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Modeling Traffic Flow Along Four-Lane Dual Carriageway Roads in Kandy

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Abstract: In this study, a comparative study has been carried out separately to find suitability of different methods such as pneumatic tube detector, moving observer, manual classified vehicle count and video capturing method, depending on this existing roadway conditions. After that video capturing method was selected and the data thus obtained were used to develop traffic flow models along four lane dual carriageway roads in Kandy. Traffic flow measurements were obtained directly from the extracted data. Traffic speeds were calculated by considering journey time of each vehicle. For the density measurement, input output method was used. The scatter plots of data measured fit to five different models; Greenshields, Linear two regimes, Eddie, Greenberg and Underwood model. Greenshields model gave the highest R^2 value among them. For the validation purposes residual analysis was done for each model using Minitab software.

Keywords: traffic flow modeling, four lane dual carriageway

1. INTRODUCTION

The fundamentals of traffic flow and their characteristics have become more important and form the foundation for all theories, techniques and procedures that are being applied in the design, operation and development of road transportation system. The three most important characteristics of traffic are flow, speed and density. These characteristics can be observed and studied at microscopic level and macroscopic level. This study it has been done at macroscopic level. Flow is the number of vehicles passing a point on a road during stated period of time. Measurement of speed requires observation over both time and space. There are two methods of calculating average traffic stream speed: a time mean speed and a space mean speed. The space-mean speed reflects the average speed over a spatial section of roadway, while the time-mean speed reflects the average speed of the traffic passing a specified point over a specified time. In this study space mean speed has been calculated. Traffic density is the number of vehicles occupying unit length of a roadway at instant of time. There are lots of methods to calculate traffic density. In this study, it has been calculated using input-output method. When considering the road conditions, in this study it is restricted to four-lane dual carriage way roads in Kandy. This type of roads consists of four lanes (two lanes per each direction) and they are divided by a central reservation. Even though relatively high speeds can be observed in four-lane dual carriageway roads, they are much safer when compare with two-lane dual carriageway roads. Head-on collisions, slide swipe collisions are less in four-lane dual carriageway roads because of the central reservation. In this study,

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traffic flow along two four-lane dual carriage way roads in Kandy has been modeled using above three traffic characteristics. The two dual carriage way roads considered are Gannoruwa road and William Gopallawa Mawatha. Both of them are urban artirial roads connecting western with central of Sri Lanka. Gannoruwa road is connected to a class A road and it is a B class road. William Gopallawa Mawatha is a class AB road and it is in a level terrain. Traffic flow data along these roads has been collected using video capturing method and has been analyzed separately to observe the traffic flow-speed-density relationships.

2. LITERATURE REVIEW

2.1 Introduction

Traffic congestion is a recognized problem by the researchers that affecting the quality of life of people. Because of the major impact of the traffic congestion to economic growth researches have doing lot of study to reduce traffic congestion. There are many researches available in traffic flow modeling. But only several of them had been carried out for mixed traffic condition. Mixed traffic condition consists of different kinds of vehicle categories. For an example car, vans, buses, trucks, three wheelers, motor bicycles and etc. Since Sri Lanka also has a mixed traffic condition, focus of this section goes to the literatures connected to mixed traffic condition. Traffic flow models can be used to simulate traffic. For an example: to evaluate a new part of the infrastructure traffic flow models can be used. And also traffic flow models can be used to improve road safety. There are many ways to categorize traffic flow models. But most common method of classification is the distinction between microscopic and macroscopic traffic flow modeling approach. In this study traffic flow modeling will be done at macroscopic level.

2.2 Traffic Flow and Speed Measurement

There are a lot of methods available to collect traffic data. But when it comes to heterogeneous traffic, automated methods seem to be more suitable. In most of the time video capturing method has been utilized. Sharma et.al (2011) has used video capturing method. In their study, they had considered the heterogeneous mix vehicles along on an undivided two-lane road facility. This study of traffic had not influenced by any nearby intersections or road geometry (Gradient). Therefore, this traffic is considered as an uninterrupted flow of traffic. Also, verbal recordings of vehicle categories and license plate number were done. Also, certain key features were noted down so that identification of vehicle could be done. But some researches have used software to do that. Mallikarjuna and Ramachandra (2010) have used this method to collect traffic flow data under heterogeneous conditions. They have used video data to extract speed, flow, density, lateral gap and several other parameters. There can be many other lateral movements but, in this study, it is restricted to five movements. Also, they have used software named TRAZER to track vehicles and get their trajectory data over a road length of 50m. This software is capable of classifying the vehicles and to capture the lateral movement of vehicles. Traffic speed had been obtained using the trajectory data. Also Mallikarjuna et.al (2009) has used the same method to collect traffic data under mixed traffic conditions. In their study same software had been used. The velocities and acceleration values has been obtained by performing first and second order differentiation on trajectory equations. In their study they have proved that TRAZER is capable of detecting vehicles with an average accuracy of 95% and classifying with an average accuracy of 85%. Using the software for traffic flow detection is seems to be easy and more useful in gathering other information too. But Sharma et.al (2011) had used FMV6 (full motion video) player for video data extraction. This software is capable of fragmenting the video into frames and uses that to obtain frame readings when traffic vehicle just crosses the reference point. Ranthatiyawa et.al (2017) has also utilized video capturing method. But that study roads selected were residential roads. They have used the video data to traffic flow counting. They have manually counted the traffic flow using the videos. For their study not using software is okay since they only need the traffic flow.

Other than video capturing method loop detector method was also been used to collect traffic data. Stathopoulos and Karlaftis (2001) have used loop detector method. Speeds and travel times along selected routes have been obtained using flow and occupancy data collected from the loop detectors. They have used these data to develop ITS (intelligent transportation system). For that six origin points had been defined at the major city entrances, from which a total of 17 possible routes had been considered. Traffic data along these 17 routes had been collected directly from the controllers installed at 144 locations of the down-town urban network. Also Hueper et.al (n. d) has used traffic flow and occupancy data from loop detectors. They have used the collected data to calibrate their model. In their study, they had considered the California freeway. Also, they have used PeMS database to achieve traffic measurements like occupancy, flow, speed, delay, vehicle hours traveled and productivity loss etc. Only direct measurements taken from the loop detectors are the number of cars which cross a detector station and the fraction of time a vehicle is present over the loop. These researches used loop detector method because in their contest it was easy way. Because in their countries loop detector systems were already existed along the road they have considered. But other researches have used video method because they didn’t have that facility. And also, for a mixed traffic condition it is a very effective method. Therefore, choosing video capturing method seemed to be a wise choice. Since Sri Lanka also hasn’t that kind facility video capturing method seems to be wise and cheap.

2.3 Density Measurement

Traffic density measurements have a significant value when it comes to overcoming traffic problems. There are a lot of methods available to measure traffic density. Most of the methods now a day’s using are automated methods. Several researches have used image processing method collect traffic density data (Walid et.al (2015)). They had used cameras which were fixed and capturing the images continuously. They had divided the video into frames and each frame was processed to identify the vehicles. This system seemed to be cost effective, flexible and reliable. In their study, two methods considered for object detection. Firstly, using MATLAB tools and they had got 96-97% accuracy. Next one was using SVM classifier and they had got 80-90% accuracy. Since accuracy of object detection effect, the density data, proper method should be used in image processing. But Sobky and Mousa (2012) has used moving observer method to collect traffic density data. There are two cars involve in this. First car travel along the traffic in front while the second one travels behind the traffic. In the second car there’s surveyor who counts the vehicles in the traffic & record them. Distance between two cars is taken by using GPS. Using these data density is calculated. Another common method was using the area occupancy term. Mallikarjuna et.al (2009) has obtained density data using area occupancy term. Area occupancy means that how long a particular size of a vehicle is moving on that section of the road. It gives an average density value over the road section area considered. Here the absolute width of the road is considered irrespective of number of lanes. This term is also considering the size of the vehicle. Since area of a vehicle affect the density value for a mixed traffic condition area occupancy method seems to be suitable.

