Time Zone Impact for Traffic Flow Analysis of Ahmedabad City in India

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Keywords: Traffic Flow, Traffic Density, Traffic Volume, Traffic Congestion, Traffic Occupancy.

Abstract: This paper describes time zone impact for traffic flow analysis in an one of major city in India based on one month real traffic monitoring big data. The target city is Ahmedabad of Gujarat state where is located in the west part of India. The current population in Ahmedabad is about 7.8 Million and it is one of rapid economic growing city. These days, the traffic congestion in the city become one of major issues. In order to analyse traffic congestion, large amount of the traffic big data is needed and it is collected through the traffic monitoring camera. The measurement of the data is traffic density, traffic occupancy and average of speed of vehicles which is measured at the road by every minute. The traffic data in emerging countries is not well analyzed so far because of difficulty of collecting traffic data. Author has a chance to involve one of traffic project which provides traffic condition to the drivers through traffic information boards and makes suggestions for avoiding traffic congestion. The current judgement of the traffic congestion is based on the occupancy of the road which is one of traffic flow parameters. This occupancy is not so accuracy sometimes because of difficulty of 100 % vehicle sensing. In this paper, it describes the time zone basis traffic flow analysis in the traffic flow characteristics such as traffic density to average vehicle speed curve, traffic density to traffic volume curve, and traffic volume to average vehicle speed. This analysis is able to identify the effect of time zone to traffic flow condition and provide more appropriate occupancy level for traffic congestion.

1 INTRODUCTION

1.1 Background

The aim of this research is about how to analyse real traffic condition in a developing county, which is still not quite so much before because of lack of infrastructure for collecting data.

Author has a chance to involve one of traffic management project at Ahmedabad city of Gujarat state in India since 2014. The project is installing traffic monitoring cameras at several major roads in the city and showing real time traffic condition through the electrical traffic information sign boards along the roads. The electrical traffic information sign board is usually called “Variable Message Signs (VMS)”, which becomes popular especially on express highway. The traffic condition is calculated from collecting traffic data through traffic monitoring cameras and showing the traffic condition by three classes’ level, heavy congestion, slightly congested, and smooth condition by coloured lines red, yellow, and green. The drivers are able to understand the traffic condition of the road and also recognize other alternative detour to their destination. This project has been started from October 2104 with 14 traffic monitoring cameras and 4 VMSs. And now we have 31 cameras and 11 VMSs as total these days.

On the basis of collecting traffic data, we convert into the basic traffic flow characteristics—traffic density (K) – average vehicle speed (V) or K-V curve, traffic density (K) – traffic volume (Q) or K-Q curve, and traffic volume (Q) – average vehicle speed (V) or Q-V curve. After achieving these characteristics analysis, we have the following two features.

The first one is that each curve has different value based on traffic condition of each road, but the shape of curves are similar. There is a clear boundary observation line in each curve which looks like traffic flow curve from traffic flow theory. But the plotted position of measurement data are widely spread under the boundary observation line, which is different from other advanced countries. The followings sections explain this uniqueness of traffic flow characteristics in Ahmedabad.

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The second one is to show the traffic condition transition by time zone basis traffic flow analysis. This feature provides idea about traffic congestion mechanism from the basic traffic flow characteristics.

The last part, it propose the appropriate occupancy level for the traffic congestion.

1.2 Related Studies

In terms of the study of traffic flow analysis in the emerging countries, there are several related studies these days such as in India. Goutham.M has proving data analysis at National Highway in Hyderabad. It shows trend of traffic condition and comparison with Indian Road standard IRC-106-1990 but measurement points are only two Highways and volume is two days with five CCTVs. In Salim.A et al study, it describes traffic congestion condition by headway measurement in Chennai. But measurement point is only one city road and four days data with one hour for each. It is also limited measurement data.

