DYNAMIC TRAFFIC MANAGEMENT TO REDUCE THE CONGESTION AT TOLL PLAZA BY USING VARIABLE MESSAGE SIGNS (VMS)

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February, 2014

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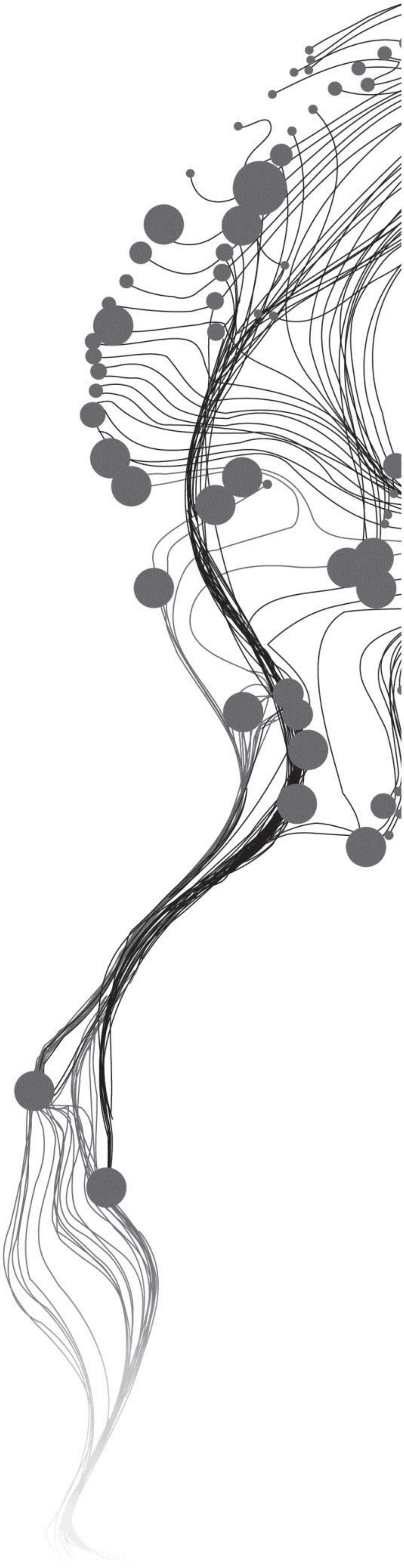

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TAUFIK SUGIAN SUMARDI
Enschede, The Netherlands, February, 2014

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ABSTRACT

From the travellers' perspective, the traffic condition may be improved by providing information. The importance of using variable message sign (VMS) for traffic congestion management was justified to ease the congestion at toll plazas as the critical nodes of traffic network

The objective of this research is to make a model of congestion prediction as inputs for variable message sign (VMS). The VMS will give reliable information based on the calculation of empirical traffic data. It is hoped that this prediction helps travellers in making a decision to avoid the congestion before they choose a certain exit of toll road system.

Located around the borderline of Bandung City, Padaleunyi section is the busiest section of Purbaleunyi toll road that links Bandung with Jakarta, the capital city of Indonesia. There are five interchanges on Padaleunyi section that lead the traveller to the city and each of them is equipped with VMS prior to its interchanges. These VMS are displaying the information of traffic condition at toll plazas based on visual observation of toll booth operators that caused flawed information and resulting exacerbate congestion on the toll road outlet.

This research has been done by a quantitative approach by firstly explored possible method in order to treat a large amount of traffic datasets. Rigorous efforts were done in order to make the available data meet the criteria as complete and consistent training datasets. The test of statistical distribution from a certain group of observation was done before predicting accumulated vehicles at toll plaza to assign the input of messages on VMS. The eventual strategy to avoid the congestion on Padaleunyi section is by displaying both quantitative and qualitative information on the VMS.

Although the simulation was built over several assumptions, several proof showed that the prediction of queuing vehicle at the toll plaza is more likely similar to the actual condition.

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1. INTRODUCTION

1.1. Background

Implementation of Intelligent Transportation Systems (ITS) on toll roads has been growing rapidly in the last few decades. Compared to the non-toll roads, people rely on the higher level of service of the toll roads in providing congested-free routes. The provisions of such demand to support their mobility are believed can enhance the socioeconomic level, and reduce noise and air pollution, to achieve sustainable transportation systems.

