	0-75
One Side Residential	1200-200	0-15	10-76	0-2	0-11	0-80
Cultivation	1300-200	0	0-26	0-2	0-5	Both side Residential: >75%, One Side Residential: >80

5.1 Limitations and future study areas

In this research only the land development was considered and the land use effect within a 50m buffer zone was considered. But there is always an effect from the catchment that has to be added for future studies.

In this research the geometric variations have not been considered in the analysis and the model accuracy could be improved by the addition of evaluation of travel time delays due to land use variations. Complex land use issues were not discussed and the research on that area will be necessary with the increase in traffic flow. In addition to that a study to identify the patterns related to traffic flows from the land use type would be enlightenment to this research area as there is not much research done in Sri Lanka.

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APPENDIX A: Regression Model of Un-Signalized Three Leg Intersections

Table A.1 - Regression Summary - Model 2

Regression Analysis: Travel time(s) versus Commercial, Distance (m)

Stepwise Selection of Terms

Candidate terms: Commercial, Distance (m)

	-----Step 1-----		-----Step 2-----	
	Coef	P	Coef	P
Constant	-0.29		0.84	
Distance(m)	0.14085	0.000	0.10784	0.000
Commercial			0.01636	0.000
S		18.2232		17.6784
R-sq		68.71%		70.65%
R-sq(adj)		68.60%		70.45%
R-sq(pred)		67.86%		69.33%
Mallows' Cp		20.84		3.00

α to enter = 0.05, α to remove = 0.05

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	225678	112839	361.05	0.000
Commercial	1	6199	6199	19.84	0.000
Distance(m)	1	43699	43699	139.82	0.000
Error	300	93758	313		
Lack-of-Fit	64	46709	730	3.66	0.000
Pure Error	236	47049	199		
Total	302	319436			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
17.6784	70.65%	70.45%	69.33%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.84	1.65	0.51	0.609	
Commercial	0.01636	0.00367	4.45	0.000	2.94
Distance(m)	0.10784	0.00912	11.82	0.000	2.94

Regression Equation

Travel time(s) = 0.84 + 0.01636 Commercial + 0.10784 Distance(m)

Fits and Diagnostics for Unusual Observations

Travel

Obs	time(s)	Fit	Resid	Std Resid		
18	114.00	123.38	-9.38	-0.54		X
19	95.00	51.31	43.69	2.48	R	
23	121.00	51.31	69.69	3.96	R	
27	56.00	93.97	-37.97	-2.17	R	
29	17.80	37.75	-19.95	-1.16		X
60	49.00	8.07	40.93	2.32	R	
70	176.00	64.81	111.19	6.32	R	
71	104.00	42.40	61.60	3.50	R	
83	139.00	123.38	15.62	0.91		X
87	58.00	93.97	-35.97	-2.06	R	
101	110.00	123.38	-13.38	-0.78		X
105	16.00	37.75	-21.75	-1.27		X
106	28.00	37.75	-9.75	-0.57		X
116	241.00	126.32	114.68	6.71	R	X
155	131.00	81.57	49.43	2.82	R	
168	58.00	17.57	40.43	2.29	R	
169	177.00	123.38	53.62	3.11	R	X
173	55.00	93.97	-38.97	-2.23	R	
185	22.00	37.75	-15.75	-0.92		X
187	104.20	60.93	43.27	2.46	R	
192	20.60	37.75	-17.15	-1.00		X
193	128.00	126.32	1.68	0.10		X
229	83.00	42.40	40.60	2.31	R	
231	47.00	93.97	-46.97	-2.69	R	
242	61.00	19.59	41.41	2.35	R	
250	128.00	123.38	4.62	0.27		X
258	24.00	37.75	-13.75	-0.80		X
266	90.00	108.96	-18.96	-1.17		X
270	112.00	126.32	-14.32	-0.84		X
279	34.60	75.00	-40.40	-2.30	R	
293	53.00	17.16	35.84	2.03	R	
303	79.00	41.72	37.28	2.11	R	

R Large residual
X Unusual X

Durbin-Watson Statistic

Durbin-Watson Statistic = 1.87551

Figure A.1 - Randomness of Residuals – Model 2

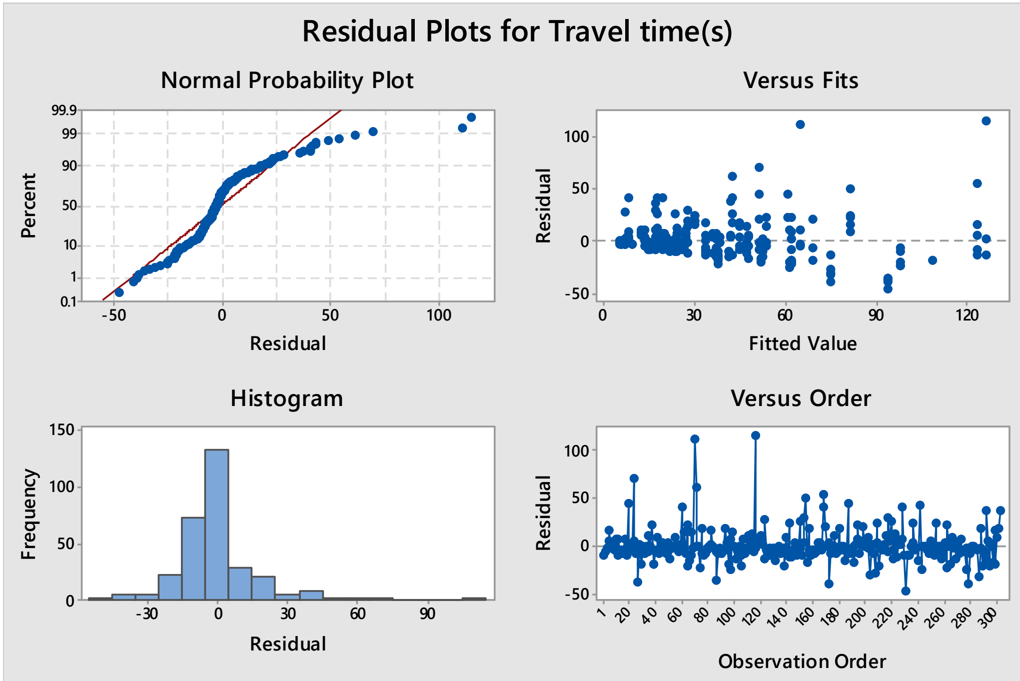

Table A.2 – Cross Validation Results – Model 2

Fi = Predicted value

Test set-set 2						MODEL VALUE(NON CATAGORICAL)			
Intersection name	Commercial	Travel time (s)	Distance (m)	Speed (km/h)	next Speed (km/h)	Fi	MSE	RMSE	MAPE
1	244	43	118	9.9	23.1	17.6	647.0	8.3	0.6
6	1439	111	918	29.8	25.9	123.4	153.1	2.0	0.1
11	890	64	333	18.7	22.4	51.3	161.0	2.1	0.2
13	0	4	78	70.2	59.4	9.3	27.6	0.4	1.3
14-2	0	32	60	6.8	40.0	7.3	609.6	7.8	0.8
20	323	55	357	23.4	37.5	44.6	107.7	1.4	0.2
22	1190	61	683	40.3	31.1	94.0	1086.6	13.9	0.5
14	161	7	102	52.5	61.9	14.5	55.9	0.7	1.1
5	229	31	160	18.6	35.7	21.8	83.8	1.1	0.3
10	94	14	139	35.7	46.9	17.4	11.3	0.1	0.2
14-2	0	6	60	36.0	36.3	7.3	1.7	0.0	0.2
3	846	52	306	21.2	30.4	47.7	18.6	0.2	0.1
8	157	64	248	14.0	147.0	30.2	1145.6	14.7	0.5

Test set-set 2						MODEL VALUE(NON CATAGORICAL)			
Intersection name	Commercial	Travel time (s)	Distance (m)	Speed (km/h)	next Speed (km/h)	Fi	MSE	RMSE	MAPE
13	0	4	78	70.2	53.0	9.3	27.6	0.4	1.3
21	371	26	174	24.1	29.3	25.7	0.1	0.0	0.0
23	0	3	43	51.6	49.9	5.5	6.1	0.1	0.8
17	378	29	280	34.8	52.3	37.2	67.6	0.9	0.3
2	216	30	141	16.9	17.7	19.6	108.5	1.4	0.3
7	1248	100	712	25.6	35.2	98.0	3.9	0.0	0.0
12	248	29	205	25.4	12.6	27.0	4.0	0.1	0.1
25	0	5	56	40.3	45.1	6.9	3.5	0.0	0.4
23	0	3	43	51.6	52.7	5.5	6.1	0.1	0.8
25	0	4	56	50.4	51.1	6.9	8.3	0.1	0.7
22	1190	62	683	39.7	33.5	94.0	1021.6	13.1	0.5
17	378	30	280	33.6	39.3	37.2	52.1	0.7	0.2
5	229	20	160	28.8	47.4	21.8	3.4	0.0	0.1
3	846	40	306	27.5	41.9	47.7	59.0	0.8	0.2
13	0	5	78	56.2	53.0	9.3	18.1	0.2	0.9
17	378	30	280	33.6	52.3	37.2	52.1	0.7	0.2
114	163	34	157	16.6	30.8	20.4	184.1	2.4	0.4
135	0	3	40	48.0	25.8	5.2	4.6	0.1	0.7
94,95	532	63	410	23.4	22.5	53.8	85.5	1.1	0.1
192	1049	88.8	398	16.2		60.9	776.8	10.0	0.3
55	196	25	210	30.2	34.7	26.7	2.8	0.0	0.1
135	0	4	40	36.0	42.9	5.2	1.3	0.0	0.3
94,95	532	48	410	30.8	28.0	53.8	33.1	0.4	0.1
192	1049	60	398	23.9	22.4	60.9	0.9	0.0	0.0
145	1046	46.4	410	31.8	45.6	62.2	248.7	3.2	0.3
145	1046	81	410	18.2	36.1	62.2	354.5	4.5	0.2
114	163	13	157	43.5	37.0	20.4	55.3	0.7	0.6
208	86	14	91	23.4	18.2	12.1	3.7	0.0	0.1
4	0	7	60	30.9	26.7	7.3	0.1	0.0	0.0
199	2409	96.2	798	29.9	28.3	126.3	906.9	11.6	0.3
293	1111	59	465	28.4	32.1	69.2	103.3	1.3	0.2
289	1052	76	407	19.3	36.4	61.9	197.5	2.5	0.2
293	1111	79	465	21.2	44.1	69.2	96.8	1.2	0.1
289	1052	53.4	407	27.4	27.1	61.9	73.0	0.9	0.2
432	0	3	45	54.0	63.0	5.7	7.3	0.1	0.9
545	0	11	60	19.6	38.1	7.3	13.6	0.2	0.3
564	390	57.2	420	26.4	3.6	52.5	22.0	0.3	0.1
585	123	19.8	103	18.7	19.0	14.0	34.1	0.4	0.3
432	0	3	45	54.0	65.8	5.7	7.3	0.1	0.9

