Short Duration Traffic Flow Prediction of an Urban Road Segment

Submitted by :

Prodip Kumar Kundu

Abidur Reja

Ainul Hasan

Irin Parvin

Mst. Mymuna Lucky

BACHELOR OF SCIENCE IN CIVIL ENGINEERING

Department of Civil Engineering
DAFFODIL INTERNATIONAL UNIVERSITY

March 2021

Short Duration Traffic Flow Prediction of an Urban Road Segment

A Project and Thesis Submitted to Department of Civil Engineering Daffodil International University, Bangladesh in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science (B.Sc.) in Civil Engineering.

Course Code: CE-400

Course Title: Project & Thesis

Prepared By :

Prodip Kumar Kundu ID#173-47-594

Abidur Reja ID#173-47-574

Ainul Hasan ID#173-47-554

Irin Parvin ID#173-47-585

Mst. Mymuna Lucky ID#173-47-577

Supervisor: Saurav Barua

Assistant Professor

Department of Civil Engineering

Date: March 2021.

APPROVAL

The Thesis and Project titled **"**Short Duration Traffic Flow Prediction of an Urban Road Segment" Submitted to the Department of Civil Engineering has been examined Thoroughly and satisfactorily accepted in partial fulfillment of the requirement for the Degree of Bachelor of Science (B.Sc.) in Civil Engineering on 18th March 2021.

Saurav Barua

Supervisor and

Assistant Professor

Department of Civil Engineering

CANDIDATE'S DECLARATION

This is hereby declared that this thesis or any part of it has not been submitted elsewhere and any degree.

Prodip Kumar Kundu

Abidur Reja

Ainul Hasan

Irin Parvin

Mst. Mymuna Lucky

DEDICATION

This thesis dedicated to our honorable thesis supervisor ***Saurav Barua***. His continuous inspirations made this effort possible.

Table of Content Page

Chapter-2

LITERATURE REVIEW

Chapter-3

METHODOLOGY & DATA COLLECTION

Chapter-4

DATA ANALYSIS

Chapter-5

CONCLUSION AND RECOMMENDATON

Acknowledgments

Thanks to almighty Allah for his graciousness, unlimited kindness and with the blessing of whom the good deeds are fulfilled.

I would like to express my deepest sincere gratitude to my supervisor **Assistant Professor Saurav Barua** for giving me a unique opportunity to work on such an important topic. His continuous guidance, invaluable suggestion, affectionate encouragement, generous help and invaluable acumen are greatly acknowledged. His keen interest on the topic and enthusiastic support on my effort was a source of inspiration to carry out of study. I consider myself fortunate to work under his supervision. I take this opportunity to express my deep sense at gratitude to **Professor & Head Dr. Miah M. Hussainuzzaman** for his valuable guidance laced with suggestion and help. Finally, I would like to express a very special indebtedness to my mother and father whose encouragement and support was a continuous source of inspiration for this work.

March 2021

Abstract

The study involved to estimate short duration traffic flow count using mathematical filtering technique named Kalman filtering. The area of study was taken Mirpur road, Dhaka city near Sobhanbagh mosque. There are traffic of heterogeneous mix in the traffic stream. Though efficiency of Kalman filtering technique (KFT) is tested for homogeneous traffic already, however efficacy of KFT under heterogeneous traffic yet to be explored. Short duration traffic estimation is a useful tool for traffic operation and transportation system management. Route guidance and advance traveler information system can use the outcome of short duration traffic count for travel time estimation. The proposed technique is implemented using python library developed by Kalman.py library API. The library is widely implemented in the advance modeling of database in KFT framework. The data were obtained from 1 hour traffic count of the vehicle. The heterogeneous traffic count were converted into equivalent passenger car unit (PCU) as per Indian road congress manual. The PCU obtained over every 5 minutes aggregation then used as the dataset for KFT model. The proposed model has mean absolute error (MAE) 15.39%, which represent that the KFT model has reasonably good forecasting capacity. The root mean square error (RMSE) shows 19.36% accuracy. The developed model have R2 value 0.543 i.e. the model can explain 54.3% variability of the dataset. The proposed estimation technique can be implemented in the application tool developed for travel time prediction and traffic flow count estimation dynamically. The application of KFT is tested for both motorized and non-motorized vehicle. The study can be extended for other geographic location. Also traffic under various level of service can be studied for wide range validation of the study.

Chapter One

Introduction

1.1 General

The purpose of this study is to predict short duration traffic flow (approximately 1-2hr) for urban midblock road segment. Traffic flow is the demand in a transportation system. It influences level of service of road condition, vehicle speed and travel time. Increasing traffic flow causes traffic congestion, long queue and delay. Short duration traffic flow prediction can be incorporated with Advanced Traveler Information System (ATIS) which provides travelers' route guidance services, multi-modal trip planning and advisory functions.

Prediction of traffic flow helps to estimate travel time and level of service We use Kalman Filtering technique (KFT) to predict traffic flow in our study. KFT is an algorithm that provides estimates of some unknown variables given the measurements observed over time.

1.2 Background Study

Several studies have been performed relevant to our researches. Kumar et al. (2017) predict traffic flow using KFT. He found that Kalman Filtering performs better than time series models. Another study by Yin et al. (2002) performed on urban traffic flow prediction using Fuzzy-neural approach. He revealed that Fuzzy-neural method works well with real and simulation traffic data. Castro-Neto et al. (2009) worked on Short term traffic flow prediction for non-recurrent traffic by Support vector machine (SVR). He marked that SVR works better than Generalized linear model. Tan et al. (2009) performed aggregation of traffic flow prediction using Neural Network (NN), data aggregation (DA). They revealed that DA model more accurate to predict real traffic flow. Abadi et al. (2014) studied traffic flow prediction for limited traffic data by Monte Carlo Simulation. They revealed that errors of traffic flow prediction varies around 2% for 5 minutes time frame.

1.3 Objectives

The objective of this study is to predict 5 minutes aggregated traffic count of 1 hour duration using Kalman Filtering Technique (KFT). Short duration traffic flow count is important in Intelligent Transportation System (ITS). It provides route guidance for traveler and provides travel information dynamically to users. On contrary, long duration traffic flow subject to daily and monthly variation. It requires for transportation planning and management. However, short duration traffic flow count is required for traffic operation dynamically.

1.4 Summary

This chapter gives brief over view on the short duration traffic flow prediction. The next chapter deals with literature review and illustrative description on Kalman filtering process.

Chapter Two

Literature Review

2.1 General

This chapter illustrates detail theoretical issues on the research topic. We arrange the chapter discussion with the details of Kalman Filtering Techniques (KFT). We give the definition and usage of KFT. Also, we note here on the ADT, AADT, flow parameters and traffic flow related measurements. Different flow operation related usage and traffic operational techniques are discussed here also.

2.2 Previous works

In this section, we show the literature we have read through. We try understand the subject matter and detailing of those study are presented in the tale in the following.