There are more advanced technology available by using information communication technology (ICT). For example, there is so called Probing technology by collecting traffic data with Global Positioning System (GPS) in side vehicles. This study is estimation by using probing vehicle behavior but this case study is limited number of probe data and a study in the advanced country i.e. Italy. For probing technology based traffic analysis, there are many case studies in the vehicular ad hoc network (VANET) environment. These research are useful to estimation traffic safety application especially in the congested traffic condition. In VANET environment, the advanced communication technology is sued such as Dedicated Short Radio Communication (DSRC), Cellular phone network like Long term Evolution (LTE), 3G, 4G, and 5G etc. Most of the advanced network communication technology has just been released in the advanced countries and will be installed in new manufacturing vehicles in future.

2 TRAFFIC MONITORING SYSTEM AND MEASUREMENT

2.1 Traffic Monitoring System

The total system configuration of Ahmedabad traffic management consists of 14 traffic monitoring cameras and 4 VMSs at the first stage in October in 2014. The traffic data is collected by the traffic cameras and is send to the clod server. The traffic condition is calculated based on the collected data and then the results of calculation analysis of the traffic condition is transpired to VMSs. The total system configuration is illustrated in Figure.1.

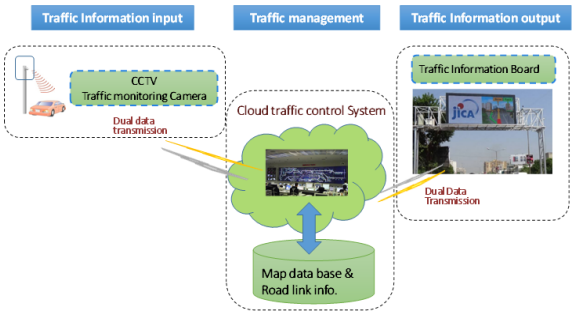


Figure 1: Traffic Management System Configuration.

The location of the traffic management system is the west side of Ahmedabad city where there are new business buildings and new shopping centre and more crowded by people. Therefore .it becomes heavy traffic jams in the morning and the evening every day. The installation place of each cameras and VMSs is shown in Figure.2. In Figure.2, Cam# means Camera and its number. And VMS# means VMS and its number. The number of cameras is 10 in Figure.2 but it is also setting with VMS system. So the total number of camera is 14 (10 plus 4).

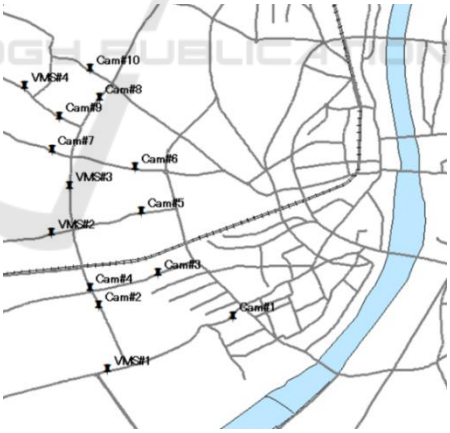


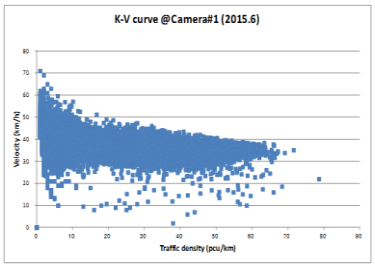
Figure 2: Traffic Management System Location.

2.2 Measurement Data

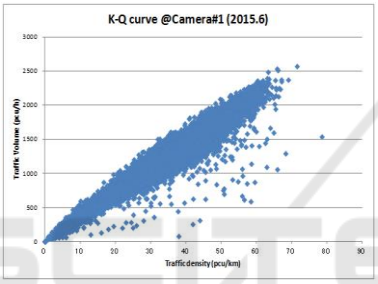
In this section, let's show several examples of traffic characteristics based on measurement traffic data. The Figure.3 (A) shows the traffic density (*K*) to average vehicle speed (*V*) or *K*-*V* curve at the Camera#1 in June 2015. And the Figure.3 (B) shows *K*-*Q* curve at the Camera#1 and Fig.3 (C) shows *Q*-*V* curve at Camera#1. Those three curves are called the

fundamental diagram about the traffic flow characteristics.