After considering these methods, a comparative study was carried out using pneumatic tube detector method, manual vehicle classified method, moving observer method and video capturing method with the aid of RDA. It has been found out that video capturing method was more suitable for this study since in this study, data extraction has been done manually from the videos collected. Therefore, accuracy of the data collected is much higher than any other methods. For more details please refer Lowe et.al (2018). When using video capturing method there were few things to be considered. The recordings were synchronized so that extraction errors due to time lag are avoided. Also, it was done in normal days which were free of any special activities in the area. The attention has been paid to the camera angle as well. Since it was necessary to identify the vehicle registration plate number. The camera mounting locations were also important. Sharma et.al (2011) had considered a 500m long road stretch for their study. But Mallikarjuna and Ramachandra (2010) had considered only 50m long road stretch. It varies according to the traffic condition. If the vehicle speeds are relatively high selecting long road stretch will be wise because otherwise it will affect the accuracy of speed measurements. Special attention has been paid to the mentioned feature to achieve successful traffic flow video recordings.

3. METHODOLOGY

3.1 Site Selection

Firstly, suitable sites have been selected. Few major attentions have been paid when selecting the sites. First one was to avoid any junctions along the road section. Also, suitable lengths for the road sections have been selected to get accurate data. And also, the road stretches have been selected such that they don't consist central opening, pedestrian crossings and bus stops. The tube detector installation locations were selected such that it's in the middle of the road stretch. The video cameras mounting places were selected such that they had the capability to capture the vehicle registration number clearly. In Gannoruwa road, stretch of 200 m is selected and in William Gopallawa Mawatha, road stretch is 264 m.

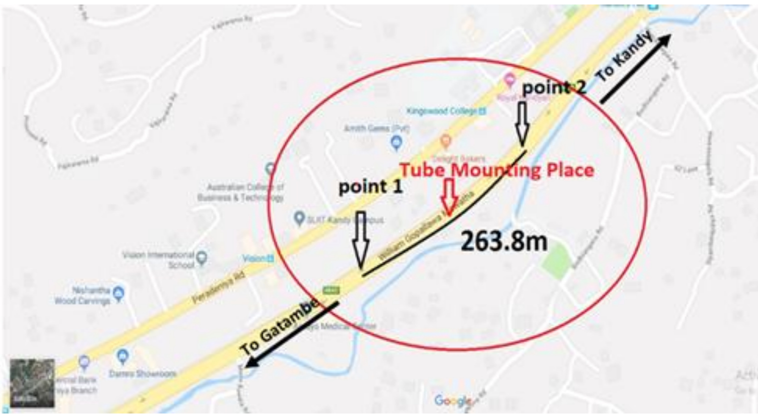

Figure 3.1: Survey locations of William Gopallawa Mawatha

3.2 Equipment Selection

Firstly, Equipment should be selected so that it is capable of capturing vehicle number plates clearly. Then the Optimum video quality should be selected giving considerations to the frame rates, storage and power consumption. The selected equipment was smart camera phone.

3.3 Field Data Collection

As the method of collecting data, video capturing method had been selected. Four cameras have been used per one direction which has been synchronized earlier. That's because to get the speed measurement travel time of each vehicle is required and to do so each vehicle should be identified when it's entering to the road stretch and when it's leaving. Two of them have been mounted at the middle barrier of road capturing the inner lane flow and the other two have been mounted at outer side of the road capturing the outer lane road. Video data have been collected one direction at a time for two roads in two different times. The cameras have been focused on the front sides of the vehicles. The distance between two camera locations and widths of the road sections have been measured using surveyor's wheel. A reference line was marked 5m away from the camera mounted place so that when a vehicle reaches the reference line data extraction can be done.

Figure 3.2: Mounted camera in Gannoruwa Road

3.4 Data Extraction

The collected data have been extracted manually. The extracted data such as vehicle registration plate number, time stamp and vehicle type when vehicle reaches the reference line, were directly fed into a computer database (Excel sheets). Vehicle type was recorded according to the RDA classification which is shown in Table 3.1. Figure 3.2 illustrates the data extracted.

Table 3.1. RDA Vehicle Classification

Type of vehicle	class	Description
Motor cycle	MCL	All type of motor cycles and scooters
Three wheelers	TW	All type of three wheelers
Car	CAR	All type of cars, Jeeps, cabs, dual cabs, micro van and van with three rows of seats
Van	VAN	Van with seats more than three rows
Buses	MBUS	Buses with lower 26 seats
	LBU	Buses with more than 26 seats
Light goods vehicle	LGV	Small lorries with 2 axels and 4 tyres
Medium goods vehicle	MG1	Small lorries with 2 axel and 6 tyres
	MG2	Large lorries with 2 axel and 6 tyres
High goods vehicles	HG3	Large lorries with 1 chacy with 3 axel
Articulated Vehicle	AG3	3 axels with tailor
	AG4	4 axels with tailor
	AG5	5 axels with tailor
	AG6	6 axels with tailor
Farm Vehicle	FVH	Tractor with 4 tyres with tailor, Tractor with 2 tyres with tailor

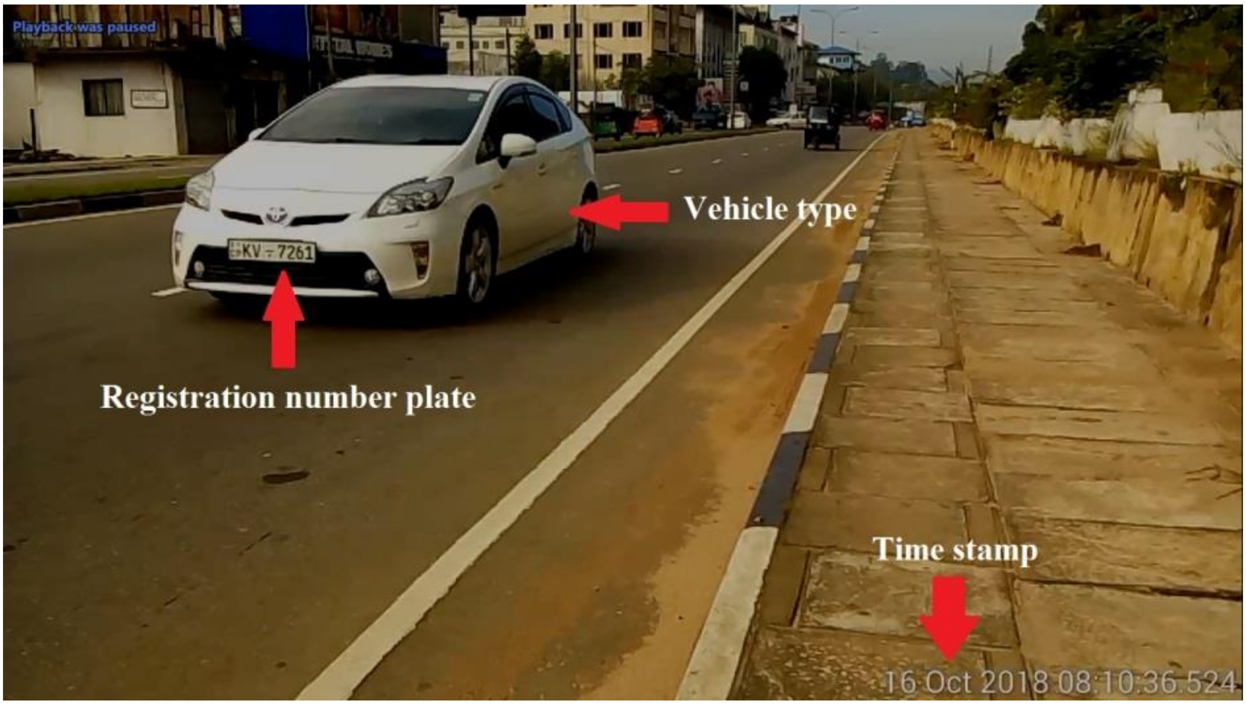

Figure 3.3: Screen shot of a sample video

3.4 Data Analysis

The objective of the project is to establish traffic flow-speed-density relationships. Traffic flow has been manually counted using collected videos. Since the extracted data recording was done according to RDA vehicle classification system, flow was directly taken from the extracted data. To divide flow into 5 minutes interval pre-developed Excel code was used. For the density measurements input-output method was utilized. Using the same code mentioned earlier was used to achieve cumulative traffic flow. Using the cumulative flow density was calculated as shown below. Equation (1) has been used for the calculations. Then traffic flow and density data have been converted to passenger car units. Passenger car units were obtained from RDA.