Nowadays, toll plazas are representing the critical nodes of traffic network that causes delays and pollution (Astarita et al., 2001). Despite technological development in toll collecting systems, a closed-system toll road always requires many service booths in order to reduce queues of vehicles and to enhance throughput at the exit and the entrance of the gates. However, if the total of incoming flow is beyond the downstream capacity, traffic congestion at the toll plaza is inevitable (Papageorgiou et al., 2008).

From the travellers' perspective, the traffic condition may be improved by providing information. In fact, available transport infrastructure will be more efficient if the provision of travel demand management tools, such as travel information, helps travellers to make better choices (Arnott et al., 1991). Sheu and Yang (2008) and Papageorgiou et al. (2008) noted the importance of variable message sign (VMS) for traffic congestion management and improvement of traffic efficiencies (Shaokuan et al., 2008). VMS is one of the major component in Intelligent transportation systems (ITS) since it provides a variety of information related to traffic such as traffic conditions, speed limits, and alternatives routes (Jindahra & Choocharukul, 2013).

Many toll road operators utilize VMS to deal with congestion issues. These VMS are placed at each outlet interchange and aim to inform travellers about the traffic situation of certain toll plaza. It is expected that travellers will use the traffic information displayed to change their behaviour, leading to reduce congestion. The traffic will evolve response to travel behaviour changes, in response to VMS information. It is important to provide valid traffic information displayed on the VMS derived from a scientifically sound method and based on verifiable data instead of personal intuition. A proactive traffic management should be deployed to anticipate the reactive manner that causes a lag between data collection and strategy to control the traffic (Smith et al., 2002). This research aims to simulate the traffic condition based on single traffic detection zone prior to the exit of each toll plaza. The simulation results will become inputs for VMS to give reliable information for the traveller before they choose a certain exit of toll road system. Nonetheless, since all detectors are placed within the closed toll road system, anything related to traffic behaviour, volume, and congestion outside the toll road system is excluded from the scope of this research.

1.2. Problem Statement

Congestion slows down socioeconomic activities, creates air and noise pollution, and causes loss of man hours. In the case, congestion invariably occurs at toll plazas, where people are lining up to pay the tariff of their use of the toll road before they exit into normal road system.

This research is an effort to ease potential traffic congestion at toll plazas by addressing the message to be displayed on VMS. Since manually-inputted VMS of the flawed information most probably will worsen the traffic congestion, hence, to provide intelligent and trustworthy information through VMS to the toll road users is inevitable. Similarly, there has to be a strategy to distribute the traffic to other toll plazas so the congestion will be avoided.

There are two separate concepts in order to give reliable information to the travellers by operationalization of VMS as shown in Figure 1. The first concept is "traffic flow identification" which deals with statistical distribution of traffic flow and incorporates variables such as: intensity, mean of speed, and standard deviation of mean speed (Huisken & van Maarseveen, 2006). The second concept is "congestion simulation" which includes reservoir's occupancy, queue length, and toll booths' throughput.

Traffic congestion simulation will be based on the length of queued vehicles and occupancy of reservoir area before the toll plaza. Logically, if traffic flow predicted is less than throughput of toll plaza (i.e. its capacity), then there will be no congestion.

The third concept is related to the VMS board, is employed to disseminate the information. This concept is constructed by estimated thresholds to display information on VMS. The type of information is formulated in chapter 4.4.