Test set-set 2						MODEL VALUE(NON CATAGORICAL)			
Intersection name	**Commercial**	**Travel time (s)**	**Distance (m)**	**Speed (km/h)**	**next Speed (km/h)**	**Fi**	**MSE**	**RMSE**	**MAPE**
441	0	6.6	63	34.4	47.3	7.6	1.1	0.0	0.2
382-2	0	16	210	47.3	52.7	23.5	56.0	0.7	0.5
585	123	10.2	103	36.4	35.7	14.0	14.2	0.2	0.4
33	0	5	60	43.2	57.3	7.3	5.3	0.1	0.5
441	0	6	63	37.8	46.1	7.6	2.7	0.0	0.3
361	114	11.4	170	53.7	53.5	21.0	93.0	1.2	0.8
441	0	5.2	63	43.6	50.1	7.6	5.9	0.1	0.5
585	123	10	103	37.1	33.3	14.0	15.7	0.2	0.4
361	114	15	170	40.8	45.5	21.0	36.5	0.5	0.4
417	831	55	437	28.6	34.7	61.6	43.0	0.6	0.1
24	520.9	39	300	18.0	28.5	41.7	7.4	0.1	0.1
5	346.6	67	380	10.5	47.4	47.5	380.7	4.9	0.3
20	406.6	44	288	16.0	19.9	38.5	29.7	0.4	0.1
24	520.9	214	300	3.3	10.0	41.7	29682.5	380.5	0.8
21	111.2	22	141	31.9	26.3	17.9	17.1	0.2	0.2
6	210.8	23	342	30.5	37.6	41.2	330.1	4.2	0.8
6	210.8	42	342	16.7	37.8	41.2	0.7	0.0	0.0
18	699.6	98	487	7.2	11.5	64.8	1102.0	14.1	0.3
22	8.8	36	150	19.5	16.7	17.2	354.9	4.6	0.5
19	514.7	62	260	11.3	2.9	37.3	610.1	7.8	0.4
2,3	514.5	23	228	30.5	50.6	33.8	117.6	1.5	0.5
2,3	514.5	19	228	36.9	56.3	33.8	220.4	2.8	0.8
15	475.3	62	400	11.3	37.4	51.8	105.0	1.3	0.2
20	406.6	38	288	18.5	15.0	38.5	0.3	0.0	0.0
16	1115.9	38	400	18.5	37.7	62.2	587.2	7.5	0.6
							546.0	23.4	0.4

APPENDIX B: Regression Model of Commercial Development

Figure B.1 – Histogram of Speed – Model 4

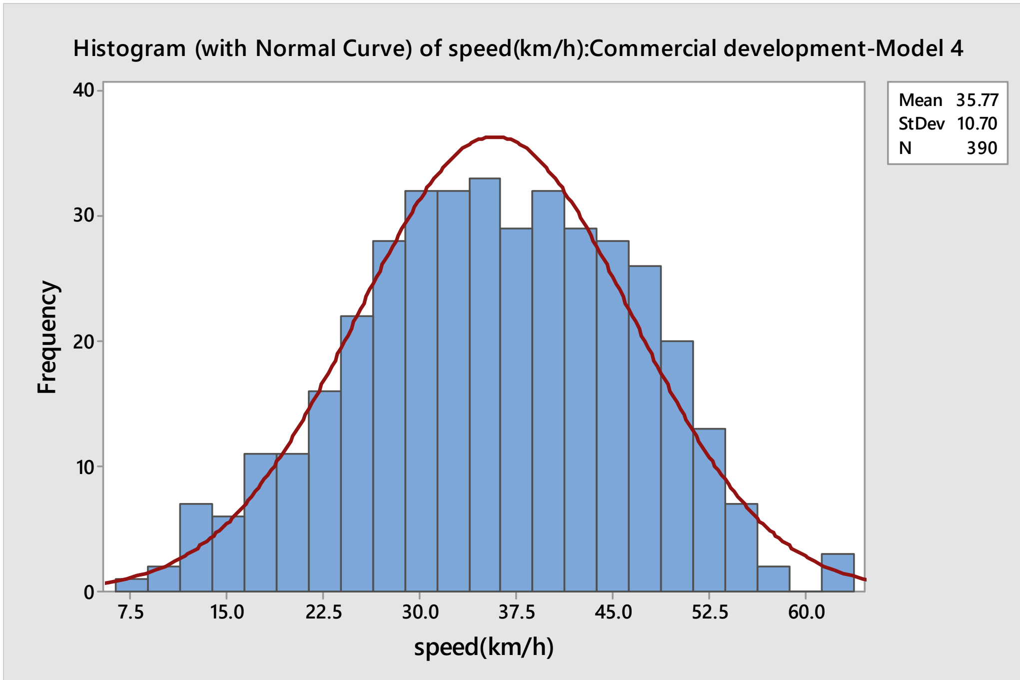

Table B.1 – Model Summary – Model 4

Regression Analysis: TT (s)3 versus Length(m), commercial l, residential, no of import,

```
Method

Rows unused   84


Stepwise Selection of Terms

Candidate terms: Length(m), commercial length(m), residential, no of important
places,
     cultivation(m)

                        -----Step 1-----    -----Step 2-----    -----Step 3-----
                           Coef        P       Coef        P       Coef        P
Constant                   1.03               -1.23               -1.40
Length(m)               0.11138    0.000    0.07905    0.000    0.08119    0.000
commercial length(m)                        0.04318    0.000    0.03345    0.000
no of important places                                             6.77    0.000
```

S	22.2346	18.7667	17.6235
R-sq	51.31%	65.43%	69.61%
R-sq(adj)	51.15%	65.20%	69.31%
R-sq(pred)	50.51%	64.42%	68.07%
Mallows' Cp	179.31	41.47	2.02

α to enter = 0.05, α to remove = 0.05

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	215571	71856.9	231.36	0.000
Length(m)	1	64411	64410.6	207.38	0.000
commercial length(m)	1	22394	22394.0	72.10	0.000
no of important places	1	12958	12957.6	41.72	0.000
Error	303	94108	310.6		
Lack-of-Fit	60	36678	611.3	2.59	0.000
Pure Error	243	57430	236.3		
Total	306	309679			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
17.6235	69.61%	69.31%	68.07%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-1.40	2.65	-0.53	0.597	
Length(m)	0.08119	0.00564	14.40	0.000	1.31
commercial length(m)	0.03345	0.00394	8.49	0.000	1.53
no of important places	6.77	1.05	6.46	0.000	1.20

Regression Equation

TT (s)3 = -1.40 + 0.08119 Length(m) + 0.03345 commercial length(m)
+ 6.77 no of important places

Fits and Diagnostics for Unusual Observations

Obs	TT (s)3	Fit	Resid	Std Resid		
19	165.00	105.55	59.45	3.46	R	X
31	73.00	106.80	-33.80	-1.96		X
49	167.00	147.47	19.53	1.15		X
50	138.60	147.47	-8.87	-0.52		X
51	128.00	147.47	-19.47	-1.15		X
52	53.20	96.25	-43.05	-2.48	R	
69	62.00	24.08	37.92	2.16	R	
91	125.00	120.42	4.58	0.27		X
119	102.00	58.01	43.99	2.51	R	
120	93.80	58.01	35.79	2.04	R	
129	151.20	105.55	45.65	2.66	R	X
130	78.00	105.55	-27.55	-1.60		X
148	79.00	106.80	-27.80	-1.61		X
156	108.00	62.32	45.68	2.60	R	
159	125.00	147.47	-22.47	-1.32		X
221	78.00	31.42	46.58	2.65	R	
228	157.00	105.55	51.45	2.99	R	X
229	102.00	105.55	-3.55	-0.21		X
243	118.00	106.80	11.20	0.65		X
244	79.00	106.80	-27.80	-1.61		X
259	211.00	147.47	63.53	3.74	R	X
260	66.00	28.00	38.00	2.17	R	
288	127.00	120.42	6.58	0.38		X
307	73.00	31.42	41.58	2.37	R	
308	93.00	31.42	61.58	3.51	R	
319	141.00	68.20	72.80	4.20	R	

```
331   197.00  106.80   90.20        5.23  R  X
344   142.00  147.47   -5.47       -0.32     X
386   162.80  120.42   42.38        2.47  R  X
391    98.00   53.75   44.25        2.52  R

R  Large residual
X  Unusual X


Durbin-Watson Statistic

Durbin-Watson Statistic =  1.67863
```

Figure B.2 – Randomness of Residuals – Model 4

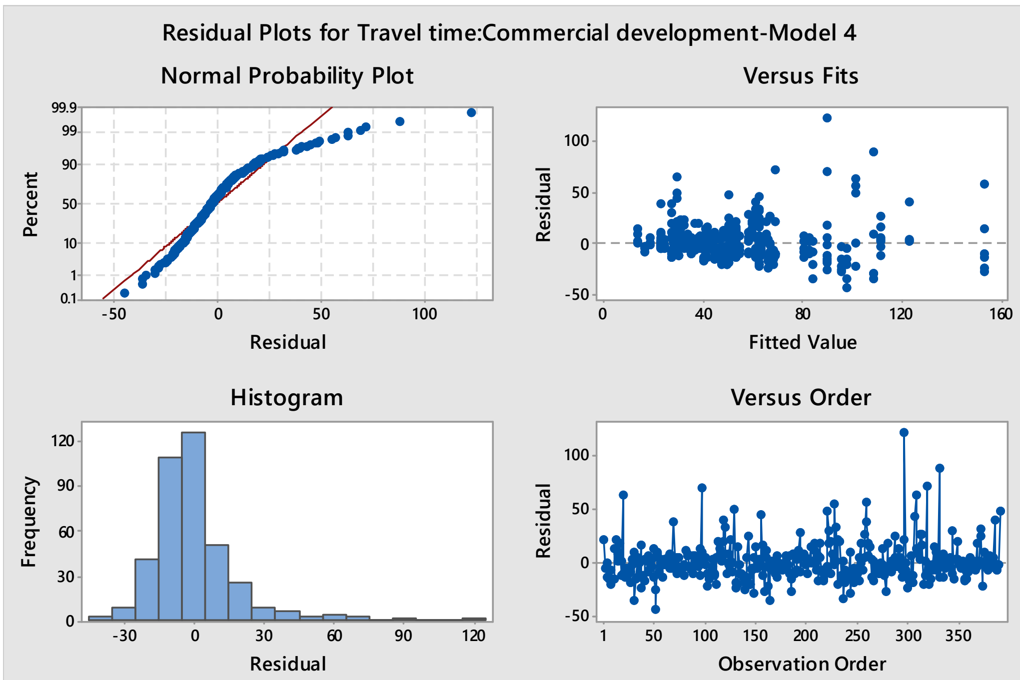

Table B.2 – Cross Validation – Model 4

Fi = Predicted value   I= Important Places   TT(s) =Travel Time

Section number	Road type	Section Name	Length(m)	Commercial Length (m)	I	TT (s)	*Fi*	MSE	RMSE	MAPE
4	A1	36	347	216	0	32	34.0	3.9	0.0	0.1
4	A1	39	479	278	1	65.6	53.6	145.1	1.5	0.2
4	A1	39	479	278	1	46.4	53.6	51.2	0.5	0.2
4	A1	42	541	945	2	113	87.7	641.1	6.7	0.2
4	A1	43	388	370	0	44.8	42.5	5.3	0.1	0.1
4	A1	43	388	370	0	45	42.5	6.3	0.1	0.1
4	A1	43	388	370	0	59	42.5	272.6	2.8	0.3