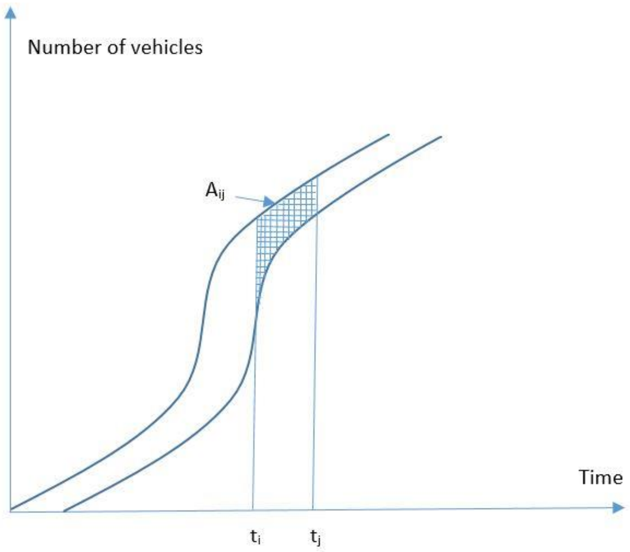

Figure 3.4: Cumulative traffic flow with time

$$k = \frac{A_{ij}}{L(t_i - t_j)} \quad (1)$$

where,

A_{ij} : Area

$t_i - t_j$: Time difference

L : Length of the road section

Speeds of each vehicle have been calculated using time measurement extracted from the videos and length between the specified points.

$$V = \frac{L}{t_1 - t_2} \quad (2)$$

where,

V : Speed of the vehicle

$t_1 - t_2$: Time difference

L : Length of the road section

4. RESULTS AND DISCUSSION

4.1 Comparative Study

A comparative study has been carried out separately to find out the suitability of different methods as applied for four lane dual carriage way roads. Several methods have been used here including moving observer method, manual classified vehicle count method, pneumatic tube detector method and video capturing method. Traffic flow and speed measurements data have been compared. So, in conclusion several facts have been identified. First one is that Manual counting method seems more accurate than the tube detectors because it shows different results when it comes congestion condition which means that tube detectors could underestimate the traffic flow during congested period. Also, for a short road stretch moving observer method seems not suitable because then it always underestimates the speed and it underestimate flow during peak condition while overestimate the flow during off-peak conditions. Most importantly it has been identified that video capturing method is much accurate than other methods since data extraction was done manually. Therefore, to develop the model video data have been used in this study.

4.2 Model Development

To develop the mathematical description between flow-speed-density measurements, they were plotted first using Microsoft Excel. Scatter plots have been made considering speed-density measurements. After plotting the flow-speed-density measurement data best fit line was observed and through that mathematical descriptions were obtained. These graphs are plotted according to five different models to obtain five different mathematical models. They are,

- Greensheild hypothesis
- Two regime hypothesis (Linear)
- Eddie hypothesis
- Greenberg hypothesis
- Underwood hypothesis

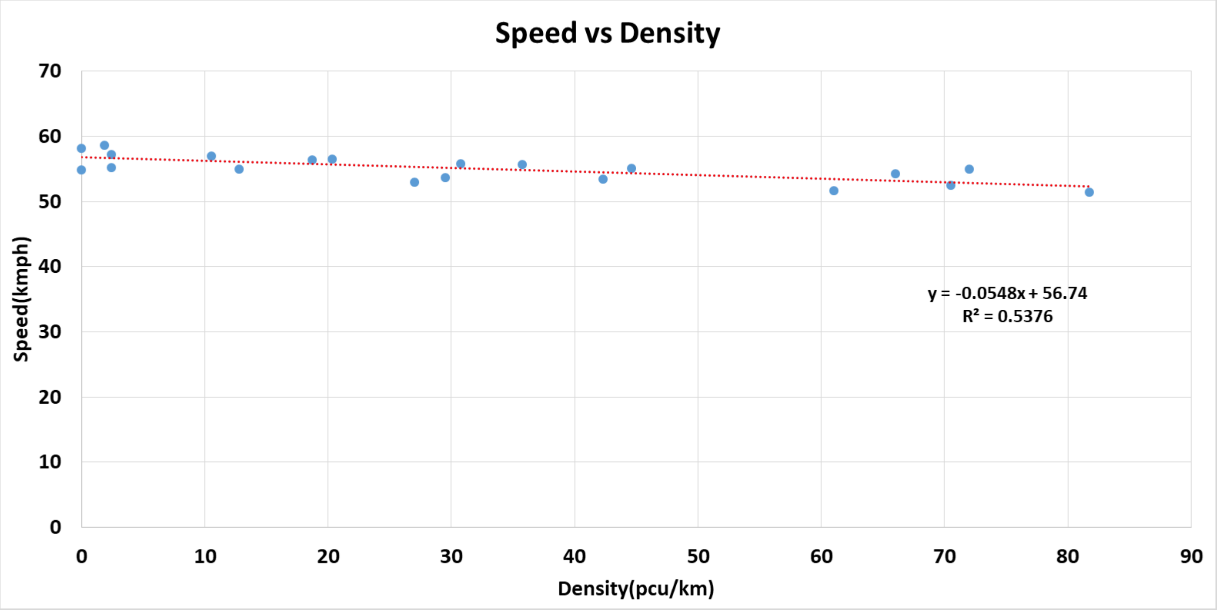

Figure 4.1: Speed-density model (Greensheilds)

Figure 4.1 shows the graphical description between traffic speed and density measurements in William Gopallawa mawatha in city bound direction. It has been drawn according to Greensheilds model which is the simplest mathematical model to represent the relationship between speed and density. It shows a linear relationship between speed and density. The mathematical equation observed from the plot is shown below. *v* and *k* represent speed and density respectively

$$v = -0.054k + 56.74 \quad (3)$$

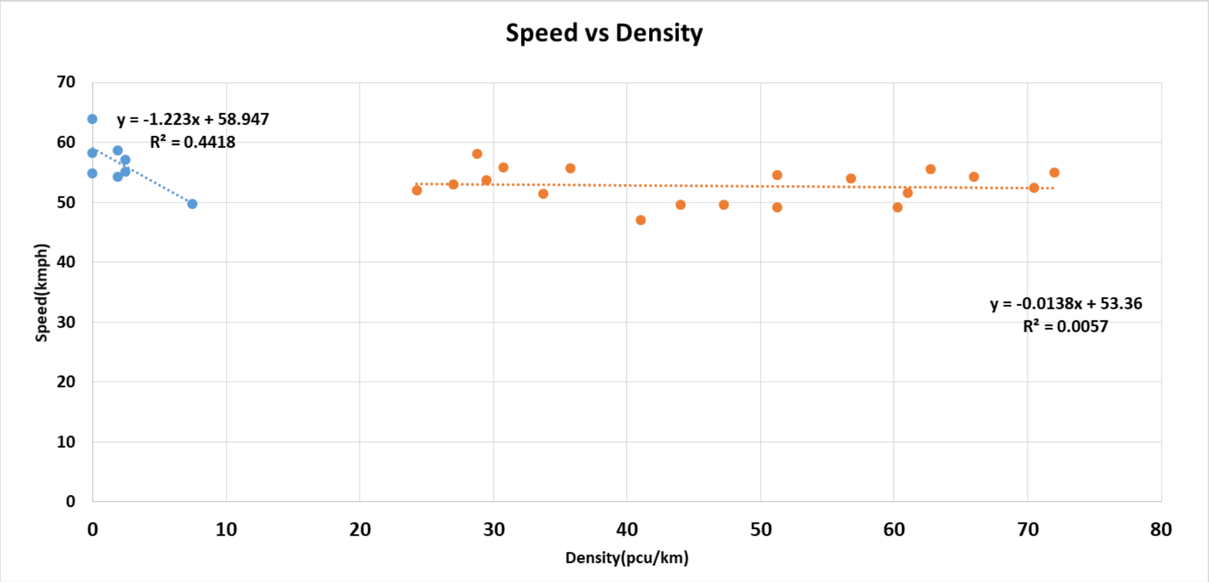

Figure 4.2: Speed-density model (Linear two regime)