Study Content	References	Method used	Remarks
Traffic flow prediction	Kumar (2017)	Kalman Filtering Technique	KFT performs better than time series models

Urban traffic flow prediction	Yin et al. (2002)	Fuzzy-neural approach	Fuzzy-neural method works well with real and simulation traffic data
Short term traffic flow prediction for non-recurrent traffic	Castro-Neto et al. (2009)	Support vector machine (SVR)	SVR works better than Generalized linear model.

Study Content	**References**	**Method used**	**Remarks**
Aggregation of traffic flow prediction	Tan et al. (2009)	Neural Network (NN), data aggregation (DA)	DA model more accurate to predict real traffic flow
Traffic flow prediction	Abadi et al. (2014)	Monte Carlo Simulation	Errors of traffic flow prediction varies around 2% for 5 minutes

for limited traffic data			time frame

2.3 Kalman Filtering technique

What is KFT?

We will discuss about the Kalman filter in this section of the paper. It is not work as regular filtering concept. It is a type of optimum estimation algorithm. We will go through some examples which will describe some common uses of kalman filtering. In the first example, we will see a system estimate which cannot be estimated directly. Let's go to Mars, through space craft. If engine of a space craft burn enough fuel and produce heat, it can receive enough thrust to fly to Mars from Earth. Liquid hydrogen is the fuel for the space craft which can burn at 550º F. But, the problem is this high temperature will put the mechanical component of the space craft at the risk.

Examples of KFT

It will lead to failure of some of the mechanical parts. In that case, the space craft may burst out and we may stuck in space craft. To counter this situation, we need to monitor the temperature of internal combustion chamber. However, this is not an easy task. A sensor located inside the internal combustion chamber will melt in this high temperature. In this situation, the sensor is placed in the cooler surface of the combustion chamber, located nearby. The problem here comes that, we want to measure the internal temperature, however, we can’t. We measure the external temperature in this situation. In this case, we can use Kalman filter to measure the internal temperature through indirect measurement. This way, we may measure what we cannot through what we can measure indirectly. Take a look on another scenario on Earth. Weight in earth of a person and weight of the same person in Mars is not same because of gravity. In this example, we will discuss how Kalman filter can be used to estimate the measurement obtained from different sources, those are subjected to noise.

For example, we have guest from overseas and we have to pick them up from airport. We are driving cars and getting in a tunnel while boarding to the airport. An onboard sensor is attached to the car. The sensor measure our car’s position and navigate to the airport. The inertial measurement unit (IMU) estimates acceleration and angular velocity of our car. The odometer measures the relative position of the car. GPS receiver receives signal from satellite the get the absolute position of the car. All this will locate the position of car in the earth surface.

2.4 Flow rate

Traffic flow rate is the hourly traffic flow in a road segment. It is expressed in terms of vehicle/hr. For example, traffic flow rate in Mirpur road is 1000 veh/hr. It means that average traffic flow is 1000 vehicle per hour. The flow rate varies over time to time. There are hourly, daily, weekly, seasonal variation of traffic flow rate. It is essential to know the flow rate, because it represent the traffic volume. And, traffic volume is the demand for transportation system. If we consider, broadly, the flow rate is the demand and road capacity is the supply of a transportation system. Hence, transportation system is a combination of demand-supply system.

If demand is less than capacity the system works well. If demand is much less than capacity the transportation system will work very well, however, the system is uneconomical. In the second situation, if demand is below capacity, it works well. There is no traffic congestion. Travel time will be less. Road users do not need to wait a lot of time in the road. Their working hour will be saved. Whenever, demand is same as supply. i.e. traffic volume is same as road capacity, the system will become little congested. The delay occur and road users will suffer traffic jam. In the scenario, if the demand i.e. flow rate is very high compare to road capacity or supply, the road becomes too much congested. It will be a huge loss of travel time. It will cost valuable loss of money in terms of working hour. Each year 22.0 million working hour loss in Dhaka city. If we consider each hour is 1 USD as per World Bank suggestion. There will be a loss of 22.0 million USD in terms of working hour loss by traffic congestion.

2.5 AADT

AADT is the average annual daily traffic. It is counted over more than 365 days. If the count is less than 365 days, we cannot define is AADT. One of measure of traffic volume count is AADT. In many cases, especially for road design we need axle load. For the structural design of pavement, we need the traffic load. Many design manual require AADT to estimate total annual axle load. For bridge design, we need AADT as well. Based on AADT we have calculate live load on the bridge. The live load will add up to the dead load and combining to total load. The estimation of total load will decide, how much girder and of which thickness are required. Consequently, we also need to design pier and pile cap in that way.

For example, a traffic survey company calculate the traffic for 370 days and found 37 million traffic. Then AADT will be the division of 37 million/ 370 days = 370 thousand. If the company counts traffic for 10 days and found 10000 traffic. The value 10000/100 = 1000 is not AADT. Since the traffic was counted in the second case less than 365 days. For long term traffic prediction, AADT is helpful. Long term traffic prediction is needed for transportation planning and making policies.

2.6 ADT

The abbreviation of ADT is average daily traffic. ADT is required for short duration traffic count. It is expressed by vehicle per day. If the count of vehicle is less than 365 days then dividing total number of traffic to the number of days will give us the ADT. Transportation operation works require ADT count. However, we do not need long duration traffic count for transportation operation. So calculating AADT is cumbersome and it fetches huge cost. When we need to run a project quickly, we should use ADT instead of AADT. Though the measure of ADT is not as accurate as AADT. Measurement of ADT will give a rough estimate of traffic volume count.

For example, a survey company counts traffic 15000 for a count of 7 days. Then, the ADT is 15000/7 = 1500. The value of traffic count 1500 is the ADT here. The ADT can give us daily and weekly variation of traffic. Sometimes it can provide monthly variation also. The traffic volume is varies and it is in the peak in the week days and low in the week end. The volume is fluctuate and the traffic volume is high during festival season. Because, during festival, people go out and they go for vacation. Traffic volume is increased in the highway. During this time people hang out from one city to another city.

2.7 Passenger Car Unit

Passenger car unit is also known as PCU is an equivalence used to convert different types traffic to one type i.e. passenger car. There are various types of vehicle running in the roads. Trucks, buses, cars, motor cycles, micro buses, mini buses all are plying on the road. The PCU will account for traffic volume. To express total traffic per hour, we have to convert different types of vehicle count to one equivalent unit. It is the PCU, also known as passenger car equivalent. This help to compare traffic volume of one road to another. Sometimes, equivalent truck unit is also used for the road where there are significant truck vehicle. Especially for axle load calculation, in engineering point of view, we consider equivalent truck load.