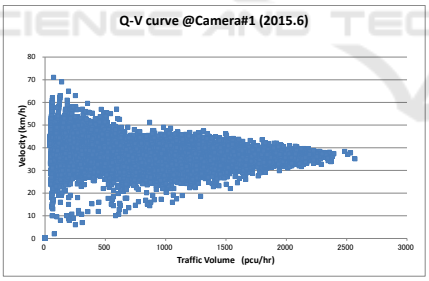
In terms of *K-V* curve, there are several theoretical curves which explains traffic condition. The typical curve is known as Greenshields curve. This curve is linier relationship between the traffic density (*K*) and average vehicle speed (*V*). The illustration of Greenshields curve is shown in Figure.4 (A).



(A) *K-V* curve at Camera#1.



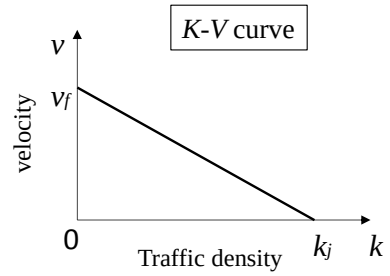
(B) *K-Q* curve at Camera#1.



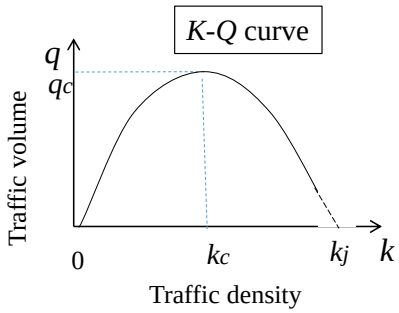
(C) *Q-V* curve at Camera#1.

Figure 3: Basic Traffic Flow curves at Camera#1.

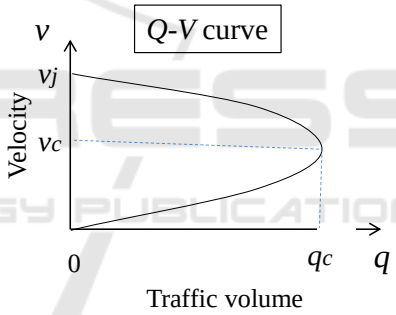
When it is compare between Figure.3 (A) and Figure.4 (A), the boundary observation line in Figure.3 (A) is similar with the Greenshields curve in Figure.4. However there are wide spread measurement data under its boundary observation line in Figure.3 (A). This is also same condition in *K-Q* curve and *Q-V* curve compared with Figure.3 (B) and Figure.4 (B), and Figure.3 (C) and Figure.4 (C). It is also same results from other measurement points. We will see this reason in detail at the chapter 3.



(A) Theoretical *K-V* curve.



(B) Theoretical *K-Q* curve.



(C) Theoretical *Q-V* curve.

Figure 4: Theoretical Traffic Flow curves.

2.3 Theoretical Traffic Flow Equations

From Figure.4 (A), the average vehicle speed (v) is calculated by the equation (1) of the traffic density (k) under Greenshields curve.

$$v = v_f \left(1 - \frac{k}{k_j}\right) \quad (1)$$

where v_f is free flow speed and k_j is the jam density at speed equal to zero condition. The equation (2) is given from the traffic theory.

$$q = k \times v \quad (2)$$

After eliminating v between equation (1) and (2), the equation (3) is achieved.

$$q = v_f\left(1 - \frac{k}{k_j}\right)k \tag{3}$$

Then equation (4) is taken by transforming equation (3).

$$q = -\frac{v_f}{k_j}\left(k - \frac{k_j}{2}\right)^2 + \frac{v_f k_j}{4} \tag{4}$$

Based on the result of equation (4), theoretical *K*–*Q* curve and is shown in Figure.4 (B). It is quadratic curve of traffic density (*k*). As same manner as reaching equation (4), equation (5) is taken by eliminating traffic density (*k*) between equation (1) and (2).