Second mathematical model considered is linear two regime hypotheses. Figure 4.2 has been developed under this. This is also plotted considering sped-density measurements along William Gopallawa mawatha in city bound direction. This model is also similar to first model, the difference is having two regimes. *v* and *k* represent speed and density respectively. This is a discontinuous model. Therefore, there are two regimes representing the relationship.

$$v = -1.223k + 58.94 \quad (4)$$

$$v = -0.0138k + 53.36 \quad (5)$$

The third mathematical model considered is the Eddie hypothesis. Figure 4.3 shows the graph developed according to Eddie hypothesis. Similar to other plots this also represent the speed-density relationship along William Gopallawa mawatha in city bound direction. Eddie hypothesis also have two regimes. But unlike linear two regime model, in Eddies' two regime shows different relationships. One regime shows an exponential relationship between speed and density while the other regime shows a logarithm relationship.

$$v = 56.7e^{-0.014k} \quad (6)$$

$$v = -0.415\ln(x) + 54.393 \quad (7)$$

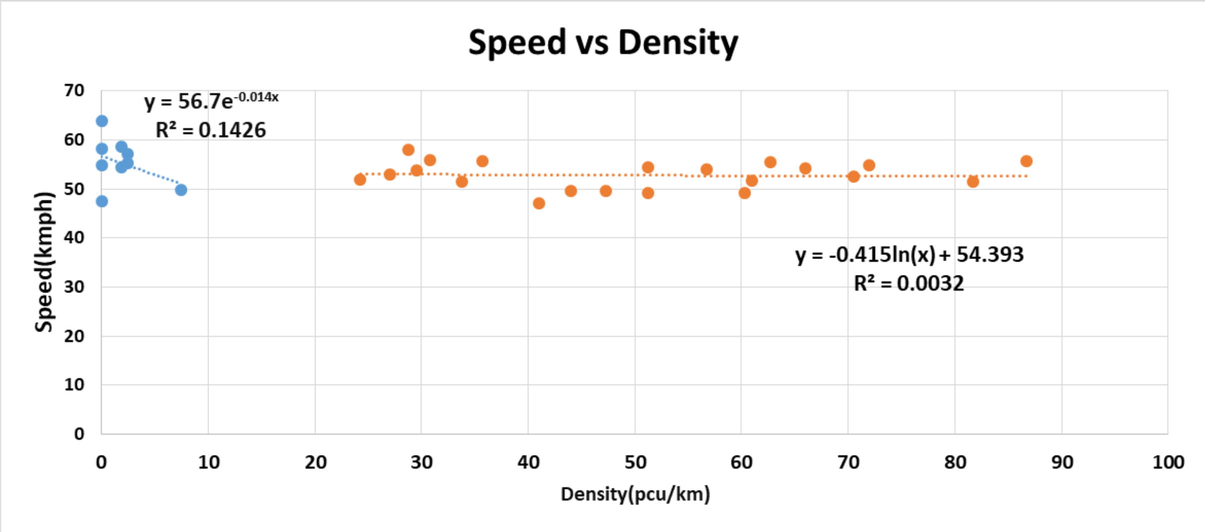

Figure 4.3: Speed-density model (Eddie)

The fourth mathematical model considered is the Greenberg hypothesis. Figure 4.4 shows the graphical representation. It's one regime model. Similar to others this is also developed considering speed-density measurements along William Gopallawa mawatha in city bound direction. This model shows logarithm relationship between speed and density measurements. Equation obtained is shown below. *v* and *k* represent speed and density respectively.

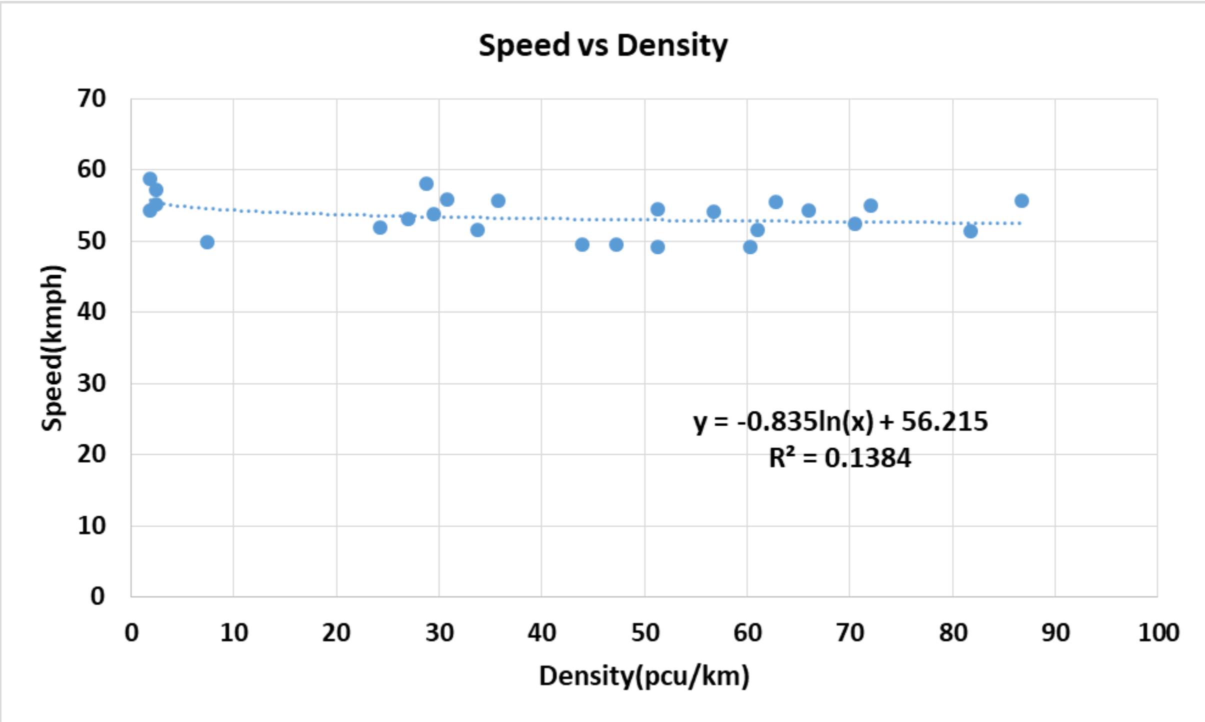

Figure 4.4: Speed-density model (Greenberg)

$$v = -0.835\ln(k) + 56.215 \tag{8}$$

The final model considered in this study is Underwood hypothesis. Figure 4.5 shows the graphical illustration of that. Here also model represents the traffic speed-density measurements along William Gopallawa mawatha in city bound direction. This is also single regime model. It shows an exponential relationship between speed and density measurements. The mathematical equation obtained is shown below. *v* and *k* represent speed and density respectively.