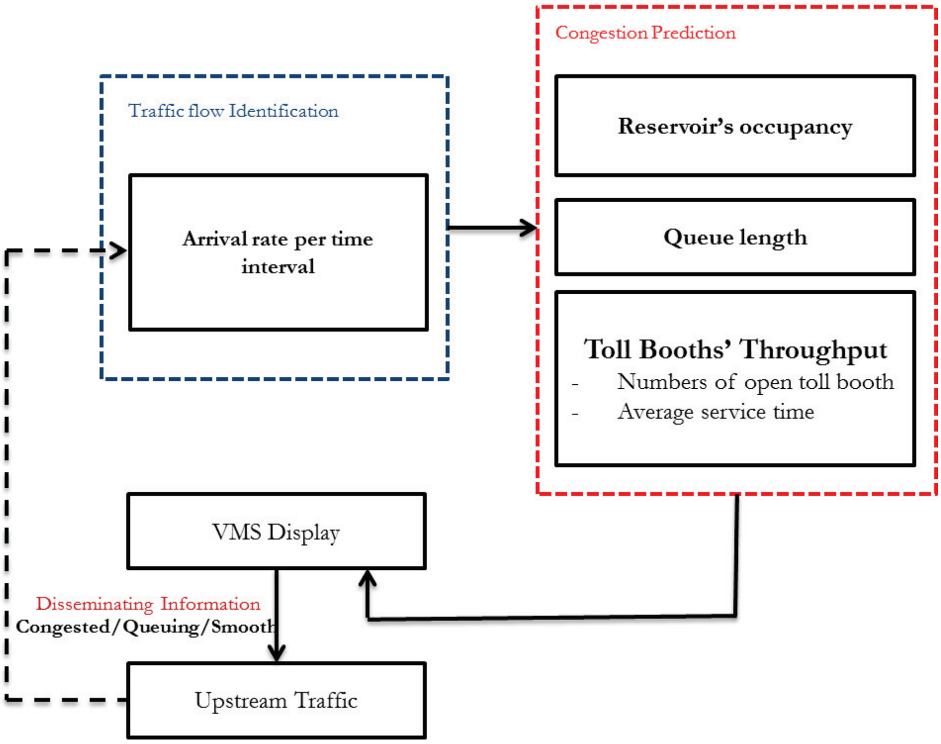


Figure 1 Conceptual framework

1.3. Research Identification

1.3.1. Research Objective

The objective of this research is to make a model of congestion prediction as inputs for VMS. The VMS will give reliable information for the traveller to avoid the congestion before they choose a certain exit of toll road system. With the intention of creating transparent results, this data driven research is conducted to achieve the following sub-objectives:

1. To extract datasets derived from utilization of dual virtual loop detector at each outlet that leads to toll plaza,
2. To simulate the congestion at each toll plaza as a result derive from upstream traffic flow,
3. To disseminate information to the traveller (upstream) by VMS based on simulated traffic condition at each toll plaza (downstream)

1.3.2. Research Questions

The research questions are formulated on the basis of each sub-objective in order to give expectation of ways to answer it by operational research methods.

Sub-objective 1: To extract datasets that are derived from utilization of dual virtual loop detector at each outlet that leads to toll plaza

- What are the available data that can be used for modelling/analysing traffic flow?
- Which methods are most suited for data extraction?

Sub-objective 2: To simulate the congestion at a toll plaza as a result that is derived from upstream traffic flow

- How is the correlation between the traffic flow with the forming of vehicle queue in the reservoir area?
- Under what conditions of the traffic flows that causes queue forming in the reservoir area?
- How will the throughput of toll plaza affect the queue?

Sub-objective 3: To disseminate clear and reliable information to traveller (upstream) by VMS regard to traffic condition at a toll plaza (downstream)

- Which type of message should be delivered to travellers to avoid ambiguity?
- How precise are the messages shown to upstream traffic compared to the actual conditions?