We can draw an example here. Airport road have an estimation of traffic count for one hour. There are 500 cars, 100 trucks, 50 buses, 100 motor cycles and 50 mini buses counted in the survey. Now, the question comes, how to convert the different types of stuffs into single equivalence. Good luck for us that there are lot of convention or manual. In our country, we follow roads and highway manual to count the equivalence. In India there is IRC code. IRC stands for Indian road congress. For the USA, they have highway capacity manual. All these manuals and codes help to interpret the different mixture of traffic volume into PCU. In context of our country, we have 1 truck equal to 3 passenger car. Similarly, 1 motor cycle equal to 0.5 passenger car and 1 micro bus equal to 1.5 car.

Now the question comes, why and how these number comes. Each vehicle occupies road space and time while moving. So based on vehicle dynamics, they have different physical characteristics. A bus off course do not have same dynamic space as car. Because it takes more space and time in the road, compare to a car. And again, a motorcycle takes much smaller space and time while moving in the road compare to car. The concept behind the whole issue is that. So, we need to make all the same unit. Therefore, we need to quantify all the traffic count into equal unit. We need passenger car equivalent to do such.

2.8 Importance of traffic flow study

Traffic flow study is necessary for the understanding of transportation dynamic and statics. Now comes the issue to discuss of importance and why we should study such. In this section, we will discuss and illustrate the whole matter in a nutshell. Broadly, we can divide the entire importance into direct importance and indirect importance. Firstly, we will discuss the direct measures. Traffic flows are needed for both short and long duration traffic count. Short duration traffic count is required to implement traffic operation purpose. For example, traffic signal timing adjustment. Consider a four leg intersection, where north-south approach have combined 800 veh/hr and east-west approach have combined 400 veh/hr. Obviously, whenever we will assign the signal timing of 120 seconds, we will use 80 second green for north-south approach and 40 seconds green time for east-west approach. Again, if the traffic volume in north-south approach become 500 veh/hr and traffic volume in east-west approach become 1000 veh/hr. It is wise to allocate 80 seconds green time to the east west approach and 40 seconds green time to the north south approach. Hence, traffic count survey plays a role in the signal timing adjustment here.

Another traffic operation issue we will discuss here is public bus headway. Headway is the vehicle to vehicle travel time distance. Buses of same bus company come after fixed headway. So the question comes, what should be the value of headway. Also we need to know the minimum and maximum headway value allotted for specific public bus service. Traffic flow is indirectly related to the topic. If the headway time is very long, passenger will be bored, it loss their time. It increases their delay time and causing mental illness. On the other hand, if the headway time is very small, there is a tendency of bus platooning. The bus to bus arrival time become very short. It causes traffic jam, since, the road will occupy by public bus. Private cars, ambulance, different types of emergency vehicle stuck into jam. The whole thing will make public hassle. Simultaneously, since public demand is not high enough and people have less queue in the bus stop, all buses will have lot of empty space. It is a problematic situation and fully uneconomical. So, traffic volume coming to a specific road is urgent to know. Studying traffic flow can give us an idea on the appropriate headway needed for a public bus

Another issue relevant to traffic flow is allocating separate motorcycle lane measure. It is actually a long term planning decision. For example, there are so many motorcycle in Jakarta and Taiwan. One road has 600 motorcycle compare to entire other traffic count is 1000 vehicle. Hence, almost 60% of the traffic in the road are motorcycle. Motorcycle occupy small space and it tries to make an over take. Motorcyclist try to disregard traffic signals and rules. So, to monitor them closely and put them separate space, we need separate motorcycle lane. This will not interrupt with the other traffic. What happen that, motorcycles used to queue up in the front stream near signal light, causing hindrance to the all other queuing vehicle. Allocating separate motorcycle lane can sole the problem.

Next topic which will be described here is one way traffic circulation. The operation restriction is usually implemented where traffic in both direction is hazardous, there are some short of risk while ensuring two way flow. If traffic volume in both direction is very high compare to the width of road and two way traffic flow creates a lot of traffic conflict. We can implement one way traffic circulation. In many residential area in Dhaka, we have one way traffic circulation. Some roads in Dhanmondi area of Dhaka city have one way circulation. In those roads, assigning two way traffic we increase confusion among drivers. It also creates more conflicting small intersection or junction. All vehicle have to wait at the junction and causing time loss. Sometimes, this short of vehicle maneuver require to deploy traffic policy. Therefore, overall cost of transportation becomes very costly for those two way operation. So, it is preferable to implement one way traffic circulation for those cases.

In this section, we have banning U-turn operation. U-turn requires where north bound traffic needs to change direction to the south bound or east bound traffic need to move to the opposite west bound. So, U-turn involves with the change movement of traffic direction to the exact opposite. Though Engineers' try to avoid as much as possible. But the reality is that, every long section of road need to allocate provision of U-turn after some distance to provide the ease for the motorist. U-turn maneuver requires a lot of space and it takes long time while the operation. All traffic coming to the direction of the traffic stuck behind and they wait until the turning vehicle leaves the lane. On the other hand, traffic in the other direction also have to wait so that the tuning vehicle will clear away. Obviously, U-turn cause traffic congestion and delay.

We may give a simple example of U-turn related real life example here. The progati sarani road has lot of U-turn along its length. Lots of them are closed now. There were turning provision at Rampura, Badda, Norda, Malibag and lots more. Because, traffic of the road become too many over time. Those U-turn become source of intense traffic jam. Studying traffic flow, we come to the solution that, numbers of unnecessary U-turn have to ban or restricted. Now, the traffic of that road become much smooth. Restriction of frequent U-turn make traffic flow smooth. However, it has also some drawbacks. One is the restriction force number of vehicle to move a long distance and causing long travel distance in some cases. Location of U-loop to remove the turning movement in another approach. The loop ensures smooth movement, but vehicle which can easily do the U-turn within short distance, now have to make a long movement to reach to the destination. It increases fuel consumption and increase travel time of vehicle also. We can compromise it in respect to previous long traffic jam due to U-turning vehicle.

In the next, but the last, traffic flow study is required for the feasibility study of new construction of a bridge project. There are one Kanchanpur bridge, one Meghna bridge and one Gumti bridge in the Dhaka-Chittagong highway. However, the road is becoming four lane, based on the traffic flow survey. Too many vehicles in Chittagong port coming to the Dhaka, those are freight fully loaded. The Size of those freight vehicle are very large, therefore, previous two lane road can meet up the demand. Hence, the project of four lane road is taken into action. Another problem arise in this case. Roads are become four lane, however, bridges located in the road are remain two lane. Therefore, it needs to be expand the bridges. However, expanding brides is not as easy to say. New bridges at Gumti, Meghna and Kanchpur are construction underway to solve the problem of bottleneck. It is very expansive and time consuming, side by side a challenging project now.