$$v = -56.166e^{-0.001k} \tag{8}$$

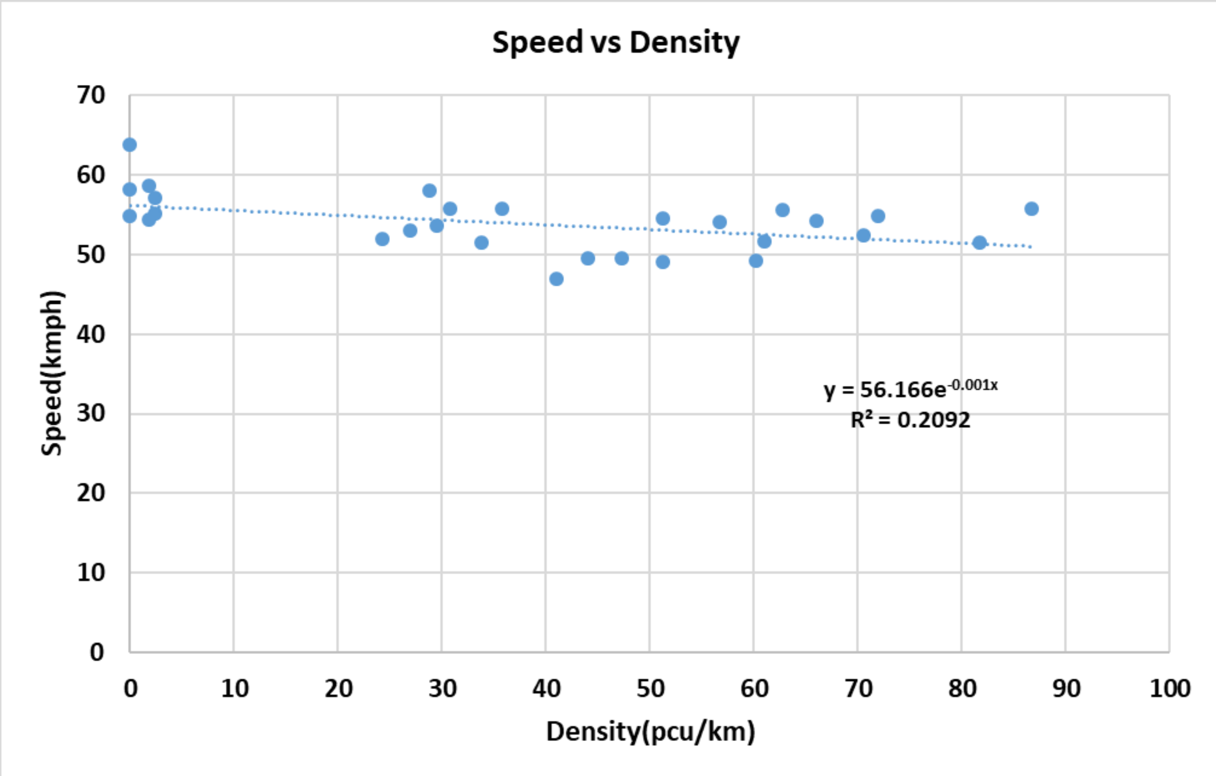

Figure 4.5: Speed-density model (Underwood)

When consider the above plots, a comparison can be done considering the R^2 value of each model. According to R^2 values, Greensheild model has the highest value among other models. One of the reasons that affected the R^2 values is the lack of data points. Due the manual data extraction method it has been difficult to add more data points which ultimately results in lower R^2 values. Also, other models showed lower values than 0.5 since they are not suitable to this road. The data best fitted to the Greensheild model. Therefore, Greensheild model has been selected to develop the rest of the relationships. Table 4.1 summarize the R^2 values of the models considered.

Table 4.1: Summary of R^2 values

Model Considered	**R^2 value**
Greenshield	0.537
Greenberg	0.1384
Underwood	0.2092
Linear two regime	0.4418
	0.0057
Eddie	0.1426
	0.0032

Since the plot has relatively less R^2 value, to verify the model three different tests have been carried out using Minitab software. High R^2 alone does not guarantee that model fits the data well because as anscombe's quartet's shows, a high R^2 can occur in the presence of misspecification of the functional form of a relationship or in the presence of outliers that distort the true relationship.

First plot was normal plot of residuals. It is drawn to find out whether the residuals are normally distributed. According to the resulted graph obtained P-value (0.207) > 0.05 which indicates that residuals are normally distributed. The second plot obtained was Residuals versus Fits which indicate whether the errors are random or not. According to the plot residuals shows a random pattern on both sides of zero which indicate the error is random. The third one is residuals verses order. This is a plot of all residuals in the order that the data was collected and can be used to find non-random error, especially of time-related effects. The resulted graph shows a negative correlation is indicated by rapid changes in the signs of consecutive residuals. Also, variance analysis shows a P-value of 0.003 which is less than 0.5. It indicates that model is significant. Therefore, considering all of these aspects the developed model can be considered as a significant model.

Below graphs represent the relationship between traffic flow and density. Figure 4.6 shows the graphical description between traffic flow and density measurements. It has been drawn according to Greensheilds model and also it represents traffic flow-density measurements in William Gopallawa mawatha in city bound direction. The mathematical equation observed from the plot is also shown below. A significant observation that can be seen here is that high density- low flow conditions haven't been covered in this study.

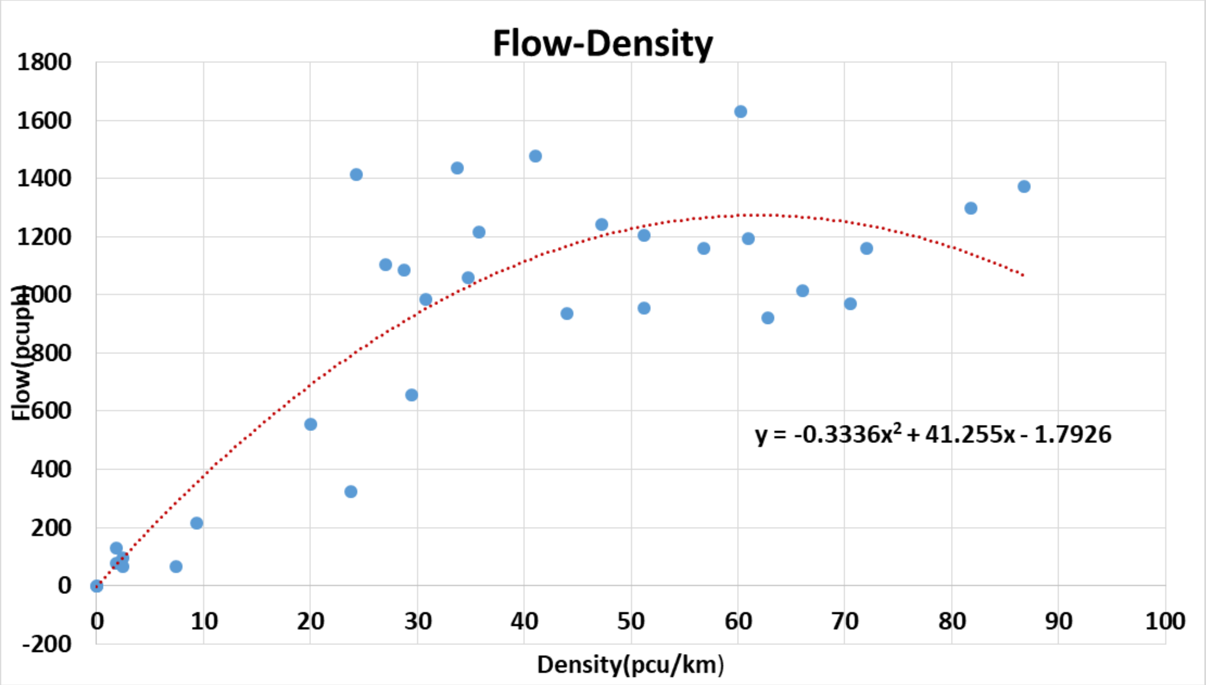

Figure 4.6: Flow-density model (City bound direction)

Below graph represents the relationship between traffic flow and speed. Figure 4.7 shows the graphical description between traffic flow and speed measurements. It has been drawn according to Greensheilds model. Also, it represents the traffic flow-speed measurements along William Gopallawa mawatha in city bound direction.

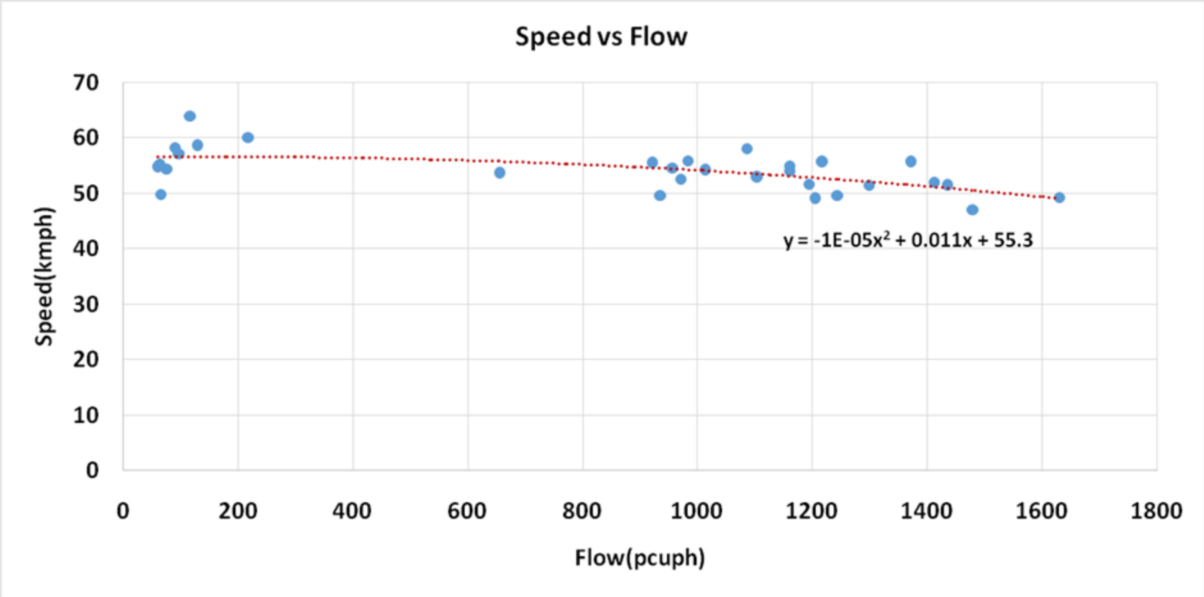

Figure 4.7: Speed-flow model (City bound direction)