$$q = -\frac{k_j}{v_j}\left(v - \frac{v_f}{2}\right)^2 + \frac{v_f k_j}{4} \tag{5}$$

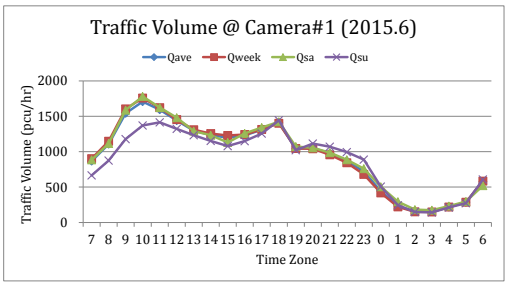
It is quadratic curve of traffic speed (*v*) and it is shown in Figure.4 (C) but x axis and y axis are opposite position.

From comparison between Figure.3 (A), (B) (C) and Figure.4 (A), (B) (C), the boundary observation line in each Fig.4 curve follows each equation (1), (4), and (5). The uniqueness from actual measurement data plot in Figure.3 is widely spread under each boundary observation line. This is big different with the experience in the advanced countries' data.

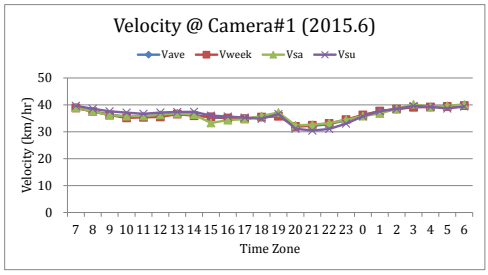
3 MESUREMENT DATA ANALYSIS

3.1 Actual Traffic Condition

In this chapter, it describes the analysis with actual traffic condition during 24 hours for one month in June 2015. The Figure.5 (A) shows time zone base traffic volume (*q*) transition at Camera#1 from 7:00 am to 6:00 am in the next day and Figure.5 (B) shows time zone base average vehicle speed from 7:00 am to 6:00 am in the next day. The measurement data is plotted by average, weekday average, Saturday average, and Sunday average.



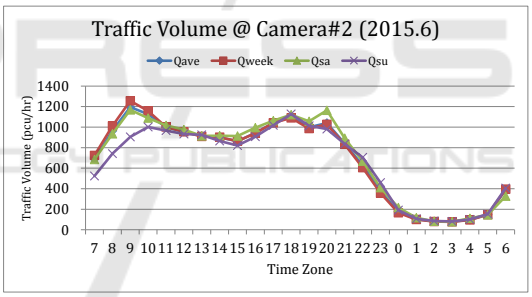
(A) Time Zone based Traffic Volume at Camera#1.



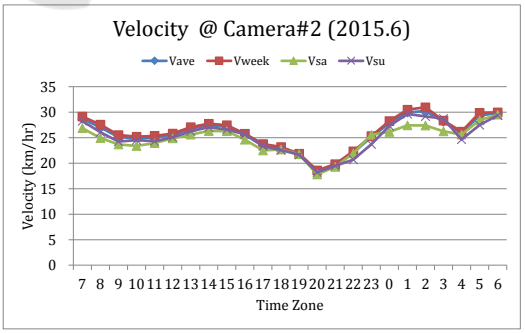
(B) Time Zone based Vehicle speed at Camera#1.

Figure 5: Actual Traffic Condition at Camera#1.

In case of Camera#2, Figure.6 (A) and (B) show time zone based traffic volume and speed.



(A) Time Zone based traffic volume at Camera#2.



(B) Time Zone based Vehicle speed at Camera#2.

Figure 6: Actual Traffic Condition at Camera#2.

From both Figure.5 and Figure.6, there are two peak of traffic volume in the morning and in the evening. But the vehicle speed drop in the evening at

Camera# 2 is significant compared by that of Camera#1, which means there is heavy traffic jam in the evening at Camera#2.