Bottleneck identification is a duty of a transportation engineer. Bottleneck is the segment of road which act like neck of a bottle. Whenever the bottle is full of water and make it upside down. The water tries to get down from the bottle and it can't. All are stuck together and only small portion of water can spill off. Same thing happen in case of road segment. Whenever, road becomes so congested and there are grid lock traffic everywhere. For example, the road is four lane in upstream and two lane in downstream. The capacity of the four lane is 1200veh/hr and the capacity of two lane is 600 veh/hr. The number of vehicle in an hour comes to 800 vehicle. In that case, those can flow easily to upstream segment, but they can't move through the downstream segment. Since 800 veh/hr <1200 veh/hr, so vehicle can pass through, but, 800 veh/hr >600 veh.hr traffic stuck. The stuck traffic will stand still and speed of whole traffic stream become slowly. The shockwave will propagate upward, it also make the upstream congested soon, until the demand of traffic drop off. So, identify the location of bottleneck is closely relevant with the traffic flow study.

2.9 Procedure of traffic flow study

Traffic flow study can be conducted by manual method and automatic method. Manual method can be again divide up to direct and indirect method. The characteristics of manual traffic count is it is done by manually. Each vehicle is counted by surveyor. So, there can be some errors. There is no provision of cross check. It takes a lot of time to do the survey. The automatic method of traffic flow count is done by computerized counting. Now, let's talk about manual method. The direct method of manual counting is performed by hand tally. A tally sheet is provided to the surveyor. The surveyor will maintain tally for each type of vehicle. They can be categorized as left turn, right turn, through traffic. Also categorized vehicle size wise, like car, bus, mini bus, motorcycle. Also those can be categorized as motorized and non-motorized vehicle. If it is raining or there are storm or even it is night time, due to vision obstruction, it is not possible to count the traffic during that time.

The problem is solved in case of indirect survey. In this techniques video cameras are deployed to record the traffic movement. The traffic is count later in the office from the retrieval of the record by hand. This is also time consuming, because counting is done in the manually. It is subjected to error and human made mistakes. The automatic method can be video image processing, laser, loop detectors. The video image processing is very popular at present. All traffic will be recorded through video camera. The camera recorded are then put into some software for image processing. The algorithm in the software will read out the vehicle and count the traffic categorically. The final output of the result is interpretable through computer in softcopy format. It can then be used for further engineering analysis.

2.10 Summary

In the above mentioned chapter, we study on the literature of the research. In the next segment of the study, we discuss on the methodology and data collection procedure of the study. Different techniques of the flow rates are describes in this section.

Chapter Three

Methodology & Data Collection

3.1 General

A datasheet for traffic count is prepared before conducting field survey. We choose a midblock urban road segment and record the traffic through video camera. Aggregate each 5 minutes traffic count and convert heterogeneous traffic into PCE as per standard code. Import the traffic count data into excel format. Use python code for Kalman Filtering technique (KFT) to predict traffic count. Conduct quantitative and graphical comparison to observe fitness of the KFT.

3.2 Study Area

The study area was at near the Sobhanbagh Mosque in Mirpur road, which is one of the major important arterial road in Dhaka city. The video record was performed from foot over bridge near the Sobhanbagh Mosque. Traffic bound to Kalabagan intersection (south bound traffic) were counted only.

Figure 3.1: Study area

Data sheet is given in the following section of the paper.

TCSF/01

Traffic Count Survey Form

The study performs classified vehicle count of a midblock road segment for short duration. The traffic count is conducted through manual counting from recorded video. The video camera is installed in a suitable elevated gantry in the study road segment for the entire survey period in order to record traffic video. Every 5 minutes traffic data are aggregated during vehicle counting. Different types of vehicle are converted to equivalent passenger car unit (PCU) as per IRC: 106, Guidelines for capacity of urban roads in plain areas, Indian Roads Congress (IRC), New Delhi. 1990.

Vehicle type	PCU
Two wheeler	0.75*
Three wheeler (Autos)	2.0*
Passenger car	1.0
Light commercial vehicle	1.4
Bus/Truck	2.2

*If proportion of two wheeler and autos<10% the PCU value will be 0.5 and 1.2 respectively.

General Information

Study road segment*:

Survey Date: Time:

Duration:

Surveyors' Name:

* Preferred road segment where non-motor vehicle are restricted

[Date] 1

Figure 3.2: data sheet format

TCSF/01

Vehicle count datasheet						
Time	Two wheeler	Three wheeler	Passenger car	Light Commercial vehicle	Bus/Truck	Total (PCU)
3:00PM	X 0.75	X 2.0	X1.0	X1.4	X2.2	
	=	=	=	=	=	
3:05PM						
3:10PM						

[Date] 2

Figure 3.3: data sheet format page 2

Figure 3.3: Photographs of study area

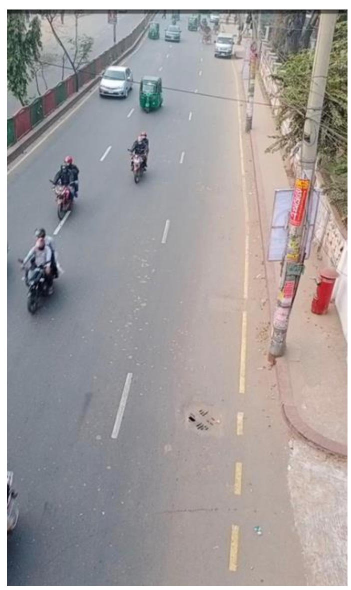


Figure 3.4: Photographs of study area

Figure 3.5: Photographs of study area

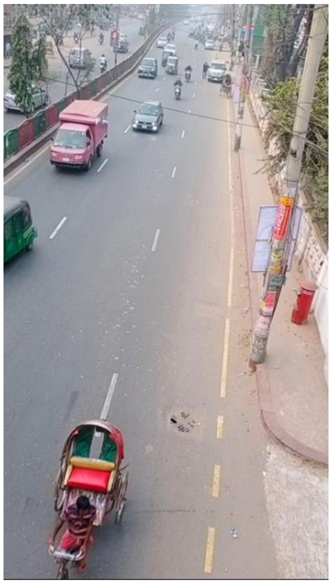


Figure 3.6: Photographs of study area

3.3 Data Collection

The study performs classified vehicle count of a midblock road segment for short duration during November 10, 2020. The traffic count is conducted through manual counting from recorded video. The video camera is installed in a suitable elevated gantry in the study road segment for the entire survey period in order to record traffic video. Every 5 minutes traffic data are aggregated during vehicle counting. Different types of vehicle are converted to equivalent passenger car unit (PCU) as per IRC: 106, Guidelines for capacity of urban roads in plain areas, Indian Roads Congress (IRC), New Delhi. 1990.

Vehicle type	PCU
Two wheeler	0.75*
Three wheeler (Autos)	2.0*
Passenger car	1.0
Light commercial vehicle	1.4
Bus/Truck	2.2

*If proportion of two wheeler and autos<10% the PCU value will be 0.5 and 1.2 respectively.

3.4 Kalman Filtering Technique (KFT)

Kalman Filtering Technique developed by R. E. Kalman in 1960. KFT is a linear quadratic estimation (LQE). It uses a series of measurement observed over time, containing noise and inaccuracy. It produces the estimation of unknown variables which tend to be more accurate than the estimation produces by single measurement. It estimates a joint probability over the variables for each time steps.