All of these graphs have been drawn considering the traffic flow in city bound direction in William Gopallawa Mawatha. Same plots have been developed to represent the traffic flow towards out bound direction in William Gopallawa mawatha.

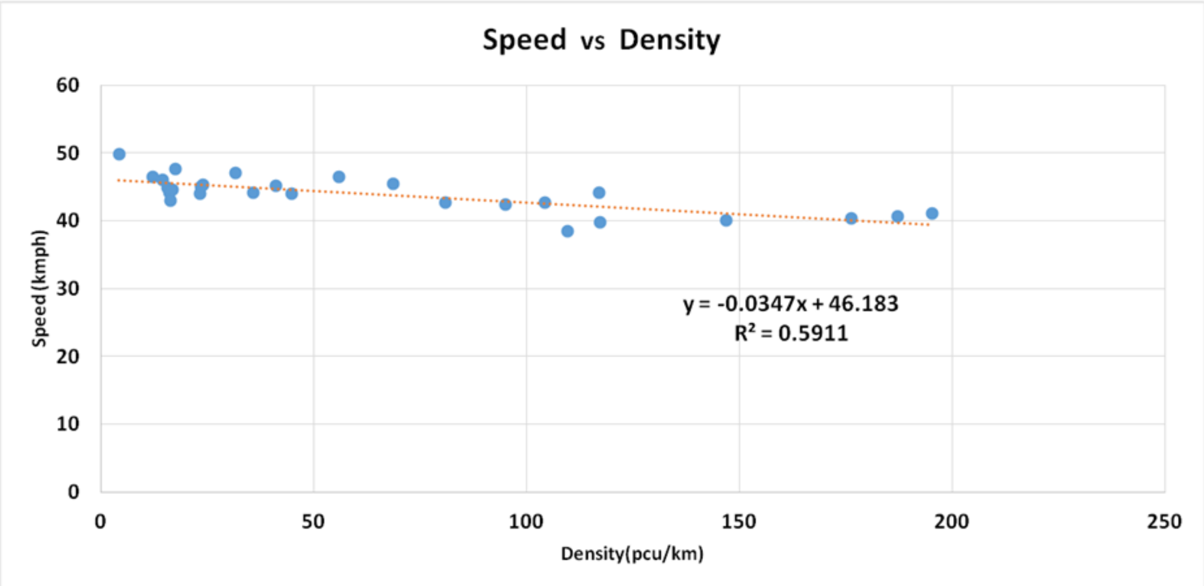

Figure 4.8: Speed-density model (Outbound direction)

Figure 4.8 represent the Greenshield behavior of speed-density measurements in outbound direction. It has a higher R^2 value than it is in city bound direction. Since R^2 value is close to 0.6 residual analyses have been carried out for this model as well.

First plot was normal plot of residuals. It is drawn to find out whether the residuals are normally distributed. According to the resulted graph obtained P-value (0.695) > 0.05 which indicates that residuals are normally distributed. The second plot obtained was Residuals versus Fits which indicate whether the errors are random or not. According to the plot residuals shows a random pattern on both sides of zero which indicate the error is random. The third one is residuals verses order. This is a plot of all residuals in the order that the data was collected and can be used to find non-random error, especially of time-related effects. The resulted graph shows a negative correlation is indicated by rapid changes in the signs of consecutive residuals. Also variance analysis shows a P-value of 0 which is less than 0.5. It indicates that model is significant. Therefore, considering all of these aspects the developed model can be considered as a significant model. Mathematical equation obtained is shown below. *v* and *k* represent speed and density respectively.

$$v = -0.0347k + 46.163 \tag{9}$$

Below graphs represent the relationship between traffic flow and density. Figure 4.9 shows the graphical description between traffic flow and density measurements. It has been drawn according to Greensheilds hypothesis. The mathematical equation observed from the plot is also shown in the graph.

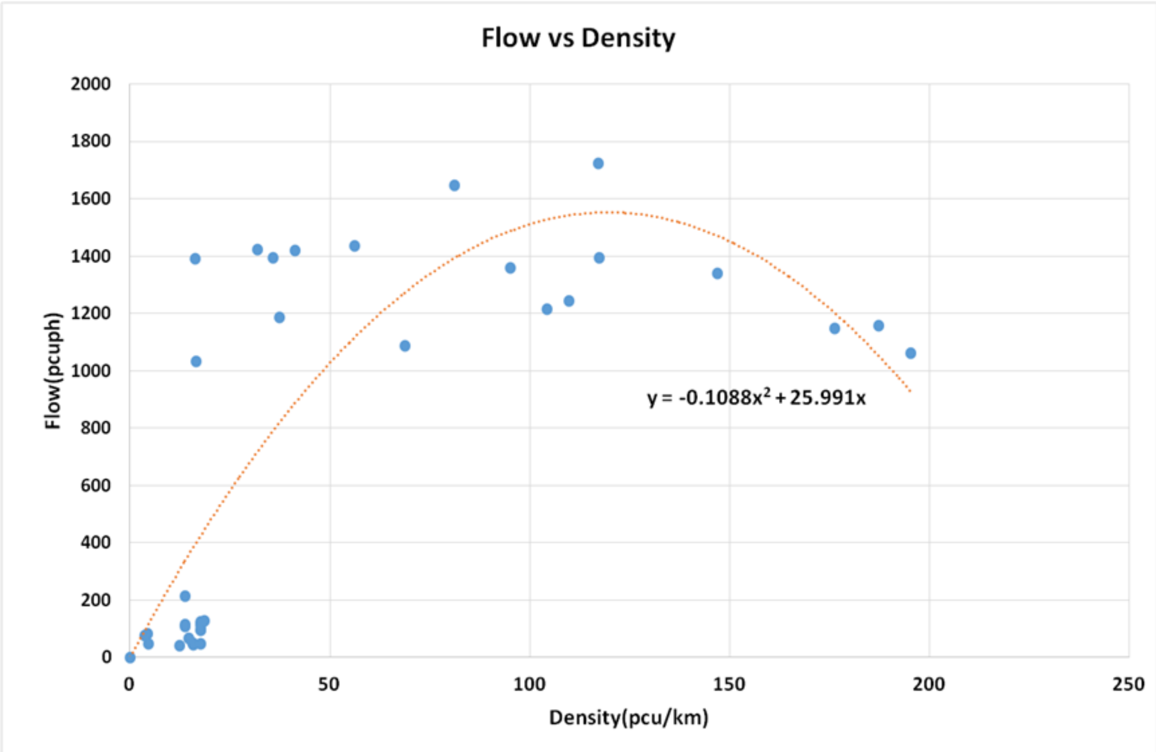

Figure 4.8: Flow-density model (Outbound direction)

Figure 4.9 shows the graphical description between traffic flow and speed measurements. It has been drawn according to Greensheilds hypothesis. It represents the flow-speed measurement along William Gopallawa mawatha in outbound direction.