Section number	Road type	Section Name	Length(m)	Commercial Length (m)	I	TT (s)	*Fi*	MSE	RMSE	MAPE
4	A1	43	388	370	0	44	42.5	2.3	0.0	0.0
4	A1	43	388	370	0	51.6	42.5	83.0	0.9	0.2
4	A1	60	187	162	0	16	19.2	10.2	0.1	0.2
4	A1	60	187	162	0	18.2	19.2	1.0	0.0	0.1
4	A1	61	440	675	1	41	63.7	514.0	5.4	0.6
4	A1	61	440	675	1	42	63.7	469.7	4.9	0.5
4	A1	63	585	687	0	54	69.1	227.3	2.4	0.3
4	A1	63	585	687	0	47	69.1	487.4	5.1	0.5
4	A1	63	585	687	0	60	69.1	82.4	0.9	0.2
4	A1	63	585	687	0	61	69.1	65.2	0.7	0.1
4	A1	72	441	424	0	52	48.6	11.6	0.1	0.1
4	A1	75	323	533	1	27	49.4	502.8	5.2	0.8
4	A1	75	323	533	1	36.6	49.4	164.4	1.7	0.4
4	A1	77	279	334	0	27.2	32.4	27.3	0.3	0.2
4	A1	79	291	275	0	58	31.4	706.2	7.4	0.5
4	A1	84	550	239	1	126	58.0	4621.4	48.1	0.5
4	A1	87	475	573	0	39	56.3	300.2	3.1	0.4
4	A1	88	639	429	1	66.6	71.6	24.9	0.3	0.1
4	A1	88	639	429	1	52	71.6	383.9	4.0	0.4
4	A1	88	639	429	1	75	71.6	11.6	0.1	0.0
4	A1	89	541	789	0	93	68.9	580.0	6.0	0.3
4	A1	89	541	789	0	53	68.9	253.3	2.6	0.3
4	A1	90	727	1433	0	96	105.6	91.4	1.0	0.1
4	A1	90	727	1433	0	96.4	105.6	83.9	0.9	0.1
4	A1	91	267	897	2	43.2	63.8	425.3	4.4	0.5
4	A1	93	213	419	0	50	29.9	403.1	4.2	0.4
4	A1	93	213	419	0	32	29.9	4.3	0.0	0.1
4	A1	93	213	419	0	32	29.9	4.3	0.0	0.1
4	A1	94	285	782	3	58	68.2	104.2	1.1	0.2
4	A3	32	290	0	1	23	28.9	35.2	0.4	0.3
4	A3	90	612	807	2	74	88.8	218.7	2.3	0.2
4	A3	91	544	543	3	76	81.2	27.1	0.3	0.1
4	A3	91	544	543	3	67	81.2	201.7	2.1	0.2
4	A3	129	652	375	0	61	64.0	9.3	0.1	0.0
4	A3	131	442	121	1	44	45.3	1.6	0.0	0.0
4	A3	131	442	121	1	38	45.3	52.9	0.6	0.2
4	A3	139	695	738	4	90	106.8	282.5	2.9	0.2
4	A3	141	441	278	1	48	50.5	6.2	0.1	0.1
4	A3	147	472	214	0	45	44.0	0.9	0.0	0.0
4	A3	157	386	340	0	37	41.3	18.5	0.2	0.1
4	A3	158	586	390	0	50	59.2	84.6	0.9	0.2
4	A3	158	586	390	0	42	59.2	295.7	3.1	0.4
4	A3	160	252	214	0	29	26.2	7.7	0.1	0.1
4	A3	160	252	214	0	32	26.2	33.3	0.3	0.2
4	A3	165	645	501	0	55	67.7	162.4	1.7	0.2
4	A6	31	750	632	0	74.2	80.6	41.0	0.4	0.1
4	A6	37	261	158	0	24	25.1	1.1	0.0	0.0
4	A6	37	261	158	0	17	25.1	65.1	0.7	0.5
4	A6	57	891	1277	5	139	147.5	71.9	0.7	0.1
4	A6	72	194	0	0	20	14.4	31.9	0.3	0.3
4	A6	92	448	446	0	49	49.9	0.8	0.0	0.0
4	A6	268	249	324	0	22	29.6	58.5	0.6	0.3
4	A6	268	249	324	0	41.8	29.6	147.7	1.5	0.3
4	A6	268	249	324	0	26	29.6	13.3	0.1	0.1
4	A6	269	343	760	0	53	51.9	1.2	0.0	0.0
4	A1	18	179	460	0	19	28.5	90.6	0.9	0.5
4	A1	18	179	460	0	12.2	28.5	266.3	2.8	1.3

Section number	Road type	Section Name	Length(m)	Commercial Length (m)	I	TT (s)	*Fi*	MSE	RMSE	MAPE
4	A1	66	279	71	0	34	23.6	107.6	1.1	0.3
4	A1	73	359	148	0	29	32.7	13.7	0.1	0.1
4	A1	73	359	148	0	37	32.7	18.4	0.2	0.1
4	A1	67	403	146	0	36	36.2	0.0	0.0	0.0
4	A6	67	595	246	1	69	61.9	50.3	0.5	0.1
4	A6	67	595	246	1	39.6	61.9	497.6	5.2	0.6
4	A1	76	487	479	0	47	54.2	51.3	0.5	0.2
4	A6	5	566	265	0	40	53.4	180.3	1.9	0.3
4	A6	5	566	265	0	43	53.4	108.7	1.1	0.2
4	A6	5	566	265	0	63.6	53.4	103.5	1.1	0.2
4	A6	58	639	321	0	82	61.2	431.6	4.5	0.3
4	A6	55	543	185	0	70	48.9	445.9	4.6	0.3
4	A6	55	543	185	0	58.2	48.9	86.8	0.9	0.2
4	A3	89	606	236	0	56	55.7	0.1	0.0	0.0
4	A3	89	606	236	0	67	55.7	127.6	1.3	0.2
4	A3	150	119	307	0	9	18.6	91.6	1.0	1.1
4	A3	150	119	307	0	12	18.6	43.2	0.4	0.5
4	A3	151	619	330	0	46	59.9	194.0	2.0	0.3
4	A3	152	493	56	1	63	47.2	248.6	2.6	0.3
4	A3	152	493	56	1	44	47.2	10.4	0.1	0.1
4	A3	152	493	56	1	40	47.2	52.3	0.5	0.2
4	A3	159	257	224	0	17	26.9	98.9	1.0	0.6
4	A3	159	257	224	0	27	26.9	0.0	0.0	0.0
4	A3	162	554	135	0	58	48.1	98.4	1.0	0.2
4	A3	163	365	220	0	28	35.6	58.0	0.6	0.3
4	A3	163	365	220	0	43	35.6	54.5	0.6	0.2
4	A6	51	1199	529	1	125	120.4	20.9	0.2	0.0
4	A6	51	1199	529	1	182	120.4	3791.1	39.5	0.3
4	A6	51	1199	529	1	148.8	120.4	805.0	8.4	0.2
4	A1	35	478	176	0	45	43.3	2.9	0.0	0.0
4	A6	4	566	170	0	39	50.3	126.7	1.3	0.3
4	A6	264	508	415	0	63.4	53.8	93.1	1.0	0.2
								229.3	15.1	24%

APPENDIX C: Regression Model of Both Side Residential

Figure C.1 – Histogram of Speed – Model 2

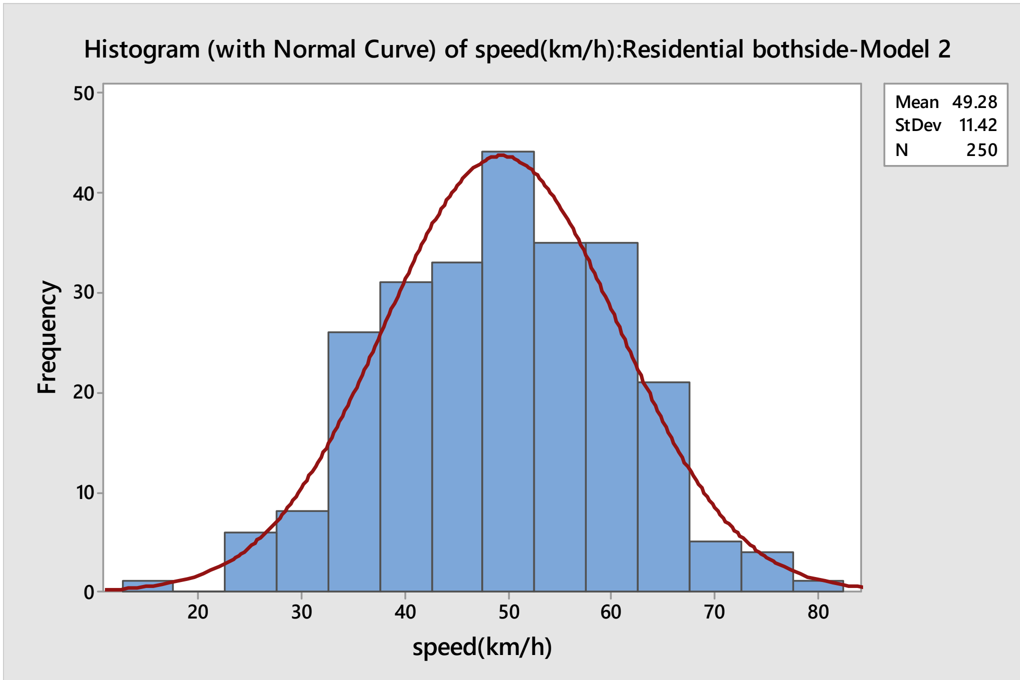

Table C.1 – Regression Model Summary – Model 2

Regression Analysis: TT (s)3 versus Length(m), residential, no of important places

```
Stepwise Selection of Terms

Candidate terms: Length(m), residential, no of important places

                        -----Step 1-----    -----Step 2-----    -----Step 3-
----
                           Coef        P       Coef        P       Coef
P
Constant                   3.93                3.58                3.05
Length(m)               0.06977    0.000    0.06100    0.000    0.06131
0.000
residential                                  0.1781    0.000     0.1644
0.000
no of important places                                            4.157
0.000

S                                 12.9174             12.6894
12.5417
```

R-sq	62.76%	64.10%	64.97%
R-sq(adj)	62.72%	64.02%	64.86%
R-sq(pred)	62.55%	63.81%	64.51%
Mallows' Cp	58.73	25.07	4.00

α to enter = 0.05, α to remove = 0.05

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	271602	90534	575.57	0.000
Length(m)	1	116438	116438	740.26	0.000
residential	1	4736	4736	30.11	0.000
no of important places	1	3629	3629	23.07	0.000
Error	931	146441	157		
Lack-of-Fit	207	84927	410	4.83	0.000
Pure Error	724	61514	85		
Total	934	418044			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
12.5417	64.97%	64.86%	64.51%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	3.05	1.07	2.85	0.004	
Length(m)	0.06131	0.00225	27.21	0.000	1.74
residential	0.1644	0.0300	5.49	0.000	1.75
no of important places	4.157	0.865	4.80	0.000	1.01

Regression Equation

TT (s)3 = 3.05 + 0.06131 Length(m) + 0.1644 residential
+ 4.157 no of important places