3.2 Time Zone based Fundamental Diagram

In this section, there is more detail traffic congestion condition observation by considering the relationship between congestion condition and its traffic fundamental diagram of the time zone. In order to simplify characteristics, it defines six time zones from T1 to T6 as shown in Table 1 rather than each hourly data like Figure.5 and 6.

Table 1: Time Zone Classification.

Zone Name	Time Zone
T1	7:00 – 10:00
T2	11:00 - 14:00
T3	15:00 - 18:00
T4	19:00 - 22:00
T5	23:00 - 2:00
T6	3:00 - 6:00

As the first case study, it describes the fundamental characteristics of Camera#1. In terms of the traffic congestion condition, it is used the occupancy percentage by time zone in Japan. The Figure.7 shows the occupancy value at Camera#1 by time zone basis. According to Figure.7, the most congested condition is occurred at Time Zone T4, when it starts from 19:00 to 22:00. The traffic volume at T4 is the second peak of traffic volume but the average vehicle speed is slightly lower than that of Time Zone T2 of which traffic volume is first peak at Camera#1. Therefore it can be said that the traffic condition at T4 is more congested at Camera#1.

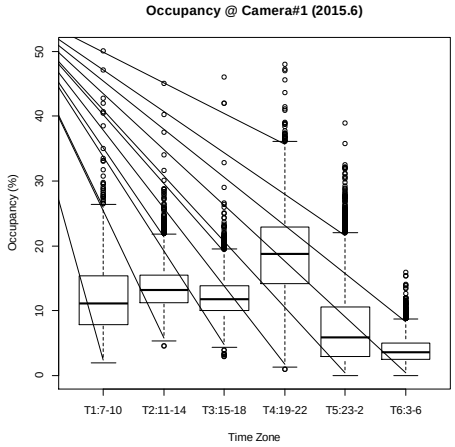
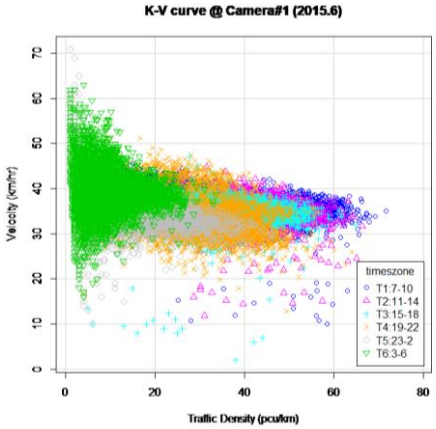
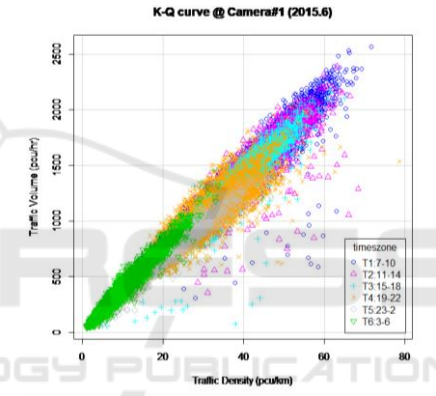


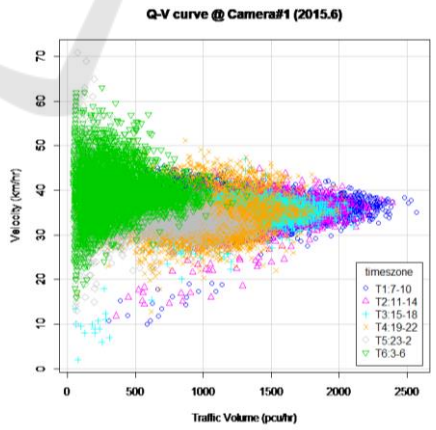
Figure 7: Occupancy at Camera#1.



(A) *K-V* curve at Camera#1.



(B) *K-Q* curve at Camera#1.



(C) *Q-V* curve at Camera#1.