Assume, t = time step, xt = input variable at t time step, Ft = Transition matrix and wt = observed disturbance

Full state model: $x_{t+1} = F_t \times x_t + w_t$ (1)

yt = output variable at t time step, Gt = measurement matrix and vt = measurement noise

Measurement: $y_t = G_t \times x_t + v_t$ (2)

Estimated Posterior observation = $\hat{}{+}t{+}1$, Estimated prior observation = $\hat{x}^-_{t+1}$ and kalman gain at (t+1) time step = k_{t+1} which depends on joint probability of measurement and estimated observation.

Updates: $\hat{x}^+_{t+1} = \hat{x}^-_{t+1} + k_{t+1} \times [y_{t+1} - \hat{x}^-_{t+1}]$ (3)

If $w_t > v_t$ the output variable relies more on model and if $w_t < v_t$ it relies more on measurement.

3.5 Summary

This chapter gives brief over view on methodology. The next chapter deals with data analysis of the study.

Chapter Four

Data Analysis

4.1 General

The obtained 5 minutes vehicle counts were converted into PCU values. Each 5 minutes PCU data were imported into excel and later transferred to python. These were the observed (Field) dataset. A Kalman filtering library "PyKalman" developed in Python v. 3.7 have been used to model traffic flow count. These were the predicted dataset. Others supporting libraries such as, pylab and numpy have been imported while coding into python environment. Detail codes are attached with the thesis book in the appendix section.

4.2 Descriptive statistics

Observed and predicted dataset have average flow count 299.83 and 288.33 respectively. Observed and predicted dataset have standard deviation of 32.113 and 40.297 respectively. Observed dataset have slightly higher flow count than that of predicted dataset.

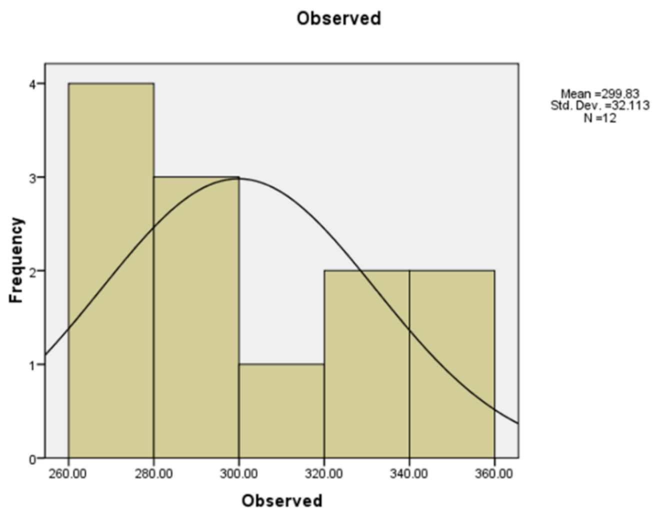


Figure 4.1: Histogram of observed data

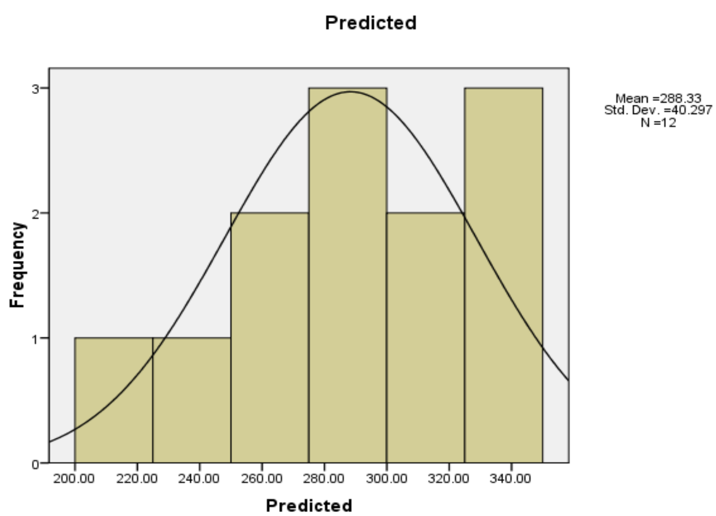


Figure 4.2: Histogram of predicted data

The observed dataset of flow count has range 262-350 PCU and predicted dataset of flow count has range 219-344 PCU. Predicted dataset has wider range than observed dataset. Median value of both dataset are same 293 PCU.

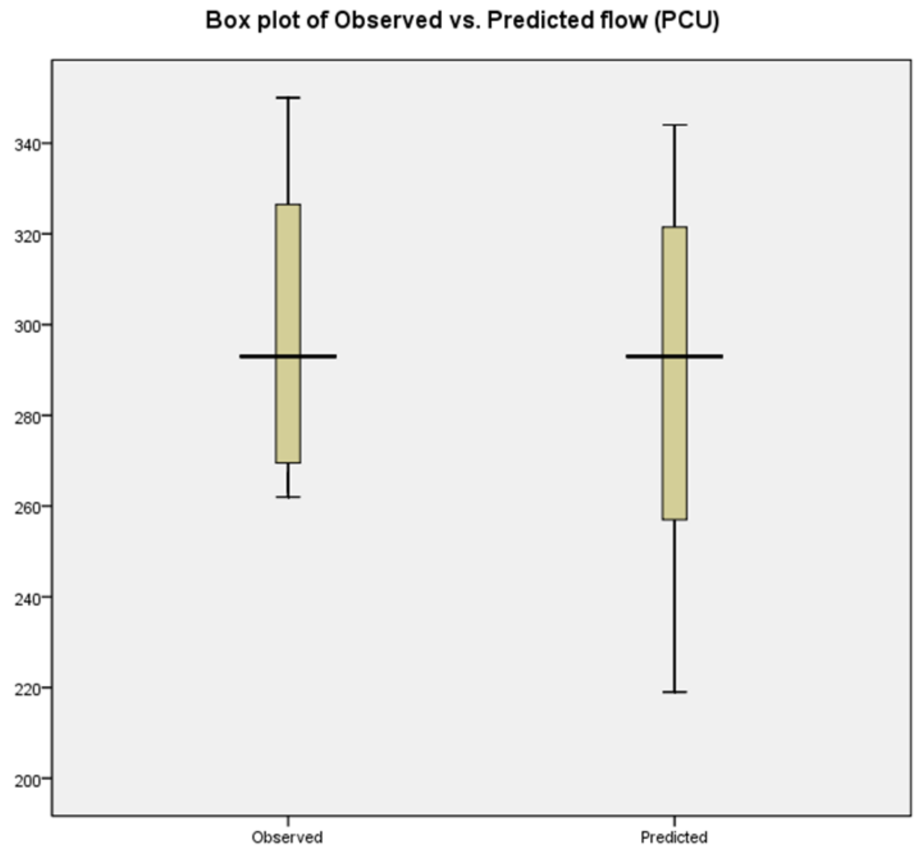


Figure 4.3: Box plot of datasets

4.3 Model comparison

Kalman Filtering Technique (KFT) is slightly under estimated the observed flow with a constant of 0.952. KFT explains 54.3% variability of observed flow.