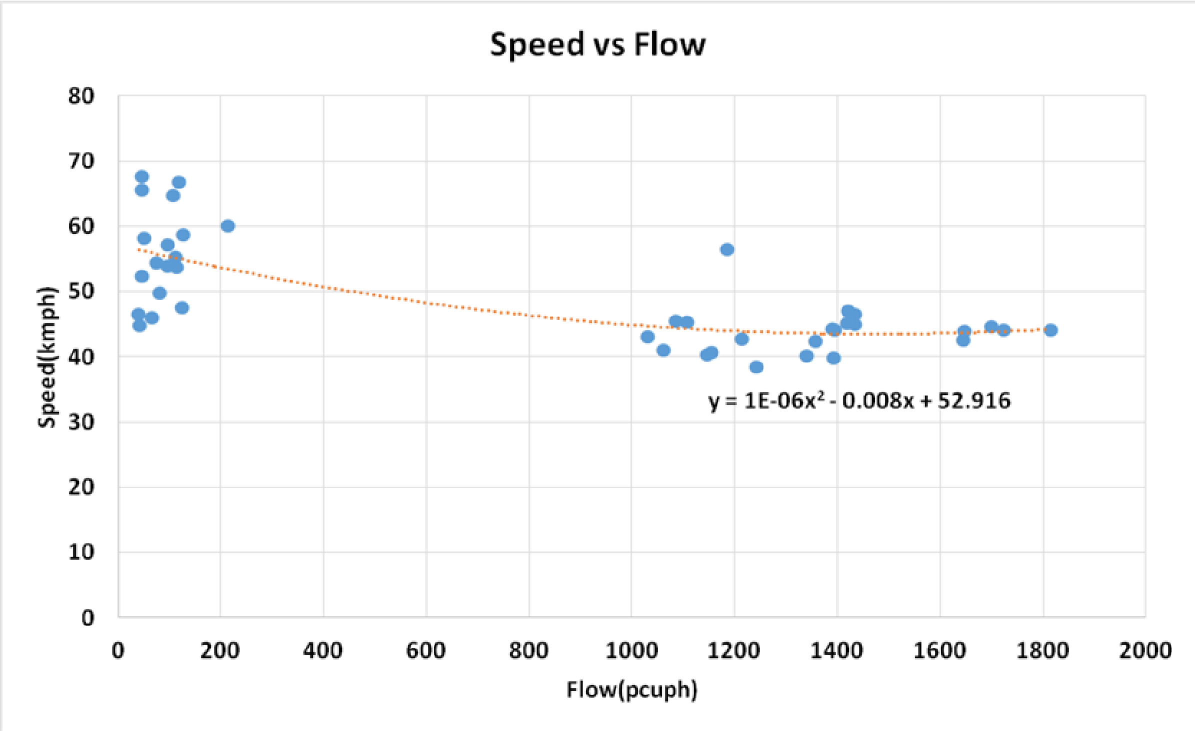

Figure 4.8: Speed-flow model (Outbound direction)

4.3 Model Validation

Even though residual analysis was done to confirm the significance of the models, after developing the models, Models have been graphically validated using several data points. Here estimated data were plotted with observed data points. Figure 4.9 and 4.10 represent them. Observed data were directly taken from the extracted data. Developed models have been used to find the estimated data.

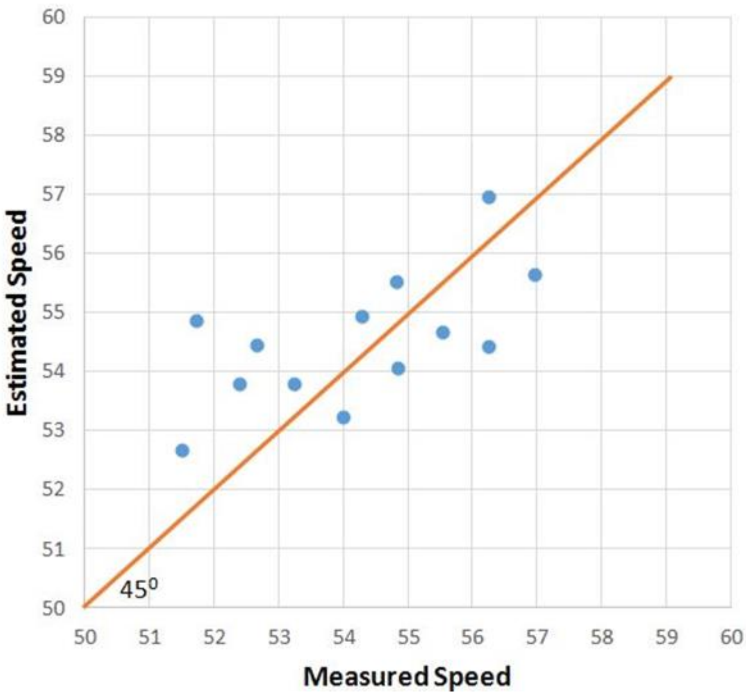

Figure 4.9: Estimated and measured speed (City bound direction)

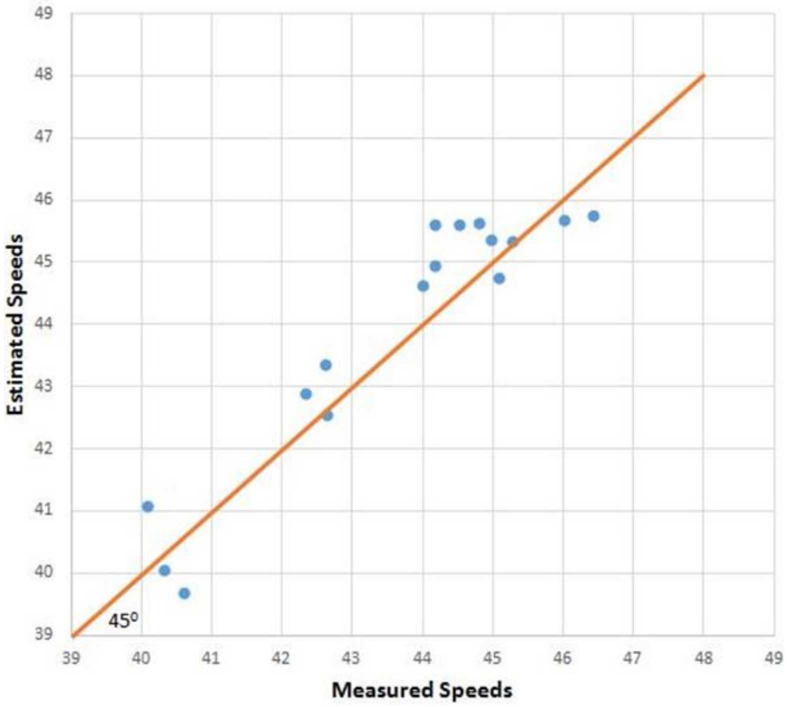

Figure 4.10: Estimated and measured speed (Outbound direction)

As observed in the plots, in both plots data points are distributed along 45^0 line which indicate that models are valid models.

4.5 Additional Finding

During the study some of the additional parameter could be found. Lane changing behavior could be only observed through the video capturing method. Therefore, this behavior only valid for those two hours of survey. To come to a conclusion about lane changing behavior along the road, more data for several days is required. Below figure 4.11 shows the lane changing behavior of the vehicles in city bound direction in William Gopallawa Mawatha.