Figure 8: The Time Zone basis Fundamental Diagram at Camera#1.

In case of the fundamental diagram at Camera#1 by Time Zone, there are *K-V* curve, *K-Q* curve, and

Q-V curve at Camera#1 in Figure.8. It is clear that the area under the boundary curve is the data from congested time zone T1, T2, and T4 from Figure.8 (A). There are also lots of measurement data under the boundary observation line in each Time Zone. From Figure.8 (B) and (C), the critical traffic volume happens at Time Zone T1, which is the first traffic volume peak of the day. This condition is clear from Figure.5 and 6. But in case of the fundamental traffic characteristics, it is clearer by using divided six time zone. The grey colour area is mixed measurement plots. In Figure.8, each dot is real measurement data by every minute during all days in June 2015. So total number of plots is 43,200 points (=60 minutes x24 hours x30 days).

In case of Camera#2 where we see more traffic congestion condition, the occupancy percentage is shown in Figure.9.

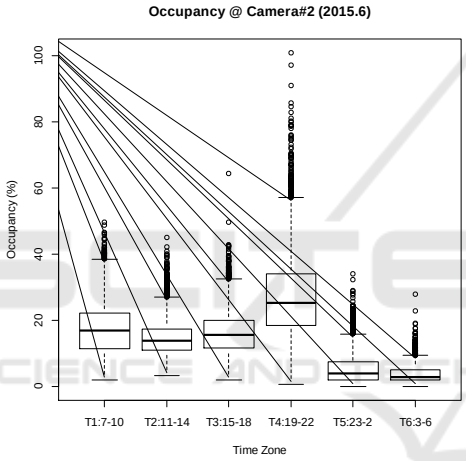
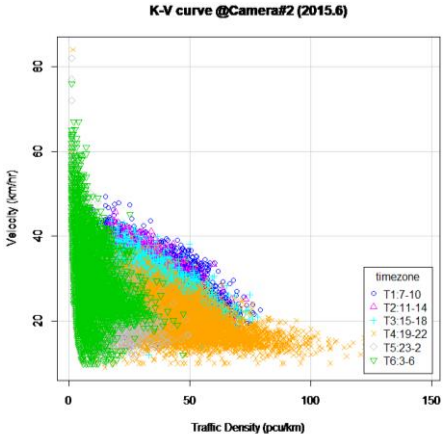
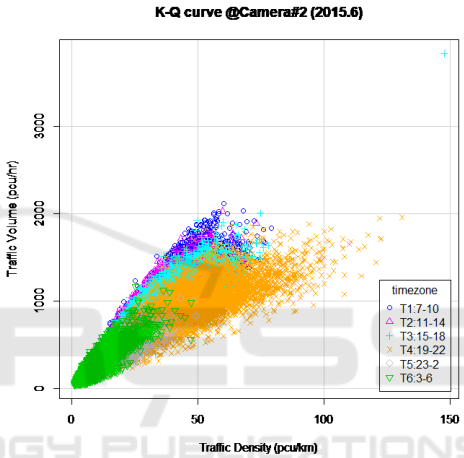


Figure 9: Occupancy at Camera#2.

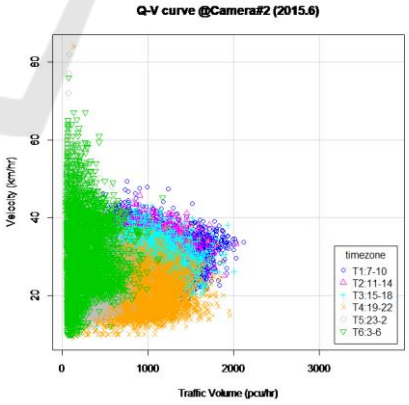
And the fundamental diagram of Camera#2 is shown in Figure.10. The trend of each fundamental curves of Camera#1 and Camera#2 is similar. But there is particular differentiation, especially in case of *K-V* curve. According to Figure 6 (B), the vehicle speed during 18:00 to 22:00 (T4) goes down, which means that traffic condition becomes congested. Therefore in Time Zone basis Fundamental Diagram, T4 (Brown colour) portion is lower position in each curves.