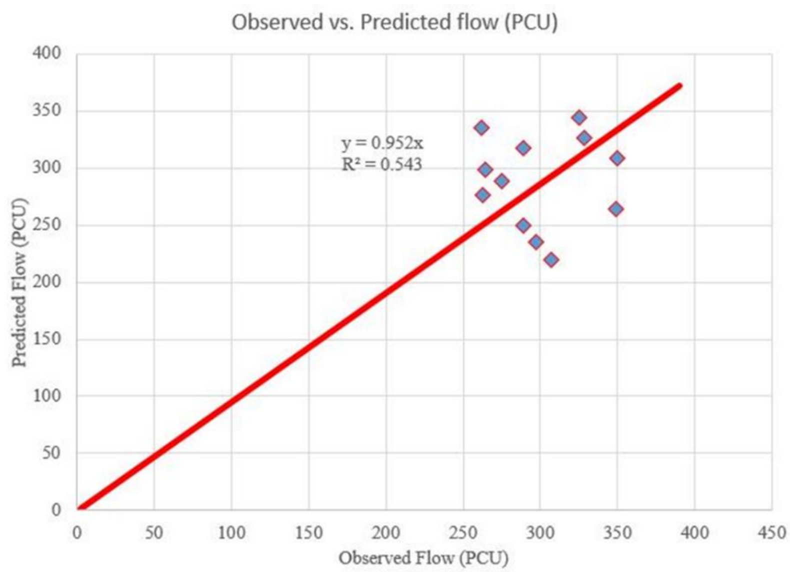


Figure 4.4: Observed vs. predicted dataset

KFT shows that observed dataset have an increasing trend. It means that the road segment is getting more congested over time during field observation time.

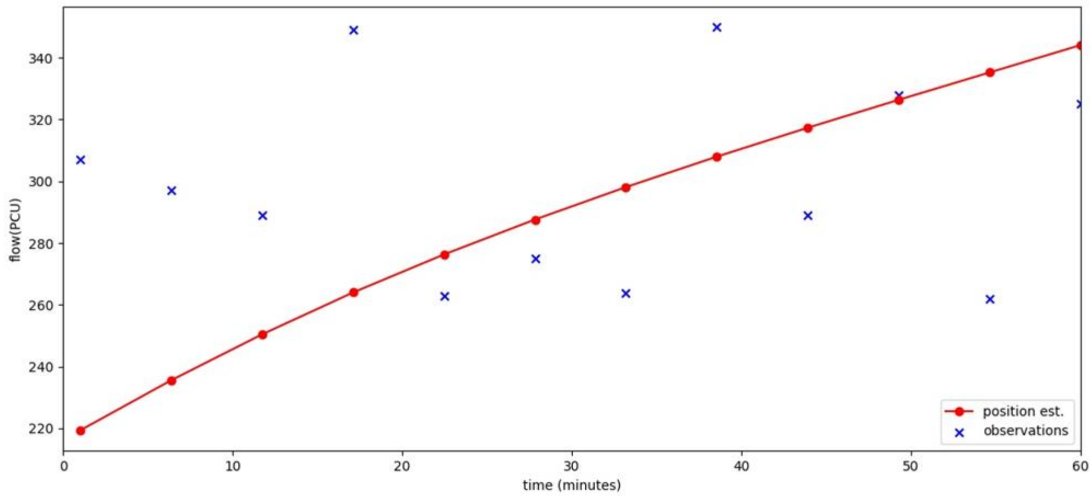


Figure 4.5: Trend predicted by KFT

4.4 MAPE and RMSPE

If xi' = predicted flow count by KFT, xi = observed flow count in field, n = number of observations.

Mean absolute percent error (MAPE) = $\frac{100}{n}\sum_{i=1}^{n}\left|\frac{x_i' - x_i}{x_i'}\right|$

Root mean square percent error (RMSPE) = $\sqrt{\frac{\sum_{i=1}^{n}\left(\frac{x_i' - x_i}{x_i'}\right)^2}{n}} \times 100$

Mean absolute percent error (MAPE) = 15.39%. Root mean square percent error (RMSPE) = 19.36%. MAPE <10% is high accurate forecasting, 10-20% is considered as good forecasting, 20-50% is reasonable forecasting and >50% weak forecasting. RMSPE <25% considers model as acceptable, >25% represents re-calibration needed and 100% means model means model and observed data have very bad conformity.

Chapter Five

Conclusion and Recommendation

5.1 General

This chapter discuss with the concluding remark of the study. The previous the chapter we discuss on the data analysis portion of our research. Traffic flow condition can be predicted through Kalman Filtering Technique (KFT). Level of service (LOS) of road under any scenario can be estimated through KFT. The proposed model can be implemented for other different types of roads, such as, highway, rural road. The KFT is applicable for heterogeneous traffic (like Dhaka city traffic) as well as homogeneous traffic stream. The proposed technique can be used to predicted short duration traffic under different scenarios with good accuracy.

5.2 Findings of the study

Observed and predicted dataset have variance of 1031 PCU and 1624 PCU respectively. KFT predicted flow count have R2 = 0.543 compared to the observed field dataset. The slope of Kalman Filtering Technique (KFT) predicted dataset is slightly positive increasing.

Obtained Mean absolute percent error is 15.39% and Root mean square percent error is 19.36%, which shows that the proposed model is acceptable.

Predicted dataset by Kalman Filtering Technique (KFT) has higher standard deviation, variance and range compared to observed dataset. KFT slightly under estimates the field flow count dataset (observed dataset). The study road segment is getting congested over time as per the prediction by KFT. MAPE shows that KFT have good forecasting to predict traffic flow and RMSPE represents that the KFT predicted model is acceptable.

5.3 Recommendations

Predicted dataset by Kalman Filtering Technique (KFT) has higher standard deviation, variance and range compared to observed dataset. KFT slightly under estimates the field flow count dataset (observed dataset). The study road segment is getting congested over time as per the prediction by KFT. MAPE shows that KFT have good forecasting to predict traffic flow and RMSPE represents that the KFT predicted model is acceptable.

Kalman Filtering Technique (KFT) uses Gaussian distribution for noise and disturbance measurements of dataset. Other filtering technique, such as, extended Kalman Filtering, Unscented Filtering, Particle Filtering combining with KFT may improve model accuracy. The proposed KFT can be incorporated for the route guidance in google traffic map and other traffic apps in real time with better accuracy.

5.4 Summary

Traffic flow prediction by KFT can be used to evaluate among alternative routes It can be conducive to identify trend of traffic congestion and its duration. GPS system, loop detector and other measurement techniques can be easily fuse with the data obtain by video camera record to get more accurate traffic flow prediction. The proposed Kalman Filtering Technique (KFT) can be tested for long term traffic flow prediction along with different time series models.