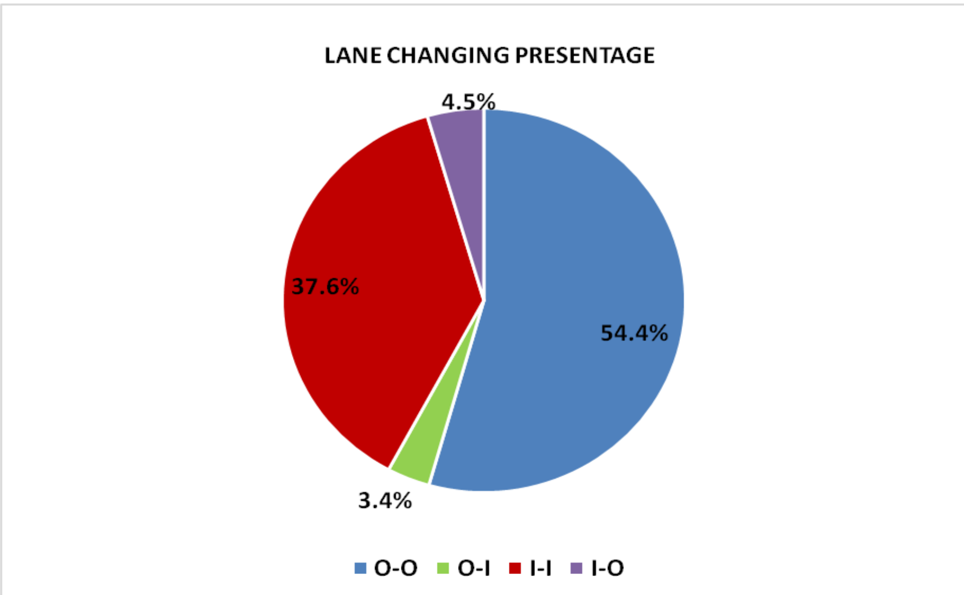

Figure 4.11: Lane changing behavior (City bound direction)

According the figure 4.11, most of the vehicles (more than 90%) leave the road stretch without changing their lane. Out of this more than 50% of the vehicles travel along the outer lane while the other vehicles use the inner lane. When considering the lane changing vehicles, they are less 10% of the vehicles and out of them higher number of vehicles change their lane from inner lane to outer lane.

Below figure 4.12 shows the lane changing behavior in outbound direction in William Gopallawa Mawatha.

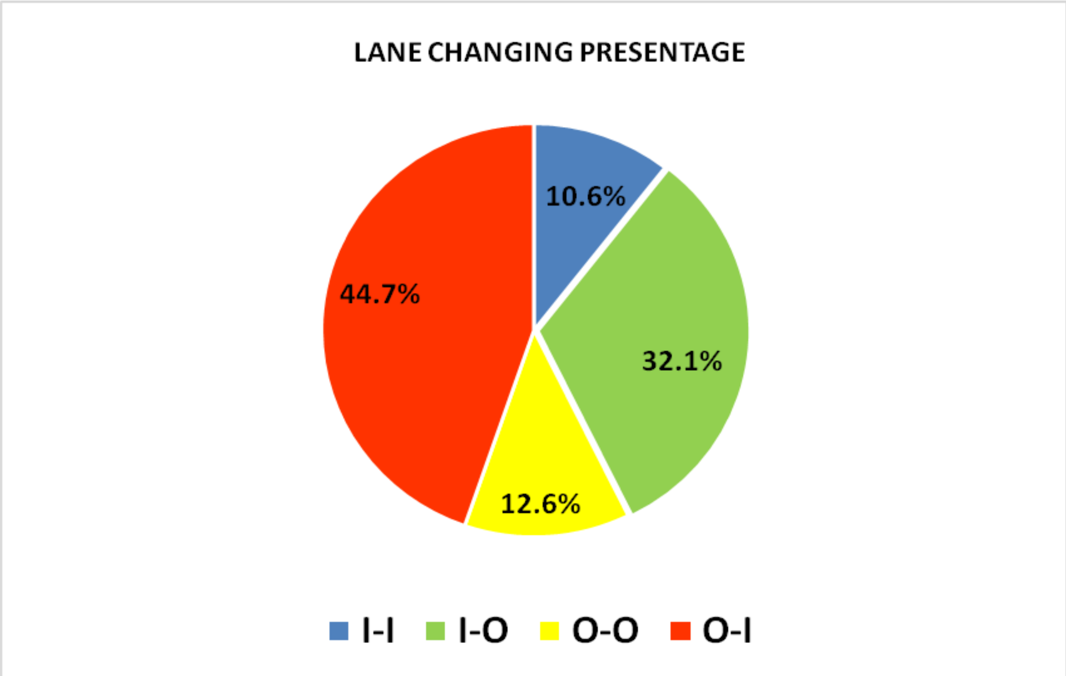

Figure 4.12: Lane changing behavior (Out bound direction)

Here the behavior of the vehicles is different from city bound direction. According to the figure 4.18 more than 75% of the vehicles change their lane within the road stretch. Out of that most of the vehicles (more than 50%) change their lane from outer lane to inner lane. Only 23% of the vehicles don't change their lane during the road stretch. Out of that more than 50% of the vehicles travel along the outer lane.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Below equations show the two models developed to represent traffic speed-density relation along William Gopallawa mawatha in both city bound and outbound directions.

$$v = -0.054k + 56.74 \tag{3}$$

$$v = -0.0347k + 46.163 \tag{9}$$

Both models show a linear variation of speed and density. But two models are quite different for city bound and outbound directions.

When considering the traffic data collection methods, it has been found out that video capturing method is more accurate since data extraction part was done manually. Therefore, pausing and playing back operations were possible. Also, in-situ speed-density-flow measurements could be taken simultaneously.

5.2 Recommendations

When carrying out the comparative study of traffic flow and speed measurements several problems arose. One is that the exact vehicle classified vehicle count survey couldn't be observed in tube detector method because of the differences in the vehicle classification system. Therefore, if the vehicle classification system used by RDA Sri Lanka can be added to the MetroCount system it would make the data collection easier and ultimately lead for accurate traffic measurement estimations.

Another recommendation is to develop an automated method for the data extraction of the video capturing method. In this study it was done manually. It was very time consuming and labour intensive which ultimately lead to a lesser number of data points. If there is an automated method, it could be used to develop more accurate traffic flow models. Because this method captures the in-situ data measurements of traffic flow, speed and density simultaneously. Therefore, models developed would be more reliable too.

In this study, models were developed considering 5-minute data measurements. But consistency of the models can be improved if 15-minute data measurements are used since it is the time period recommended in the Highway manual. Also, it has been obtained that 15-minute data measurements give a consistency to model but the models developed in this study have not considered 15-minute interval due lack of data points.

The models developed are only suitable to represent the traffic flow behavior along William Gopallawa mawatha since the traffic data used here is only from that road. But it can be further improved by comparing these results with few other four lane dual carriageway roads.

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REFERENCES

Al - Sobkey, A. & Mousa, R. M. (2016).Traffic density determination and its application using smart phone. *Alexandria Engineering journal.* Volume 55, pp. 513-525.

Arasan, T. & Gnanavelu, D. (2009). Concentration of Hetrogeneous Road Traffic. In: K. Jayanthakumaran, ed. *Advance Technologies.* , s.l.:Intch, pp. 503-530.

Gerlough, D. L. & Huber, M. J., (1975). *Traffic flow Theory.* Washingtion: Transportation Reaserch Board

Mallikarjuna, C. & Rao, K. R., (2011). Heterogeneous traffic flow modelling : complete methodology. *Transportmetrica.* , Volume 7, pp. 321-345.

Manraj, S. B., Balaji, P. & Shriniwas, s. A., (2012). *Modeling of Traffic Flow on Indian*

Expressway using Simiulation Technique. , Changsha, s.n.

Ranthatiyawa, R. D. M. D. R., Perera, B. V. L. S., Sathayaprasad, I. M. S. & Nandalal, H. K., (2017). *Use of Remote-sensed Spatial Data in Estimating Traffic Flows from Small Residential Road Catchments*, Kandy, s.n.

Sharma, N., Arkatkar, S. S. & Sarkar, A. K., (2011). Study on Hetrogeneous Traffic Flow Characteristics of a Two-Lane Road. *TRANSPORT*, Volume 26(2), pp. 185-196

Stathopoulos, A. & Karlaftis, M. G., (2003). A multivariate state space approach for urban traffic flow modeling and prediction. *Transport Reachers Part C 11*, pp. 121-135.

Lowe, W.U.A, Mendis, H.S.A & Sathyaprasad, I. M. S, (2018). A Comparative study of speed and flow measurements methods as applied to four lane dual carraigeway roads.*The 9th international conference on sustainable built environment*, ICSBE2018-497.

Lowe, W.U.A, Mendis, H.S.A & Sathyaprasad, I. M. S, (2019). Modeling traffic flow along four lane dual carraigway roads in Kandy. *Final Year Project Report*, Sri Lanka, University of Peradeniya, Faculty of Engineering, Department of Civil Engineering,

Transpotation Research Board,(1995). *Highway Capacity Manual.*, Washington, D.C: National Reaserch Council.