1.3.3. Thesis structure

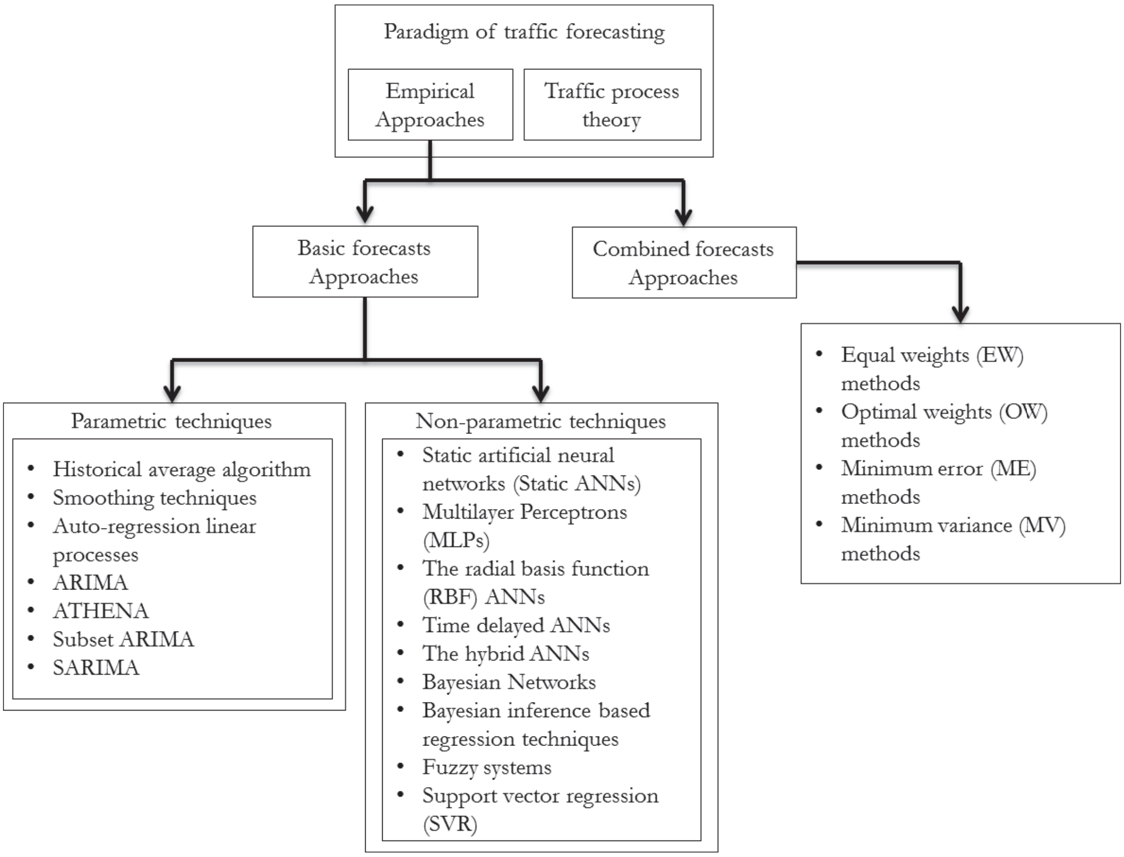
This thesis consists of six chapters. Chapter 1 consists of the outline of the background, justification and the objective of the research. Chapter 2 gives details about the ideal VMS works based on short term actual traffic flow prediction. States of the art of previous works in order to support this research are also deployed in this chapter. The explanation of case study area that is used in this research stated in the Chapter 3. The research methodology consists of data extraction and data error measurement is explained in the Chapter 4. As different methodologies are relevant to the topic, this chapter considers the methodology that will be carried out by the author as the steps to reach the objectives. Then, the result will be presented in the Chapter 5, and completed with discussions so that the interpretation will be well defined in the Chapter 6.

2. FORMULATING THE RELIABLE VMS

This chapter discussed about several methods which were used in formulating the reliable VMS. This ideal approach includes traffic flow prediction derived from traffic detections and queuing simulation that occurred at toll plazas. Also, previous research on VMS as a time saved measurement will be explained as a basic theory to determine the type of messages that should be displayed on the VMS. The last paragraph of this chapter explained the scope of this research as an initial effort to make the trustworthy VMS as one of traffic management tools.

2.1. Traffic flow prediction

Traffic volume prediction is one of the problems as well as traffic congestion prediction and travel time prediction (Yang, 2013). Furthermore, traffic condition such as traffic flow, travel time, and occupancies can be important factors that contribute to optimal advanced traffic management. Van Arem et al. (1997) separate traffic forecasting into two paradigms. The first paradigm is incorporating standard statistical methodology, and the second one is based on demand and supply. In Figure 2, proximity of empirical approaches of traffic prediction were organized by Zhang (2012). He differentiated the basic and combined approaches into two categories. The combined approaches are the types of forecasting methods which combine two or more forecasts. The differences between those two approaches lie on the robustness and accuracy of the prediction models. The basic approaches are based on the individual prediction models, whereas combined approaches incorporate the efficiency of the combination.