Fits and Diagnostics for Unusual Observations

Obs	TT (s)3	Fit	Resid	Std Resid		
92	67.00	33.34	33.66	2.69	R	
101	89.00	34.85	54.15	4.32	R	
111	78.00	51.02	26.98	2.15	R	
151	61.00	48.75	12.25	0.98		X
153	82.20	48.75	33.45	2.69	R	X
154	60.00	48.75	11.25	0.90		X
156	83.00	49.02	33.98	2.71	R	
173	69.00	63.52	5.48	0.44		X
174	87.00	63.52	23.48	1.89		X
182	65.00	38.11	26.89	2.15	R	
183	129.00	60.85	68.15	5.45	R	
190	79.00	53.45	25.55	2.04	R	
206	81.00	99.29	-18.29	-1.47		X
207	73.80	99.29	-25.49	-2.05	R	X
208	61.60	77.29	-15.69	-1.28		X

217	55.00	83.40	-28.40	-2.27	R	
234	75.00	65.48	9.52	0.78		X
238	148.00	76.33	71.67	5.74	R	
241	66.60	74.80	-8.20	-0.66		X
242	96.00	74.80	21.20	1.70		X
368	131.00	55.60	75.40	6.02	R	
382	59.00	48.75	10.25	0.82		X
393	69.20	43.85	25.35	2.02	R	
396	60.00	34.36	25.64	2.05	R	
397	72.00	43.85	28.15	2.25	R	
442	114.00	77.36	36.64	2.93	R	
443	84.00	56.19	27.81	2.22	R	
444	119.00	77.36	41.64	3.33	R	
462	108.00	76.49	31.51	2.52	R	
469	85.00	74.80	10.20	0.82		X
470	123.00	74.80	48.20	3.87	R	X
471	63.00	66.05	-3.05	-0.25		X
518	27.00	37.28	-10.28	-0.83		X
521	38.80	37.28	1.52	0.12		X
539	55.40	29.90	25.50	2.03	R	
557	97.00	63.69	33.31	2.67	R	
575	72.00	33.66	38.34	3.06	R	
595	78.00	35.76	42.24	3.37	R	
634	113.00	75.40	37.60	3.01	R	
635	66.00	63.52	2.48	0.20		X
639	99.00	60.85	38.15	3.05	R	
642	129.00	60.85	68.15	5.45	R	
651	104.00	61.60	42.40	3.39	R	
674	77.00	99.29	-22.29	-1.79		X
675	65.60	99.29	-33.69	-2.71	R	X
676	92.00	99.29	-7.29	-0.59		X
682	67.00	77.29	-10.29	-0.84		X
707	62.00	74.80	-12.80	-1.03		X
708	98.20	74.80	23.40	1.88		X
709	55.00	66.05	-11.05	-0.89		X
731	54.00	57.78	-3.78	-0.30		X
748	24.00	37.28	-13.28	-1.07		X
749	24.00	37.28	-13.28	-1.07		X
750	28.00	37.28	-9.28	-0.75		X
760	53.00	24.64	28.36	2.26	R	
840	62.00	48.75	13.25	1.07		X
843	101.00	59.12	41.88	3.35	R	
852	74.00	46.74	27.26	2.18	R	
864	120.80	60.85	59.95	4.79	R	
865	84.00	55.58	28.42	2.27	R	
867	96.00	60.85	35.15	2.81	R	
888	75.40	34.61	40.79	3.26	R	
897	109.00	59.29	49.71	3.97	R	
899	63.00	77.29	-14.29	-1.16		X
900	145.00	77.29	67.71	5.51	R	X
908	110.00	81.58	28.42	2.27	R	
919	60.40	65.48	-5.08	-0.41		X
920	68.00	65.48	2.52	0.21		X
923	49.00	66.05	-17.05	-1.37		X
924	44.20	66.05	-21.85	-1.76		X
931	49.00	57.78	-8.78	-0.71		X

R Large residual
X Unusual X

Durbin-Watson Statistic

Durbin-Watson Statistic = 1.57427

Figure C.2 – Residual Plots – Model 2

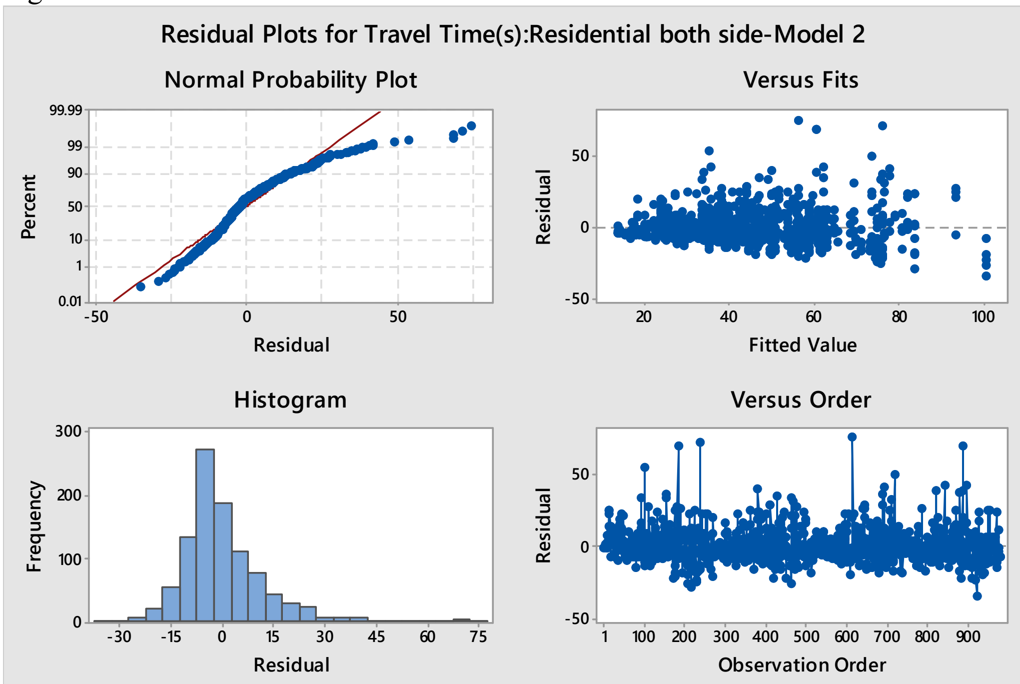

Table C.2 – Cross Validation – Model 2

Fi = Predicted value

Set no	Road type	Section Name	Length(m)	Number of houses	No of important places	Travel Time(s)	speed(km/h)	*Fi*	MSE	RMSE	MAPE
2	A1	27	651	31	0	47	50	42.0	27.5	0.1	0.1
2	A1	28	245	1	0	26	33	12.1	203.5	0.8	0.5
2	A1	28	245	1	0	38	23	12.1	669.0	2.7	0.7
2	A3	106	441	2	0	28	57	24.3	13.6	0.1	0.1
2	A3	106	441	2	0	28	57	24.3	13.6	0.1	0.1
2	A3	63	173	2	0	10	62	7.9	4.4	0.0	0.2
2	A3	16	217	3	1	13	60	14.9	3.7	0.0	0.1
2	A3	35	324	3	0	21	56	17.3	13.4	0.1	0.2
2	A3	7	187	4	1	14	48	13.2	0.6	0.0	0.1
2	A3	7	187	4	1	15	45	13.2	3.1	0.0	0.1
2	A3	108	162	5	0	10	58	7.7	5.4	0.0	0.2
2	A3	36	216	7	0	13	60	11.4	2.7	0.0	0.1
2	A6	207	253	7	0	14	65	13.6	0.1	0.0	0.0

Set no	Road type	Section Name	Length(m)	Number of houses	No of important places	Travel Time(s)	speed(km/h)	*Fi*	MSE	RMSE	MAPE
2	A6	211	270	7	0	14	68	14.6	0.2	0.0	0.0
2	A6	207	253	7	0	16	58	13.6	4.7	0.0	0.1
2	A3	36	216	7	0	19	41	11.4	58.5	0.2	0.4
2	A6	135	393	7	1	34	42	26.4	58.3	0.2	0.2
2	A6	234	198	8	0	13	55	10.4	6.8	0.0	0.2
2	A6	234	198	8	0	12	60	10.4	2.0	0.0	0.1
2	A6	234	198	8	0	10	71	10.4	0.2	0.0	0.0
2	A3	70	179	8	0	11	59	9.2	3.1	0.0	0.2
2	A3	82	301	8	0	18	60	16.7	1.7	0.0	0.1
2	A3	15	241	8	1	18	48	17.2	0.6	0.0	0.0
2	A3	82	301	8	0	22	49	16.7	28.0	0.1	0.2
2	A3	15	241	8	1	22	39	17.2	23.1	0.1	0.2
2	A6	10	399	9	2	27	54	31.2	20.9	0.1	0.2
2	A6	10	399	9	2	29	49	31.2	3.2	0.0	0.1
2	A3	59	221	9	0	13	61	12.0	1.1	0.0	0.1
2	A3	59	221	9	0	16	50	12.0	16.4	0.1	0.3
2	A6	102	318	10	0	33	35	18.1	222.5	0.9	0.5
2	A3	105	246	11	0	18	49	13.8	17.3	0.1	0.2
2	A3	25	253	11	0	15	61	14.3	0.5	0.0	0.0
2	A6	60	277	11	0	38	26	15.7	495.5	2.0	0.6
2	A3	112	447	11	0	27	60	26.2	0.7	0.0	0.0
2	A3	9	323	11	0	34	34	18.5	239.0	1.0	0.5
2	A3	9	323	11	0	32	36	18.5	181.2	0.7	0.4
2	A6	148	393	12	0	19	76	23.0	19.6	0.1	0.2
2	A3	73	309	12	0	20	56	17.9	4.5	0.0	0.1
2	A6	148	393	12	0	28	51	23.0	22.8	0.1	0.2
2	A3	73	309	12	0	21	53	17.9	9.7	0.0	0.1
2	A6	77	316	13	0	19	60	18.4	0.3	0.0	0.0
2	A6	144	449	13	0	30	54	26.6	11.3	0.0	0.1
2	A6	144	449	13	0	25	65	26.6	2.7	0.0	0.1
2	A6	144	449	13	0	31	52	26.6	20.8	0.1	0.1
2	A3	18	442	13	0	25	64	26.2	1.4	0.0	0.0
2	A3	18	442	13	0	24	66	26.2	4.8	0.0	0.1
2	A6	144	449	13	0	34	48	26.6	54.2	0.2	0.2
2	A3	123	198	13	0	21	34	11.2	95.6	0.4	0.5
2	A6	12	400	14	0	32	44	23.8	74.0	0.3	0.3
2	A3	19	464	14	0	35	48	27.7	53.5	0.2	0.2
2	A3	71	419	15	0	25	60	25.1	0.0	0.0	0.0