References

Kumar, S.V., 2017. Traffic flow prediction using Kalman filtering technique. Procedia Engineering, 187, pp.582-587.

Yin, H., Wong, S., Xu, J. and Wong, C.K., 2002. Urban traffic flow prediction using a fuzzy-neural approach. Transportation Research Part C: Emerging Technologies, 10(2), pp.85-98.

Castro-Neto, M., Jeong, Y.S., Jeong, M.K. and Han, L.D., 2009. Online-SVR for short-term traffic flow prediction under typical and atypical traffic conditions. Expert systems with applications, 36(3), pp.6164-6173.

Tan, M.C., Wong, S.C., Xu, J.M., Guan, Z.R. and Zhang, P., 2009. An aggregation approach to short-term traffic flow prediction. IEEE Transactions on Intelligent Transportation Systems, 10(1), pp.60-69.

Abadi, A., Rajabioun, T. and Ioannou, P.A., 2014. Traffic flow prediction for road transportation networks with limited traffic data. IEEE transactions on intelligent transportation systems, 16(2), pp.653-662.

Appendix

Traffic Count Survey Form

The study performs classified vehicle count of a midblock road segment for short duration. The traffic count is conducted through manual counting from recorded video. The video camera is installed in a suitable elevated gantry in the study road segment for the entire survey period in order to record traffic video. Every 5 minutes traffic data are aggregated during vehicle counting. Different types of vehicle are converted to equivalent passenger car unit (PCU) as per IRC: 106, Guidelines for capacity of urban roads in plain areas, Indian Roads Congress (IRC), New Delhi. 1990.

Vehicle type	PCU
Two wheeler	0.75*
Three wheeler (Autos)	2.0*
Passenger car	1.0
Light commercial vehicle	1.4
Bus/Truck	2.2

*If proportion of two wheeler and autos<10% the PCU value will be 0.5 and 1.2 respectively.

General Information

Study road segment*:

Survey Date: Time:

Duration:

Surveyors' Name:

* Preferred road segment where non-motor vehicle are restricted

Vehicle count datasheet						
Time	**Two wheeler**	**Three wheeler**	**Passenger car**	**Light Commercial vehicle**	**Bus/Truck**	**Total (PCU)**
3:00 PM	X 0.75	X 2.0	X1.0	X1.4	X2.2	

	=	=	=	=	=	
3:05 PM						
3:10 PM						

Observations, x	Predictions, x'	x'^2	abs(x'-x)	(x'-x)^2	abs((x'-x)/x')	(x'-x)^2/x'^2	((x'-x)/x')^2
307	219	48122	88	7679	0.40	35.01	0.16
297	236	55499	61	3772	0.26	16.01	0.07
289	250	62726	39	1486	0.15	5.93	0.02
349	264	69699	85	7224	0.32	27.36	0.10
263	276	76349	13	177	0.05	0.64	0.00
275	288	82725	13	159	0.04	0.55	0.00
264	298	88875	34	1164	0.11	3.90	0.01
350	308	94860	42	1765	0.14	5.73	0.02
289	317	100710	28	804	0.09	2.53	0.01

Predictions

[219.36757132 235.58156088 250.4517649 264.00548991 276.31395501 287.61957659 298.11887769 307.99388105 317.34801053 326.3880283 335.25059284 344.10112109]

328	326	106529	2	3	0.00	0.01	0.00		
262	335	112393	73	5366	0.22	16.00	0.05		
325	344	118406	19	365	0.06	1.06	0.00		Observations
	1016893	497	29964	1.85	114.75	0.45			[307. 297. 289. 349. 263. 275. 264. 350. 289. 328. 262. 325.]

Count	12		
RMSE	49.97		
MAPE	15.39 %	R-square	0.543
RRMSE	0.011	equation	0.952
MAE	41.4136592	predicted = 0.952 x observed	
%RMSE	19.36 %		

Output results

Using matplotlib backend: Qt5Agg

Populating the interactive namespace from numpy and matplotlib

fitted model: <pykalman.standard.KalmanFilter object at 0x055D7A90>

RMSE= 49.9696054974964

MAE = 41.413653115816494

MAPE = 13.802449917894863

Observations	KFT data
307	219
297	235
289	250
349	264
263	276
275	288
264	298
350	308
289	317
328	326
262	335
325	344

Predictions

[219.36757132 235.58156088 250.4517649 264.00548991 276.31395501 287.61957659 298.11887769 307.99388105 317.34801053 326.3880283 335.25059284 344.10112109]

Traffic is getting congested

Observations

[307. 297. 289. 349. 263. 275. 264. 350. 289. 328. 262. 325.]