(Based on Zhang (2012))

Figure 2 Traffic forecasting approaches

Huisken and van Maarseveen (2000)compared six various short-term congestion prediction methods. Multi-linear regression, time series analysis, multi-layer perceptron, radial basis function networks, self-organising systems, and fuzzy logic were deployed to forecast congestion within the A10 Motorway in The Netherlands. These data driven methods used four week periods of traffic data containing volume, occupancy and speed. The methods were tested by comparing the prediction performances with existing data and use a reliability indicator and a congestion indicator to describe the state of traffic. Since the method of self-organising maps produced large errors, effectively they compared only 5 methods. The results of the errors are almost equal for time series analysis (ARMA), MLP neural networks, RBF neural networks, and fuzzy logic which outperformed the MLR method.

Auto-regression Integrated Moving Average (ARIMA) is a model to forecast time series. This is the most general class of model and a flexible tool that helps to understand complex data, and predict future data points (NAG, 2011). Many variant of ARIMA models were being constructed in order to reduce the gaps between predicted and observed data as a robust and accurate traffic prediction methodology (Min & Wynter, 2011).

Deploying traffic detector for data collection such as inductive loop, optical sensor, and image analyser is frequently useful for traffic management purposes. However, since typical data from the traffic detector is aggregated in pre-set time intervals (Hazelton, 2004), traffic engineers often found bias in less aggregate data if it is compared to manual counting which deals with individual vehicle level.

Traffic flow series have a unique pattern that cannot be accommodated by a single ARIMA model. Therefore, Yu and Zhang (2004) made a modification by creating a so called switching ARIMA, which defines the hidden state of traffic flow changing. They fitted each transition of pattern changing with a separate ARIMA model with the assumption the pattern will last for some duration. Because of the fact that ARIMA is a univariate model, it does not consider the relationship between variables, and is not describing the factors which support the predicted data (Segura & Braun, 2004). Also, the non-linearity of traffic demand can not be easily captured by ARIMA models which only use linear combination as their measurements (Thomas et al., 2010)

The ideal approach to traffic forecasting is a network-based simulation model (Smith et al., 2002). Extensive utilization of traffic detector can contribute to provide real-time traffic data as a major requirement of traffic flow prediction. In many developed countries such as The Netherlands, traffic data collection is derived from a high concentration inductive loops within its road networks (Thomas et al., 2010). However, in this research, the information of traffic volume and velocities is yielded only from a single detection zone at each toll road's outlet. Smith et al. (2002) noted the single detection zone can be an important subset as a time series problem to predict the future traffic flow. It can be treated as a historical algorithm whereas old information in regular intervals is measured to predict the next interval.

The data availability derives from day-by-day traffic counting makes the profile of a whole day can be easily seen from its historical data. The seasonal and non-linear features also have been portrayed by the profile. Eventually, this research will observe systematic variation based on historical algorithm proposed by Thomas et al. (2010). They concluded, by using this model, the errors are very small so the short-term traffic predictions are nearly accurate. Therefore, this method considered simple in making prediction of traffic flow.

2.2. Queuing simulation at toll plaza

In the past decades, studies were concerned with toll gate optimisation with the objective to estimate the optimal number of tollbooths. They calculated the minimal number of toll booths that should be operationalized in a typical morning and evening rush hour.

The complexity of the queuing processes at the toll plaza makes simulation the more appropriate approach, when we compared to analytical queuing methods (Van Dijk et al., 1999). This simulation incorporates the traffic volume from the detectors prior the services, extent of queuing area, and throughput after services.

The queue at the toll plaza is the length of the line of vehicles that will eventually pass through the exit toll booths to receive services (Figure 3). Mean arrival rate (λ) is expressed in term of vehicles/minute while inter-arrival time (τ) is a dimension in minute. Standard variable names include the length of the queue (q), stated in minutes, andN_q, the number of vehicles waiting to receive service. Also, N_s is the number of vehicles in the service with s is service time per vehicle.