Set no	Road type	Section Name	Length(m)	Number of houses	No of important places	Travel Time(s)	speed(km/h)	*Fi*	MSE	RMSE	MAPE
2	A3	21	418	15	0	25	60	25.1	0.0	0.0	0.0
2	A6	87	492	16	0	29	60	29.7	0.1	0.0	0.0
2	A3	102	401	16	0	22	66	24.1	4.6	0.0	0.1
2	A3	138	355	16	0	24	53	21.3	7.1	0.0	0.1
2	A3	102	401	16	0	25	58	24.1	0.7	0.0	0.0
2	A3	138	355	16	0	36	35	21.3	214.9	0.9	0.4
2	A6	219	457	17	0	24	67	27.7	11.1	0.0	0.1
2	A6	161	574	17	0	27	75	35.0	57.1	0.2	0.3
2	A6	217	862	17	0	55	56	52.6	5.8	0.0	0.0
2	A3	146	233	17	0	13	65	14.1	1.1	0.0	0.1
2	A6	217	862	17	0	82	38	52.6	853.3	3.5	0.4
2	A6	217	862	17	0	62	50	52.6	88.6	0.4	0.2
2	A3	145	374	18	0	28	48	22.8	26.7	0.1	0.2
2	A3	92	379	18	0	27	50	23.1	15.1	0.1	0.1
2	A3	92	379	18	0	28	49	23.1	23.8	0.1	0.2
2	A3	110	359	18	0	23	56	21.9	1.1	0.0	0.0
2	A3	145	374	18	0	40	34	22.8	294.9	1.2	0.4
2	A3	145	374	18	0	33	41	22.8	103.5	0.4	0.3
2	A6	224	544	19	0	31	64	33.4	7.9	0.0	0.1
2	A6	255	938	19	0	61	56	57.6	9.1	0.0	0.0
2	A1	46	286	19	0	23	45	17.6	29.1	0.1	0.2
2	A1	46	286	19	0	23	44	17.6	33.5	0.1	0.2
2	A3	81	599	19	0	34	63	36.8	7.9	0.0	0.1
2	A3	81	599	19	0	38	57	36.8	1.4	0.0	0.0
2	A6	53	443	19	0	49	33	27.2	473.5	1.9	0.4
2	A3	81	599	19	0	48	45	36.8	125.2	0.5	0.2
2	A1	46	286	19	0	40	26	17.6	501.4	2.0	0.6
2	A6	32	284	20	0	28	36	17.6	107.4	0.4	0.4
2	A6	32	284	20	0	23	44	17.6	28.8	0.1	0.2
2	A6	240	497	20	0	29	63	30.7	4.3	0.0	0.1
2	A3	68	487	20	1	28	63	34.3	39.4	0.2	0.2
2	A6	240	497	20	0	32	56	30.7	2.3	0.0	0.0
2	A3	68	487	20	1	33	53	34.3	1.6	0.0	0.0
2	A6	271	465	20	0	49	34	28.7	410.2	1.7	0.4
2	A6	84	402	21	1	34	43	29.2	23.0	0.1	0.1
2	A6	84	402	21	1	32	45	29.2	7.8	0.0	0.1
2	A6	193	648	21	0	37	63	40.1	9.8	0.0	0.1
2	A3	85	419	22	0	26	58	26.3	0.1	0.0	0.0

Set no	Road type	Section Name	Length(m)	Number of houses	No of important places	Travel Time(s)	speed(km/h)	*Fi*	MSE	RMSE	MAPE
2	A3	85	419	22	0	30	50	26.3	14.0	0.1	0.1
2	A3	85	419	22	0	32	47	26.3	32.9	0.1	0.2
2	A6	69	438	23	0	49	32	27.6	459.9	1.9	0.4
2	A6	80	496	24	1	34	52	35.4	2.1	0.0	0.0
2	A6	163	718	24	0	47	55	44.9	5.2	0.0	0.0
2	A6	163	718	24	0	57	45	44.9	155.8	0.6	0.2
2	A6	80	496	24	1	66	27	35.4	933.7	3.8	0.5
2	A6	226	661	25	0	44	54	41.6	5.9	0.0	0.1
2	A6	2	326	25	0	31	38	21.0	95.6	0.4	0.3
2	A6	2	326	25	0	33	36	21.0	143.5	0.6	0.4
2	A3	94	486	25	0	37	47	30.8	37.9	0.2	0.2
2	A3	57	723	25	1	50	52	49.5	0.2	0.0	0.0
2	A6	167	787	26	0	39	72	49.5	101.9	0.4	0.3
2	A3	34	473	26	0	29	59	30.2	1.5	0.0	0.0
2	A3	144	463	26	0	31	54	29.6	1.9	0.0	0.0
2	A3	34	473	26	0	34	50	30.2	14.1	0.1	0.1
2	A3	34	473	26	0	27	63	30.2	10.5	0.0	0.1
2	A3	140	453	27	1	44	37	33.3	114.4	0.5	0.2
2	A3	140	453	27	1	42	39	33.3	75.6	0.3	0.2
2	A3	140	453	27	1	48	34	33.3	215.9	0.9	0.3
2	A6	266	404	28	0	32	46	26.3	30.0	0.1	0.2
2	A1	32	564	28	0	41	50	36.1	23.7	0.1	0.1
2	A1	32	564	28	0	61	33	36.1	618.4	2.5	0.4
2	A1	74	687	28	0	73	34	43.7	860.1	3.5	0.4
2	A1	74	687	28	0	90	27	43.7	2146.2	8.7	0.5
2	A1	74	687	28	0	74	33	43.7	919.7	3.7	0.4
2	A6	86	686	29	0	43	57	43.8	0.6	0.0	0.0
2	A3	103	646	29	0	38	61	41.3	11.2	0.0	0.1
2	A3	103	646	29	0	46	51	41.3	21.7	0.1	0.1
2	A1	45	580	29	0	62	34	37.3	591.6	2.4	0.4
2	A3	103	646	29	0	52	45	41.3	113.6	0.5	0.2
2	A3	134	667	29	0	60	40	42.6	301.3	1.2	0.3
2	A1	45	580	29	0	62	34	37.3	611.2	2.5	0.4
2	A3	134	667	29	0	46	52	42.6	11.3	0.0	0.1
2	A6	230	485	30	0	27	65	31.6	21.0	0.1	0.2
2	A6	52	529	30	2	47	41	42.6	18.9	0.1	0.1
2	A6	256	756	30	0	46	59	48.2	5.9	0.0	0.1
2	A6	191	780	30	0	44	64	49.7	32.3	0.1	0.1

Set no	Road type	Section Name	Length(m)	Number of houses	No of important places	Travel Time(s)	speed(km/h)	*Fi*	MSE	RMSE	MAPE
2	A6	256	756	30	0	45	60	48.2	10.4	0.0	0.1
2	A3	83	608	30	0	38	58	39.1	1.3	0.0	0.0
2	A3	84	516	30	0	33	56	33.5	0.3	0.0	0.0
2	A3	95	380	30	0	28	49	25.2	8.0	0.0	0.1
2	A3	84	516	30	0	35	53	33.5	2.1	0.0	0.0
2	A3	84	516	30	0	34	55	33.5	0.2	0.0	0.0
2	A6	52	529	30	2	69	28	42.6	694.5	2.8	0.4
2	A6	39	764	31	1	71	39	53.0	323.5	1.3	0.3
2	A3	55	570	31	0	37	55	37.0	0.0	0.0	0.0
2	A3	148	667	31	0	52	46	42.9	82.5	0.3	0.2
2	A3	148	667	31	0	60	40	42.9	291.9	1.2	0.3
2	A3	148	667	31	0	56	43	42.9	171.2	0.7	0.2
2	A6	160	688	32	0	46	54	44.4	2.6	0.0	0.0
2	A3	80	629	32	0	35	65	40.8	33.6	0.1	0.2
2	A3	80	629	32	0	36	63	40.8	23.0	0.1	0.1
2	A1	29	577	33	0	54	38	37.8	264.0	1.1	0.3
2	A1	29	577	33	0	72	29	37.8	1173.0	4.7	0.5
2	A1	29	577	33	0	72	29	37.8	1173.0	4.7	0.5
2	A3	149	622	33	0	59	38	40.5	342.1	1.4	0.3
2	A3	86	632	34	1	48	47	45.5	6.5	0.0	0.1
2	A6	192	1086	35	0	62	63	69.3	53.3	0.2	0.1
2	A3	99	899	35	0	70	46	57.8	148.6	0.6	0.2
2	A3	136	757	35	2	70	39	57.4	158.3	0.6	0.2
2	A3	136	757	35	2	70	39	57.4	158.3	0.6	0.2
2	A3	136	757	35	2	69	39	57.4	134.2	0.5	0.2
2	A6	166	793	36	0	36	79	51.5	239.9	1.0	0.4
2	A6	166	793	36	0	49	59	51.5	7.2	0.0	0.1
2	A3	10	441	36	0	38	42	29.9	65.9	0.3	0.2
2	A3	10	441	36	0	41	39	29.9	123.7	0.5	0.3
2	A6	143	578	37	0	28	74	38.4	109.0	0.4	0.4
2	A3	93	607	38	0	37	59	40.4	11.8	0.0	0.1
2	A6	124	713	38	1	56	46	51.1	24.1	0.1	0.1
2	A3	93	607	38	0	50	44	40.4	91.6	0.4	0.2
2	A1	2	853	38	0	97	32	55.5	1722.7	7.0	0.4
2	A3	124	389	39	0	32	44	27.2	23.0	0.1	0.1
2	A6	247	730	40	0	39	67	48.3	85.7	0.3	0.2
2	A3	154	478	40	0	43	40	32.8	103.1	0.4	0.2
2	A3	154	478	40	0	55	31	32.8	490.7	2.0	0.4

Set no	Road type	Section Name	Length(m)	Number of houses	No of important places	Travel Time(s)	speed(km/h)	*Fi*	MSE	RMSE	MAPE
2	A3	12	515	41	0	39	48	35.3	13.8	0.1	0.1
2	A6	122	589	41	0	55	39	39.8	231.2	0.9	0.3
2	A3	12	515	41	0	56	33	35.3	429.1	1.7	0.4
2	A6	138	573	42	0	32	65	39.0	54.3	0.2	0.2
2	A6	138	573	42	0	38	54	39.0	0.9	0.0	0.0
2	A6	245	989	43	1	58	61	68.8	116.9	0.5	0.2
2	A3	153	400	45	0	30	48	28.9	1.3	0.0	0.0
2	A6	162	725	45	0	75	35	48.8	687.2	2.8	0.3
2	A6	83	695	46	0	60	42	47.1	165.2	0.7	0.2
2	A1	49	818	46	0	62	47	54.7	53.8	0.2	0.1
2	A1	49	818	46	0	72	41	54.7	300.5	1.2	0.2
2	A6	76	1127	47	1	85	48	77.9	52.7	0.2	0.1
2	A6	76	1127	47	1	107	38	77.9	844.3	3.4	0.3
2	A6	40	786	49	0	61	46	53.2	61.0	0.2	0.1
2	A6	40	786	49	0	59	48	53.2	29.3	0.1	0.1
2	A6	40	786	49	0	66	43	53.2	159.0	0.6	0.2
2	A6	81	544	50	0	44	44	38.5	32.6	0.1	0.1
2	A6	131	873	50	3	53	59	71.2	330.8	1.3	0.3
2	A6	81	544	50	0	43	46	38.5	20.3	0.1	0.1
2	A6	91	1075	51	0	75	52	71.3	14.0	0.1	0.0
2	A6	164	299	51	0	24	45	23.7	0.1	0.0	0.0
2	A1	23	678	51	0	45	54	46.9	3.6	0.0	0.0
2	A1	23	678	51	0	47	52	46.9	0.0	0.0	0.0
2	A1	3	650	52	0	46	51	45.4	0.4	0.0	0.0
2	A1	3	650	52	0	46	50	45.4	1.1	0.0	0.0
2	A6	127	837	52	0	56	54	56.8	0.6	0.0	0.0
2	A6	257	940	54	1	59	57	67.6	74.4	0.3	0.1
2	A3	125	581	54	1	47	45	45.6	1.9	0.0	0.0
2	A6	155	1032	56	0	50	74	69.4	370.2	1.5	0.4
2	A6	155	1032	56	0	109	34	69.4	1564.9	6.3	0.4
2	A6	238	816	60	0	76	39	56.8	352.7	1.4	0.2
2	A6	111	1115	62	0	103	39	75.5	757.4	3.1	0.3
2	A3	120	603	63	0	36	60	44.3	68.6	0.3	0.2
2	A3	120	603	63	0	35	62	44.3	86.2	0.3	0.3
2	A3	120	603	63	0	42	52	44.3	5.2	0.0	0.1
2	A3	120	603	63	0	45	48	44.3	0.5	0.0	0.0
2	A6	259	908	65	0	100	33	63.3	1345.6	5.4	0.4
2	A6	258	1085	66	0	65	60	74.3	94.2	0.4	0.2