Statistics

Observed Predicted

N Valid 12 12

Missing 0 0

Mean 299.83 288.33

Median 293.0 293.0

Std. Deviation 32.11 40.29

Variance 1031.24 1623.88

Range 88.00 125.00

Minimum 262.00 219.00

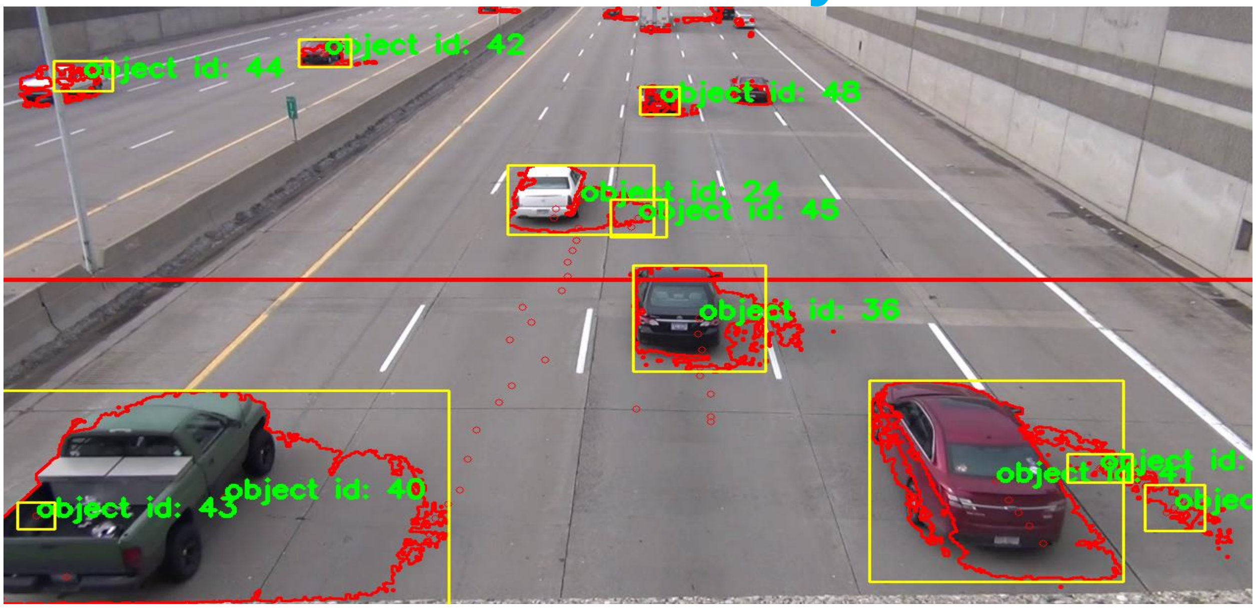
Maximum 350.00 344.00

Percentiles 25 266.75 253.50

50 293.0 293.0

75 327.25 323.75

Traffic Count Survey Form



The study performs classified vehicle count of a midblock road segment for short duration. The traffic count is conducted through manual counting from recorded video. The video camera is installed in a suitable elevated gantry in the study road segment for the entire survey period in order to record traffic video. Every 5 minutes traffic data are aggregated during vehicle counting. Different types of vehicle are converted to equivalent passenger car unit (PCU) as per IRC: 106, Guidelines for capacity of urban roads in plain areas, Indian Roads Congress (IRC), New Delhi. 1990.

Type of Vehicle

Vehicle type	PCU
Two wheeler	0.75*
Three wheeler (Autos)	2.0*
Passenger car	1.0
Light commercial vehicle	1.4
Bus/Truck	2.2

*If proportion of two wheeler and autos<10% the PCU value will be 0.5 and 1.2 respectively.

General Information

Study road segment : Sobhhanbag Masjid and Madrasha complex

Mirpur Road- Dhanmondi- Dhaka

Survey Date: 18/12/2020 Time: 04:00pm -05:00pm
Duration: One hour
Surveyors' Name:

Group : 02

Student Name	Student ID No
Ainul Hassan Rupok	173-47-554
Abidur Reja	173-47-574
Prodip Kumar Kundu	173-47-594
Mst.Mymuna Lucky	173-47-577
Irin Parvin	173-47-585

* Preferred road segment where non-motor vehicle are restricted

Vehicle count datasheet

Time	Two wheeler	Three wheeler	Passenger Car	Light Commercial Vehicle	Bus / Truck	Total (PCU)
04:00pm	79* 0.75	68*2.0	65 * 1.0	07 * 1.4	17 * 2.2	=307.45
	= 59.25	=136	=65	=9.8	= 37.4	
04:05pm	81*0.75	61*2.0	69 * 1.0	09 * 1.4	15 * 2.2	=297.35
	= 60.75	= 122	=69	=12.6	= 33	

04:10pm	77* 0.75	73*2.0	52 * 1.0	08 * 1.4	10 * 2.2	=288.95
	= 57.75	= 146	=52	=11.2	= 22	
04:15pm	72* 0.75	81*2.0	73 * 1.0	13 * 1.4	19 * 2.2	=349
	= 54	= 162	=73	=18.2	= 41.8	
04:20pm	69* 0.75	52*2.0	49 * 1.0	04 * 1.4	24 * 2.2	=263.15
	= 51.75	= 104	=49	=5.6	= 52.8	

04:25pm	85* 0.75	65*2.0	69 * 1.0	03 * 1.4	16 * 2.2	=302.15
	= 63.75	= 130	=69	=4.2	= 35.2	
04:30pm	53* 0.75	71*2.0	41 * 1.0	09 * 1.4	13 * 2.2	=263.95
	= 39.75	= 142	=41	=12.6	= 28.6	
04:35pm	91* 0.75	86*2.0	53 * 1.0	12 * 1.4	18 * 2.2	=349.65
	= 68.25	= 172	=53	=16.8	= 39.6	
	85*0.7	55*2.0	78 * 1.0	03 * 1.4	21 *	

04:40pm	5				2.2	=302.15
	= 63.75	= 110	=78	=4.2	= 46.2	
04:45pm	73* 0.75	69*2.0	61 * 1.0	08 * 1.4	11 * 2.2	=289.15
	= 54.75	= 138	=61	=11.2	= 24.2	
04:50pm	65* 0.75	68*2.0	80 * 1.0	06 * 1.4	25 * 2.2	=328.15
	= 48.75	= 136	=80	=8.4	=55	
04:55p	81* 0.75	49*2.0	60 * 1.0	04 * 1.4	17 * 2.2	=261.

m	= 60.75	= 98	=60	=5.6	=37.4	75
05:00pm	68* 0.75	81*2.0	66 * 1.0	11 * 1.4	14 * 2.2	=325.2
	= 51	= 162	=66	=15.4	=30.8	
	Total Two wheeler PCU	Total Three wheeler PCU	Total Passenger Car PCU	Total Light Commercial Vehicle PCU	Total Bus/ Truck PCU	
	= 734.25	= 1758	= 816	= 135.8	= 484	

python code

```
import numpy as np
import pylab as pl

from pykalman import KalmanFilter
%pylab
rnd = np.random.RandomState(0)
# generate time steps
n_timesteps = 12
x = np.linspace(1, 60, n_timesteps)

# import data from csv file, traffic flow data
from numpy import genfromtxt

my_data = genfromtxt('C:/Users/saurav/Desktop/Project-thesis/Thesis student to be assigned Fall 2020/Gr 2, kalman_filter traffic flow/data1.csv', delimiter=',')
observations = my_data

# create a Kalman Filter by hinting at the size of the state and observation
# space.  If you already have good guesses for the initial parameters, put them
# in here.  The Kalman Filter will try to learn the values of all variables.
kf = KalmanFilter(transition_matrices=np.array([[1, 1], [0, 1]]),
                  transition_covariance=0.01 * np.eye(2))

# You can use the Kalman Filter immediately without fitting, but its estimates
# may not be as good as if you fit first.
states_pred = kf.em(observations).smooth(observations)[0]
print('fitted model: {0}'.format(kf))

# Plot lines for the observations without noise, the estimated position of the
# target before fitting, and the estimated position after fitting.
pl.figure(figsize=(16, 6))
```

```
obs_scatter = pl.scatter(x, observations, marker='x', color='b',
                         label='observations')
position_line = pl.plot(x, states_pred[:, 0],
                        linestyle='-', marker='o', color='r',
                        label='position est.')
pl.legend(loc='lower right')
pl.xlim(xmin=0, xmax=x.max())
pl.xlabel('time (minutes)')
pl.ylabel('flow(PCU)')
pl.show()
from sklearn.metrics import mean_squared_error
predictions = states_pred[:,0]
root_mean_squared_error = sqrt(mean_squared_error(observations,
predictions))
print('RMSE= ', root_mean_squared_error)

from sklearn.metrics import mean_absolute_error
mean_absolute_error = mean_absolute_error(observations, predictions)
print('MAE = ', mean_absolute_error)

def mape(actual, pred):
    actual, pred = np.array(actual), np.array(pred)
    return np.mean(np.abs((actual - pred) / actual)) * 100
print('MAPE = ', mape(observations
```