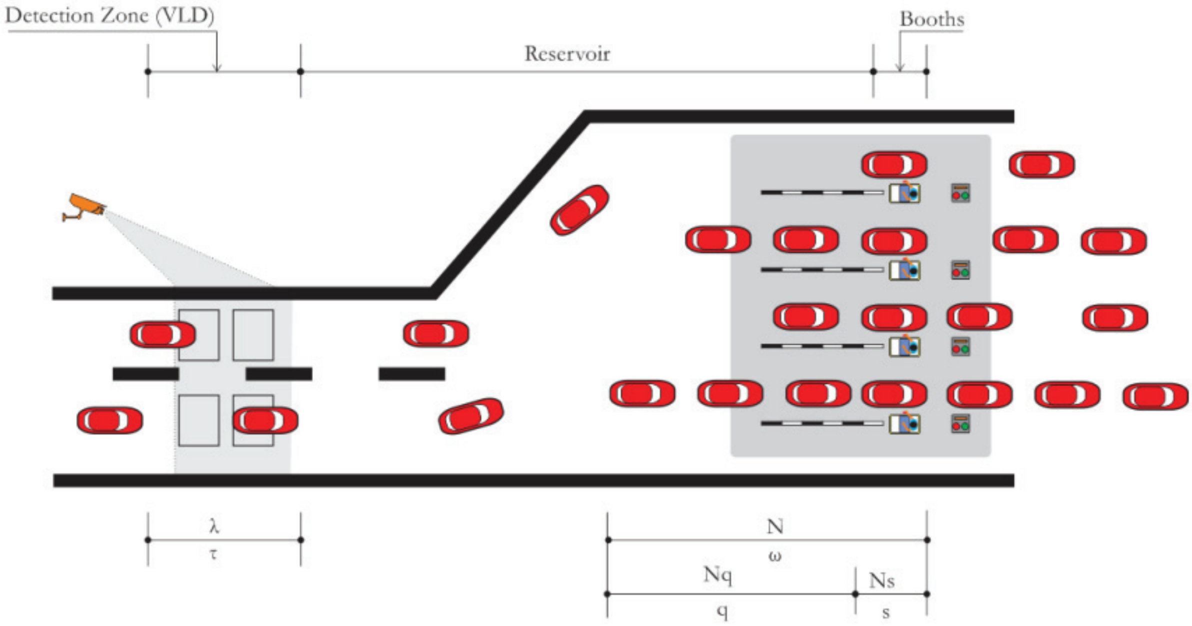


Figure 3 Schematisation of queuing system at toll plaza

The simulation of queuing vehicles at toll plaza can be accomplished using traffic flow data acquired from detectors towards it. The determination of statistical distribution of arrival rate, and service time rate (throughput) should be achieved before the calculation of queuing system's performance. Hypothesis testing helps to decide whether a group of observations are according to a certain type of statistic distribution.

To measure the toll plaza performance is to calculate the travel time through the service booth (Morrow, 2005). As drivers' objective, by moving as quickly as possible at the toll plaza, the performance of the queuing system is essential to derive the parameters such as length of the queue, number of vehicles in the queuing system, and the time that drivers need to stay in the queue until they are serviced.

In this research, traffic flow parameters such as arrival rate and throughput rate of toll gate will be treated as major components to predict the congestion. Particularly, the congestion which about to predict will be occurred in the reservoir area prior to the toll plaza. Thus, the prediction will be the input for the information displayed on the VMS. Eventually, the measurements as the length of the queue, number of vehicles in the queuing system and the time that drivers spend in the queue line, will be performed as quantitative information for the upstream traffic before they are choosing a certain toll road exit.

2.3. Displayed information on VMS

Jou et al. (2005)mentioned four categories of real time traffic information as qualitative information, quantitative information, qualitative guidance and quantitative guidance. Firstly, Jou et al. (2007)divided the traffic information into two category, qualitative and quantitative information. In qualitative information, a descriptive category such as "high", "medium", and "low" is used to describe route's travel speed. Unlike qualitative one, quantitative information shows numerical description such as "100 km/h", "60 km/h" and "30 km/h" to describe high, medium, and low route's travel speed respectively. Secondly, guidance instructions are embedded to both types of information in order to alternate the traffic to less congested routes. There are three level of guidance instruction: "switch", "recommend to switch", and "strongly recommend to switch". These types guidance are usually based on travel time measurement. "Switch" guidance is applied on low category of travel speed and low travel time. "Recommend to switch" is provided on high travel time and medium category, or medium travel time and low category. Finally, "strongly recommend to switch" guidance is applied on routes when the travel time is high and have low category. This explanation can be described in Table 1 .