Set no	Road type	Section Name	Length(m)	Number of houses	No of important places	Travel Time(s)	speed(km/h)	*Fi*	MSE	RMSE	MAPE
2	A6	45	605	66	1	44	49	49.0	25.4	0.1	0.1
2	A6	258	1085	66	0	80	49	74.3	32.5	0.1	0.1
2	A6	45	605	66	1	51	43	49.0	3.9	0.0	0.0
2	A3	137	1286	68	0	115	40	87.0	785.5	3.2	0.2
2	A3	137	1286	68	0	121	38	87.0	1157.8	4.7	0.3
2	A6	132	888	69	0	56	57	62.7	45.0	0.2	0.1
2	A6	132	888	69	0	65	49	62.7	5.3	0.0	0.0
2	A6	46	622	72	3	54	41	59.4	26.8	0.1	0.1
2	A6	46	622	72	3	63	36	59.4	13.1	0.1	0.1
2	A6	46	622	72	3	70	32	59.4	112.9	0.5	0.2
2	A3	20	700	77	1	46	55	56.7	114.5	0.5	0.2
2	A6	260	986	78	0	84	42	70.2	184.1	0.7	0.2
2	A3	87	747	81	0	59	46	56.1	8.6	0.0	0.0
2	A6	117	949	84	0	88	39	69.0	362.7	1.5	0.2
2	A1	4	570	19	0	41	50	35.0	35.8	0.1	0.1
2	A1	4	570	19	0	38	54	35.0	8.9	0.0	0.1
2	A1	14	533	16	0	33	58	32.3	0.5	0.0	0.0
2	A1	16	445	24	0	28	57	28.2	0.0	0.0	0.0
2	A1	16	445	24	0	32	50	28.2	14.6	0.1	0.1
2	A1	16	445	24	0	33	49	28.2	19.5	0.1	0.1
2	A1	22	561	38	0	42	48	37.6	19.4	0.1	0.1
2	A1	22	561	38	0	45	45	37.6	54.9	0.2	0.2
2	A1	25	596	35	0	43	50	39.2	14.1	0.1	0.1
2	A1	25	596	35	0	38	56	39.2	1.5	0.0	0.0
2	A1	53	375	5	0	36	38	20.8	232.2	0.9	0.4
2	A1	53	375	5	0	51	27	20.8	890.2	3.6	0.6
2	A1	57	520	17	0	54	35	31.6	500.6	2.0	0.4
2	A1	57	520	17	0	56	33	31.6	594.1	2.4	0.4
2	A1	57	520	17	0	57	33	31.6	633.7	2.6	0.4
2	A3	47	820	31	0	45	66	52.3	53.9	0.2	0.2
2	A3	47	820	31	0	49	60	52.3	11.2	0.0	0.1
2	A3	53	717	12	0	42	61	42.9	0.8	0.0	0.0
2	A3	53	717	12	0	50	52	42.9	50.6	0.2	0.1
2	A3	79	967	51	0	61	57	64.6	13.0	0.1	0.1
2	A3	88	343	10	0	25	49	19.6	28.9	0.1	0.2
2	A3	88	343	10	0	26	47	19.6	40.7	0.2	0.2
2	A3	97	536	4	0	34	57	30.5	12.4	0.1	0.1
2	A3	97	536	4	0	37	52	30.5	42.6	0.2	0.2

Set no	Road type	Section Name	Length(m)	Number of houses	No of important places	Travel Time(s)	speed(km/h)	*Fi*	MSE	RMSE	MAPE
2	A3	101	482	14	0	25	69	28.8	14.5	0.1	0.2
2	A3	101	482	14	0	30	58	28.8	1.4	0.0	0.0
2	A3	101	482	14	0	38	46	28.8	84.5	0.3	0.2
2	A3	132	676	33	0	52	47	43.8	66.5	0.3	0.2
2	A6	205	981	36	0	51	70	63.0	153.6	0.6	0.2
2	A6	205	981	36	0	59	59	63.0	12.9	0.1	0.1
									154.5	12.4	18%

APPENDIX D: Regression Model of One Side Residential Only

Figure D.1 – Histogram of Speed – Model 4

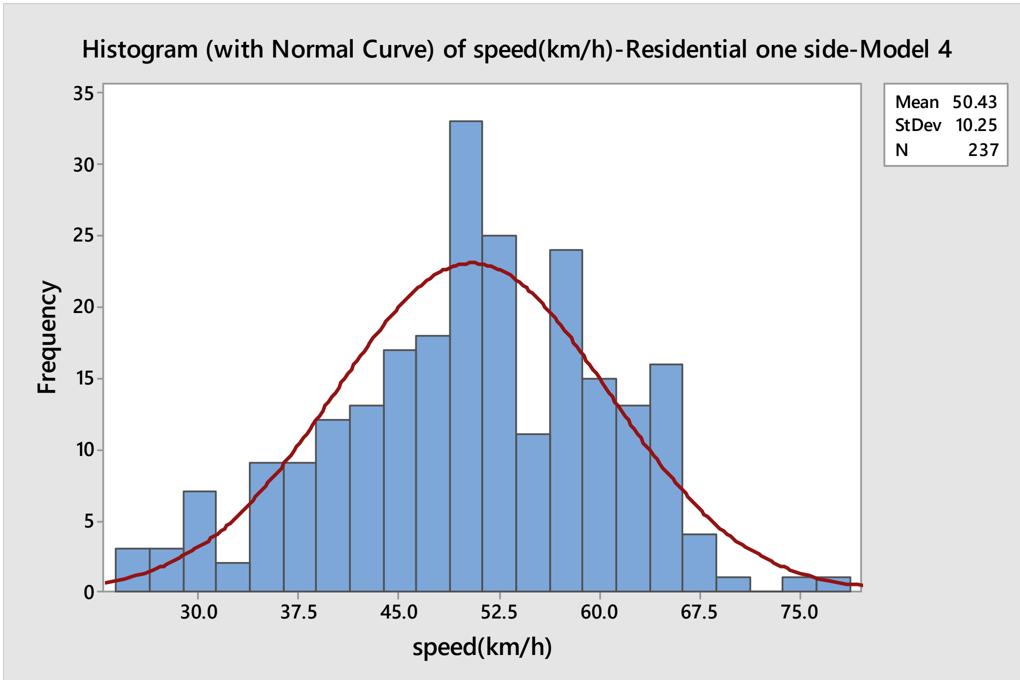

Table D.1 – Summary of Regression Analysis – Model 4

Regression Analysis: 4.2 Travel Time(s) versus Length(m):Model 5

```
Stepwise Selection of Terms

Candidate terms: Length(m)

             -----Step 1-----
                Coef        P
Constant       -2.04
Length(m)    0.07916    0.000

S                     9.89744
R-sq                   75.78%
R-sq(adj)              75.68%
R-sq(pred)             75.25%
Mallows' Cp              2.00

α to enter = 0.15, α to remove = 0.15


Analysis of Variance
```

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	1	72030	72030.4	735.31	0.000
Length(m)	1	72030	72030.4	735.31	0.000
Error	235	23020	98.0		
Lack-of-Fit	39	13042	334.4	6.57	0.000
Pure Error	196	9979	50.9		
Total	236	95051			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
9.89744	75.78%	75.68%	75.25%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-2.04	1.66	-1.23	0.220	
Length(m)	0.07916	0.00292	27.12	0.000	1.00

Regression Equation

TT (s)3 = -2.04 + 0.07916 Length(m)

Fits and Diagnostics for Unusual Observations

Obs	TT (s)3	Fit	Resid	Std Resid		
2	73.00	44.90	28.10	2.85	R	
3	73.60	44.90	28.70	2.91	R	
7	70.40	37.54	32.86	3.33	R	
20	74.00	43.43	30.57	3.10	R	
32	70.00	37.54	32.46	3.29	R	
33	61.00	37.54	23.46	2.38	R	
41	71.00	78.50	-7.50	-0.77		X
42	81.00	78.50	2.50	0.26		X
48	93.00	84.46	8.54	0.88		X
73	83.00	91.83	-8.83	-0.91		X
96	81.00	84.46	-3.46	-0.35		X
118	89.00	91.83	-2.83	-0.29		X
120	107.00	91.83	15.17	1.57		X
121	115.00	91.83	23.17	2.39	R	X
123	127.00	91.83	35.17	3.63	R	X
131	65.00	37.54	27.46	2.78	R	
132	65.00	37.54	27.46	2.78	R	
148	80.20	84.46	-4.26	-0.44		X
149	78.60	84.46	-5.86	-0.60		X
150	86.60	84.46	2.14	0.22		X
178	62.00	37.54	24.46	2.48	R	
188	62.00	78.50	-16.50	-1.69		X
189	72.00	78.50	-6.50	-0.67		X
194	83.40	54.30	29.10	2.95	R	
224	68.00	78.50	-10.50	-1.07		X
228	74.00	51.66	22.34	2.26	R	
231	76.00	84.46	-8.46	-0.87		X
232	113.00	84.46	28.54	2.93	R	X

R Large residual
X Unusual X

```
Durbin-Watson Statistic

Durbin-Watson Statistic =  1.42033
```