(A) *K-V* curve at Camera#2.



(B) *K-Q* curve at Camera#2.



(C) *Q-V* curve at Camera#2.

Figure 10: Time Zone basis Fundamental Diagram at Camera#2.

4 CONCLUSIONS

From the view point of big volume measurement data, this is the first time to make a detail traffic flow analysis in one of major mega city in India. The Ahmedabad city of Gujarat state is a one of typical rapid economical grow area in India. Author analyses one moth traffic flow data based on the traffic flow theory. By using the uniqueness of the traffic flow characteristics, it is valid to consider the boundary observation line in the fundamental diagram from its traffic flow theory equation. The following are conclusion of this study.

- The boundary observation line of the fundamental diagram is representative of its traffic flow characteristics.
- The area under the boundary observation line of the fundamental diagram comes from data of congested traffic condition time zone.
- The critical traffic volume comes from the peak traffic volume time zone.
- The traffic flow model is different from those of the advanced countries by measurement data spread plot.

This study is the begging of the analysis of traffic flow in developing country and it provides different thoughts about traffic congestion reason. And it is necessary to have more study about this kind of research such as driving behaviour, road line effect, different city case study, long term data collection.

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APPENDIX

There is little reference about the Boundary Observation method in the Appendix. The Figure.A-1 shows k-v curve at driving lane of Camera#1 with approximate line by Boundary Observation method and Least Square method. The Least Square method is generally used in Statics Analysis for understand the trend of measurement data. From Figure.A-1, the equation by Least Square method is right rising curve, which does not follow the traffic flow theory. On the other hand, the equation by Boundary Observation method is right downward curve and follows the traffic flow theory. In this example, the Boundary Observation method shows the traffic flow limitation of each road.

In case of *K*-*Q* curve at Camera #1, the traffic flow characteristics is shown in Figure.A-2. The Boundary Observation equation of *K*-*Q* curve is $q = -0.3516(k - 80)2+2250$. Therefore the jam density kj=160. From equation (4), the free speed v_f =56.25. When the Least Square equation of *K*-*Q* curve from Figure.A-2, the traffic volume $q = -0.022k^2 + 31.213k + 4.689 = -0.022(k\text{-}709.4)^2 + 503233.2$. The jam density k_j =1418.772. Then free speed v_f = 31.21. It does not match with v_f of Figure.A-1.

As the result, it is able to say that the Least Square method shows the trend of traffic measurement data

but it does not provide the traffic parameter data such as jam density and free speed.

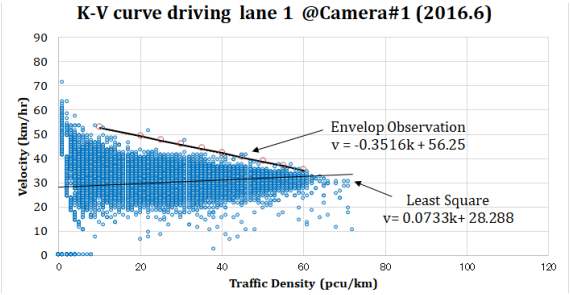

Figure A-1: *K-V* curve driving lane at Camera#1.

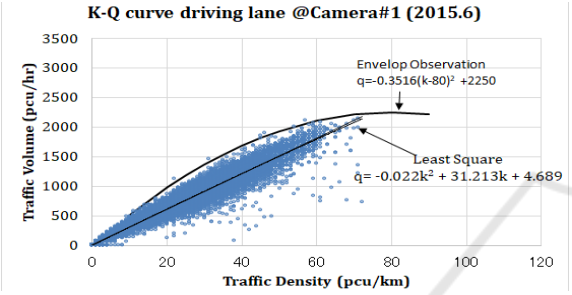

Figure A-2: *K-Q* curve driving lane at Camera#1.