Figure D.2 – Randomness of Residuals – Model 4

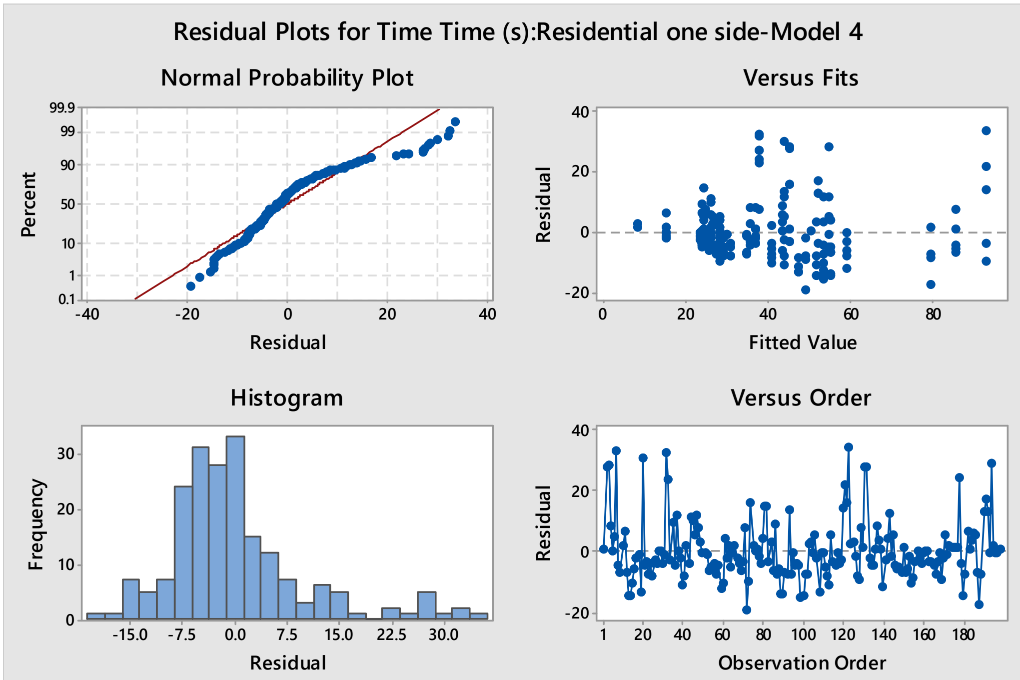

Table D.2 – Cross Validation Results – Model 4

TT(s) =Travel Time, Fi = Predicted value

set no	road type	Section _Name	Length(m)	Cultivation (m)	TT (s)3	speed(km/h)	*Fi*	MSE	RMSE	MAPE
4	A3	60	391	391	22	64.0	28.9	1230.3	25.6	0.5
4	A3	60	391	391	23	61.2	28.9	1042.8	21.7	0.5
4	A3	60	391	391	27	52.1	28.9	539.4	11.2	0.4
4	A3	52	696	696	43	58.3	53.1	27.2	0.6	0.1
4	A3	58	537	537	32	60.4	40.4	397.2	8.3	0.3
4	A3	58	537	537	37	52.2	40.4	138.6	2.9	0.2
4	A6	15	382	382	28	49.1	28.2	437.4	9.1	0.4
4	A6	15	382	382	26	52.9	28.2	609.8	12.7	0.5
4	A3	33	348	348	21	59.7	25.5	1166.5	24.3	0.6
4	A3	114	323	322	23	50.5	23.5	728.6	15.2	0.5
4	A3	24	221	220	15	53.0	15.4	1409.2	29.4	0.7
4	A3	24	221	220	15	53.0	15.4	1409.2	29.4	0.7

set no	road type	Section _Name	Length(m)	Cultivation (m)	TT (s)3	speed(km/h)	*Fi*	MSE	RMSE	MAPE
4	A3	113	326	326	20	58.7	23.8	1221.7	25.5	0.6
4	A3	113	326	326	20	58.7	23.8	1221.7	25.5	0.6
4	A3	61	416	416	26	57.6	30.9	712.7	14.8	0.5
4	A3	61	416	416	23	65.1	30.9	1169.9	24.4	0.5
4	A3	107	339	339	21	58.1	24.8	1110.6	23.1	0.6
4	A3	107	339	339	24	50.9	24.8	679.1	14.1	0.5
4	A6	154	643	642.6	40	57.8	48.8	81.1	1.7	0.2
4	A6	154	643	642.6	47	49.2	48.8	0.2	0.0	0.0
4	A6	64	363	363	32	40.9	26.7	200.2	4.2	0.3
4	A1	15	358	351	25	51.6	26.3	637.7	13.3	0.5
4	A1	15	358	351	28	46.0	26.3	389.2	8.1	0.4
4	A1	9	491	626	38	46.5	36.8	93.9	2.0	0.2
4	A1	9	491	626	37.8	46.8	36.8	98.7	2.1	0.2
4	A1	9	491	626	38	46.5	36.8	93.9	2.0	0.2
4	A1	19	332	322	25.2	47.4	24.2	537.7	11.2	0.5
4	A1	30	500	505	62	29.0	37.5	72.4	1.5	0.3
4	A6	11	472	471	31	54.8	35.3	379.4	7.9	0.4
4	A3	13	696	696	39	64.3	53.1	125.3	2.6	0.2
4	A3	13	696	696	46	54.5	53.1	2.0	0.0	0.0
4	A1	8	327	321	30	39.2	23.8	237.0	4.9	0.4
4	A6	38	570	570	44	46.6	43.1	12.6	0.3	0.1
4	A6	38	570	570	47	43.7	43.1	0.3	0.0	0.0
4	A6	38	570	570	49	41.9	43.1	1.4	0.0	0.0
4	A6	35	578	577.5	49	42.4	43.7	1.6	0.0	0.0
4	A6	41	462	293	27.6	60.2	34.5	661.7	13.8	0.4
4	A6	118	1018	606	62	59.1	78.5	377.3	7.9	0.3
4	A6	118	1018	606	72	50.9	78.5	763.4	15.9	0.5
4	A6	25	678	138	64.8	37.7	51.7	195.3	4.1	0.4
4	A6	25	678	138	69	35.4	51.7	264.6	5.5	0.5
4	A6	25	678	138	65	37.6	51.7	198.5	4.1	0.4
4	A6	17	712	711.7	54	47.4	54.3	46.9	1.0	0.1
4	A6	17	712	711.7	83.4	30.7	54.3	555.9	11.6	0.8
4	A3	3	135		10	48.7	8.7	1603.4	33.4	0.8
4	A3	4	403		29	50.0	29.9	406.5	8.5	0.4
4	A3	4	403		29	50.0	29.9	406.5	8.5	0.4
4	A3	5	657		51	46.3	49.9	12.9	0.3	0.1
								494	22	37%

APPENDIX E: Regression Model of Cultivation

Figure E.1 – Histogram of Speed – Model 5

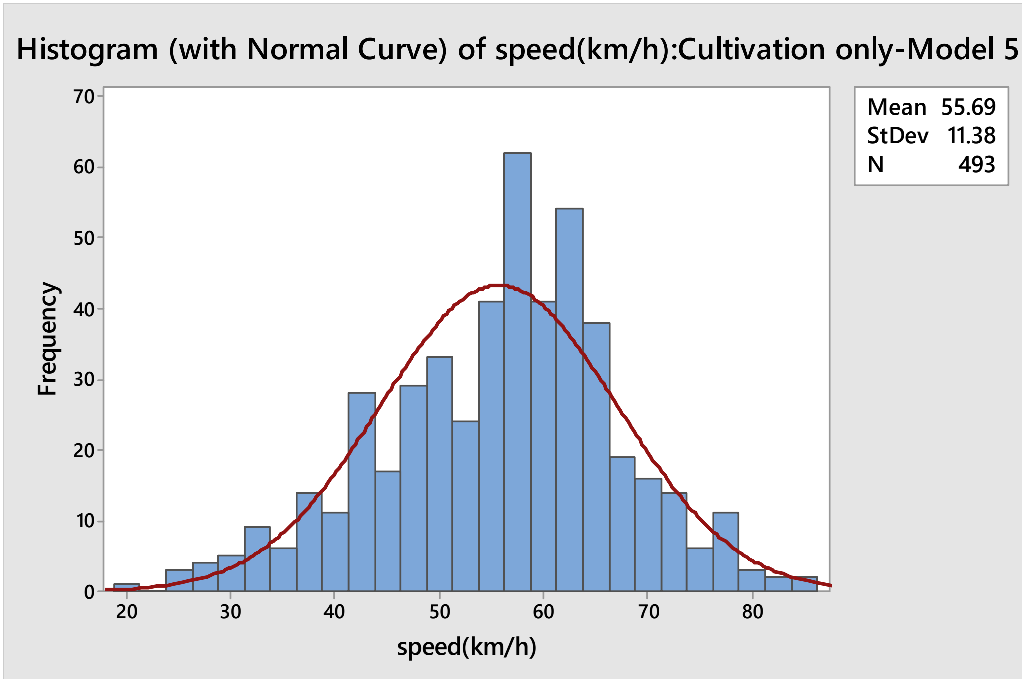

Table E.1 – Summary of Regression Analysis – Model 5

Regression Analysis: TT (s)3 versus Length(m)

```
Stepwise Selection of Terms

Candidate terms: Length(m)

             -----Step 1-----
                Coef        P
Constant       7.569
Length(m)     0.05221    0.000

S                     8.26745
R-sq                   80.17%
R-sq(adj)              80.13%
R-sq(pred)             80.01%
Mallows’ Cp              2.00

α to enter = 0.05, α to remove = 0.05


Analysis of Variance

Source          DF  Adj SS  Adj MS  F-Value  P-Value
Regression       1  135655  135655  1984.69    0.000
```

Length(m)	1	135655	135655	1984.69	0.000
Error	491	33560	68		
Lack-of-Fit	112	17834	159	3.84	0.000
Pure Error	379	15726	41		
Total	492	169215			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
8.26745	80.17%	80.13%	80.01%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	7.569	0.812	9.33	0.000	
Length(m)	0.05221	0.00117	44.55	0.000	1.00

Regression Equation

TT (s)3 = 7.569 + 0.05221 Length(m)

Fits and Diagnostics for Unusual Observations

Obs	TT (s)3	Fit	Resid	Std Resid	
36	41.200	24.016	17.184	2.08	R
46	48.000	30.438	17.562	2.13	R
74	60.000	42.279	17.721	2.15	R
77	62.000	45.232	16.768	2.03	R
80	75.000	45.526	29.474	3.57	R
81	64.000	45.950	18.050	2.19	R
107	78.800	62.072	16.728	2.03	R
110	44.800	62.223	-17.423	-2.11	R
145	40.000	19.840	20.160	2.44	R
178	53.000	32.213	20.787	2.52	R
195	57.000	39.559	17.441	2.11	R
200	70.000	45.135	24.865	3.01	R
239	46.000	65.027	-19.027	-2.31	R
270	37.200	20.664	16.536	2.00	R
302	64.000	32.213	31.787	3.85	R
319	61.000	40.086	20.914	2.53	R
342	70.000	50.158	19.842	2.40	R
358	91.000	61.581	29.419	3.57	R
418	48.400	30.438	17.962	2.18	R
444	83.000	41.873	41.127	4.98	R
447	62.000	42.279	19.721	2.39	R
452	65.000	42.754	22.246	2.69	R
455	71.000	45.396	25.604	3.10	R
466	74.000	52.303	21.697	2.63	R
475	89.000	55.222	33.778	4.09	R
493	56.000	75.020	-19.020	-2.31	R

R Large residual

Durbin-Watson Statistic

Durbin-Watson Statistic = 1.76109

Figure E.2 – Cross Validation – Model 5

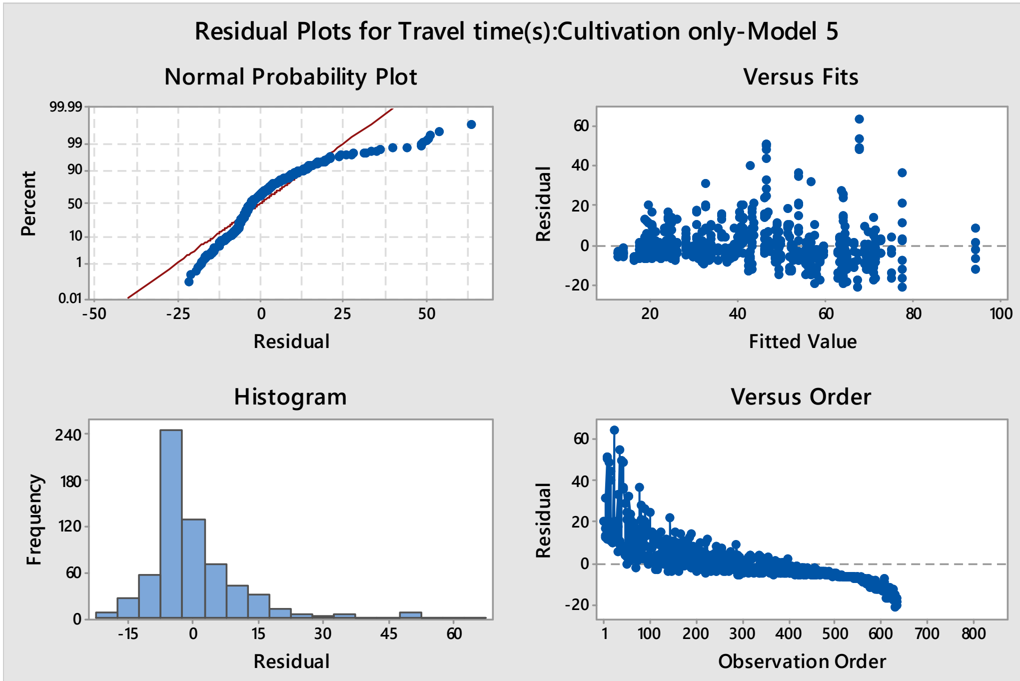

Table E.2 – Randomness of Residuals – Model 5

TT(s) =Travel Time, Fi = Predicted value

Set no	Road type	Section _Name	Length(m)	Cultivation (m)	TT (s)3	speed(km/h)	*Fi*	MSE	RMSE	MAPE
5	A6	13	131	261	13	36	14.4	473.3	3.9	0.6
5	A6	13	131	261	10	47	14.4	1062.6	8.9	0.7
5	A6	13	131	261	9	52	14.4	1430.2	11.9	0.7
5	A6	13	131	261	8	59	14.4	1966.3	16.4	0.8
5	A3	126	199	398	19	38	18.0	390.5	3.3	0.5
5	A3	155	223	223	20	40	19.2	439.8	3.7	0.5
5	A6	75	223	446	17	47	19.2	788.2	6.6	0.6
5	A6	75	223	446	13.6	59	19.2	1592.2	13.3	0.7
5	A6	42	225	451	22	37	19.3	307.9	2.6	0.5
5	A6	42	225	451	19	43	19.3	546.2	4.6	0.5
5	A3	156	235	470	31	27	19.8	55.6	0.5	0.3
5	A3	133	252	503	19	48	20.7	727.0	6.1	0.6
5	A6	26	264	528	22	43	21.4	479.3	4.0	0.5
5	A1	10	266	209	21	46	21.5	582.9	4.9	0.5

Set no	Road type	Section _Name	Length(m)	Cultivation (m)	TT (s)3	speed(km/h)	*Fi*	MSE	RMSE	MAPE
5	A1	7	270	540	16	61	21.7	1527.6	12.7	0.6
5	A3	104	277	189	20	50	22.0	771.3	6.4	0.6
5	A3	27	284	284	16	64	22.4	1725.9	14.4	0.6
5	A3	42	288	577	18	58	22.6	1228.3	10.2	0.6
5	A3	42	288	577	16	65	22.6	1785.5	14.9	0.7
5	A3	46	292	373	19	55	22.8	1055.3	8.8	0.6
5	A3	46	292	373	17	62	22.8	1520.2	12.7	0.6
5	A6	116	300	599	20	54	23.2	944.3	7.9	0.6
5	A6	116	300	599	19.8	54	23.2	978.1	8.2	0.6
5	A1	55	315	630	41	28	24.0	13.3	0.1	0.1
5	A3	117	324	649	35	33	24.5	78.4	0.7	0.3
5	A6	267	328	656	32	37	24.7	148.8	1.2	0.3
5	A3	23	328	657	23	51	24.7	711.4	5.9	0.5
5	A3	23	328	657	18	66	24.7	1676.4	14.0	0.6
5	A3	72	330	660	20	59	24.8	1199.0	10.0	0.6
5	A3	72	330	660	20	59	24.8	1199.0	10.0	0.6
5	A6	82	349	698	19	66	25.8	1623.7	13.5	0.6
5	A6	73	389	778	23.2	60	27.9	1053.2	8.8	0.5
5	A1	21	392	423	27.4	52	28.0	550.8	4.6	0.5
5	A3	28	419	839	25	60	29.5	956.5	8.0	0.5
5	A3	30	421	638	27	56	29.6	708.2	5.9	0.5
5	A3	30	421	638	24	63	29.6	1131.3	9.4	0.5
5	A1	52	438	763	34	46	30.4	254.1	2.1	0.3
5	A3	50	446	891	25	64	30.8	1111.9	9.3	0.5
5	A6	252	456	913	33.6	49	31.4	306.1	2.6	0.4
5	A6	252	456	913	31	53	31.4	466.4	3.9	0.4
5	A1	54	472	944	52	33	32.2	0.2	0.0	0.0
5	A3	75	488	976	28	63	33.0	881.7	7.3	0.5
5	A3	75	488	976	26	68	33.0	1191.7	9.9	0.5
5	A3	49	493	985	37	48	33.3	214.3	1.8	0.3
5	A3	44	493	987	32	56	33.3	492.1	4.1	0.4
5	A3	100	524	524	34	55	34.9	421.8	3.5	0.4
5	A3	26	556	1113	33	61	36.6	579.6	4.8	0.4
5	A3	26	556	1113	31	65	36.6	783.5	6.5	0.4
5	A3	51	580	1159	32	65	37.8	749.9	6.2	0.4
5	A3	31	590	590	35	61	38.4	498.7	4.2	0.4
5	A3	109	610	899	39	56	39.4	284.6	2.4	0.3
5	A6	100	613	1064	54	41	39.6	1.7	0.0	0.0
5	A6	22	623	623	50.2	45	40.1	21.0	0.2	0.1
5	A6	22	623	623	44.6	50	40.1	103.7	0.9	0.2
5	A6	121	628	1257	42.8	53	40.4	155.7	1.3	0.2

Set no	Road type	Section _Name	Length(m)	Cultivation (m)	TT (s)3	speed(km/h)	*Fi*	MSE	RMSE	MAPE
5	A6	121	628	1257	37	61	40.4	431.1	3.6	0.3
5	A3	38	657	891	46	51	41.9	91.2	0.8	0.2
5	A3	38	657	891	37	64	41.9	486.4	4.1	0.3
5	A6	34	665	1147	57.6	42	42.3	0.5	0.0	0.0
5	A6	140	666	1022	49	49	42.3	43.5	0.4	0.1
5	A6	104	674	1348	48.8	50	42.8	48.5	0.4	0.1
5	A6	108	720	1032	60	43	45.1	3.9	0.0	0.0
5	A3	67	721	1443	46	56	45.2	126.0	1.0	0.2
5	A3	56	739	716	44	60	46.2	205.1	1.7	0.2
5	A3	74	768	1536	52	53	47.7	30.3	0.3	0.1
5	A3	74	768	1536	48	58	47.7	98.8	0.8	0.2
5	A6	168	768	975	60	46	47.7	2.5	0.0	0.0
5	A6	176	777	1554	34.2	82	48.1	1132.9	9.4	0.4
5	A3	41	783	1567	43	66	48.5	293.0	2.4	0.3
5	A6	101	816	1631	62	47	50.2	7.8	0.1	0.1
5	A6	152	824	1648	41	72	50.6	473.9	3.9	0.3
5	A6	152	824	1648	38.6	77	50.6	690.0	5.8	0.3
5	A6	151	830	1659	51	59	50.9	58.9	0.5	0.1
5	A6	151	830	1659	40	75	50.9	565.6	4.7	0.3
5	A3	62	833	1125	46	65	51.1	199.7	1.7	0.2
5	A6	3	857	1293	74.8	41	52.3	122.5	1.0	0.3
5	A3	39	859	1718	49	63	52.4	114.4	1.0	0.2
5	A6	150	892	1783	53.2	60	54.1	38.6	0.3	0.1
5	A6	150	892	1783	49	66	54.1	129.6	1.1	0.2
5	A6	169	895	1790	51.6	62	54.3	66.4	0.6	0.1
5	A6	169	895	1790	51	63	54.3	78.9	0.7	0.1
5	A6	199	901	1801	46	70	54.6	252.7	2.1	0.2
5	A6	175	911	1822	50.2	65	55.1	104.0	0.9	0.2
5	A6	149	912	1611	55	60	55.2	20.4	0.2	0.1
5	A6	149	912	1611	54	61	55.2	31.6	0.3	0.1
5	A6	149	912	1611	45.2	73	55.2	305.0	2.5	0.2
5	A6	197	913	1825	46.2	71	55.2	252.8	2.1	0.2
5	A6	197	913	1825	45	73	55.2	316.7	2.6	0.2
5	A6	274	922	922	68	49	55.7	47.5	0.4	0.1
5	A6	196	946	1892	50.8	67	57.0	101.7	0.8	0.2
5	A6	196	946	1892	50.2	68	57.0	118.5	1.0	0.2
5	A6	196	946	1892	41	83	57.0	681.8	5.7	0.3
5	A6	173	1023	2047	48.6	76	61.0	219.2	1.8	0.2
5	A6	239	1031	1540	67	55	61.4	36.0	0.3	0.1
5	A6	171	1035	2069	59	63	61.6	2.4	0.0	0.0
5	A6	171	1035	2069	51	73	61.6	130.9	1.1	0.2

Set no	Road type	Section _Name	Length(m)	Cultivation (m)	TT (s)3	speed(km/h)	*Fi*	MSE	RMSE	MAPE
5	A6	178	1043	2086	54	70	62.0	56.4	0.5	0.1
5	A6	178	1043	2086	48	78	62.0	262.6	2.2	0.2
5	A6	186	1047	2094	67	56	62.2	35.7	0.3	0.1
5	A6	186	1047	2094	59	64	62.2	2.7	0.0	0.0
5	A6	253	1055	2110	67	57	62.6	35.6	0.3	0.1
5	A6	253	1055	2110	62.2	61	62.6	2.5	0.0	0.0
5	A6	177	1058	2115	66	58	62.8	26.0	0.2	0.1
5	A6	177	1058	2115	66	58	62.8	26.0	0.2	0.1
5	A6	254	1091	2181	67	59	64.5	34.9	0.3	0.1
5	A6	248	1140	2280	56.8	72	67.1	26.7	0.2	0.1
5	A6	249	1152	2304	57.4	72	67.7	20.6	0.2	0.1
5	A6	172	1170	2339	64	66	68.6	8.1	0.1	0.0
5	A6	172	1170	2339	53	79	68.6	116.9	1.0	0.1
5	A6	214	1176	2352	74	57	69.0	138.2	1.2	0.2
5	A6	170	1179	2358	79	54	69.1	237.1	2.0	0.3
5	A6	170	1179	2358	68.6	62	69.1	52.6	0.4	0.1
5	A6	250	1198	2396	75	57	70.1	159.1	1.3	0.2
5	A6	250	1198	2396	68.6	63	70.1	52.5	0.4	0.1
6	A1	10	266	209	28	34	21.5	162.4	1.4	0.4
6	A1	7	270	540	19	51	21.7	869.8	7.2	0.6
6	A1	55	315	630	38.4	30	24.0	30.4	0.3	0.2
6	A1	21	392	423	30	47	28.0	361.2	3.0	0.4
6	A1	52	438	763	41	38	30.4	64.3	0.5	0.2
6	A1	54	472	944	52	33	32.2	0.2	0.0	0.0
								440.7565	20.9942	31%