Table 1 One of the example of quantitative and qualitative traffic information interpretation

(Adapted from: Jou et al. (2007))

Attribute levels	Qualitative	Quantitative (km/h)	
		Freeway No.1	Freeway No.2
High	Smooth	100	100
Medium	Normal	60	60
Low	Congested	30	30

The congestion control can be handled by dynamic real-time guidance with dynamic prediction as a main component (Srinivasan et al., 2009). Moreover, The ability of dynamic travel information, especially travel time information, can reduce the total network travel time which outperformed the time for the re-current congestion (Lam & Chan, 2001). Jindahra and Choocharukul (2013) explained the implication of the VMS design which can contribute to the change of motorist demand in diverting their route or to stay at the same route. They described several measurements of how the motorists react to the information displayed on VMS. The VMS equipped with information about delay cause, will more likely change the motorist behaviour compare to VMS that shows only quantitative time delay. The information qualitative time delay also makes a significant increase on route diversion. Furthermore, the VMS showed the cause of delay and route suggestion will raise the diversion proportion.

In contrary, Sutandi (2008) found insignificant role of VMS in changing travel behaviour within Bandung city road network. In her survey, 68% percent of respondents assumed that the other alternative roads are congested as well. It is clearly indicates that most of all Bandung commuters rely on their experience in choosing their routes and quite familiar with the traffic conditions.

Unlike the road network within the city, most of all the traffic on Padaleunyi Toll Road comes from outside Bandung, especially on weekends and holidays. Because of insufficient research for the use of VMS on toll road in Indonesia, this research will be an initiate effort in finding the proper methodology of displaying the guidance based on local traffic characteristic.

There are three performance indicator with regard to queuing at toll plazas, according to Van Dijk et al. (1999). The first indicator is the distribution of waiting time; define as the percentage of vehicles that have to wait in certain period of time. Second, queue lengths that depend on service times, waiting times, and vehicles' arrival pattern, and third, percentage one toll booth served the toll road user, as they mentioned as workload.

2.4. Scope of this research

This research only deployed limited criteria as a reliable VMS. In other words, this research will be act as a little part of the puzzle in making a reliable VMS to relive the congestion. Specifically, the result will replace the existing manually inputted VMS method with scientifically sound method.

As traffic prediction needs an excessive traffic flow data, such part of the method was clearly excluded due to limitation of detection zone and data adequacy in this research. In fact, it is only considered temporal fluctuation on the single traffic detection zone on toll outlets.

The extrapolation of spatial regularity for a whole networks was unlikely to be done. Thus, the guidance messages which escort the travellers to a certain exit were also excluded from the option. In line with the expected outcome of this research, to improve traffic distribution towards each toll outlet of Bandung is to encourage the travellers to stay on the main route until they exit the toll roads with less congested outlet. Consequently, by synthesizing Jindahra and Choocharukul (2013) and Jou et al. (2005), the eventual strategy to avoid the congestion on Padaleunyi section is by displaying both quantitative and qualitative information on the VMS .

3. CASE STUDY AREA: PADALEUNYI TOLL PLAZAS

Although it is strategically located in the centre of West Java province, Bandung city lies at the mountainous area which takes 4 hours to travel by bus or car, and 3 hours by train from Jakarta, the capital city of Indonesia. The enhanced agglomeration of economy has created an intense linkage of these two cities (Firman, 2009). People used to reach Bandung by using Jakarta-Cikampek toll road and continued with narrow and winding roads in northern part of the city. As a shopping paradise, Bandung continues to attract people as a tourism destination (Hapsariniaty et al., 2013).

The Purbaleunyi toll road has been in operation since 2005. It connects three cities of Purwakarta-Bandung-Cileunyi for 123 kilometres. As can be seen in Figure 4, Purbaleunyi is divided into two sections of Cikampek-Purwakarta-Padalarang (Cipularang) section (red line) and Padalarang-Cileunyi (Padaleunyi) section (blue line). It has reduced the travel time from 4 hours to 2.5 hours in the normal traffic circumstances from Jakarta to Bandung city. This easy access increases migration rate (Hapsariniaty et al., 2013) and leads to increased traffic volume.

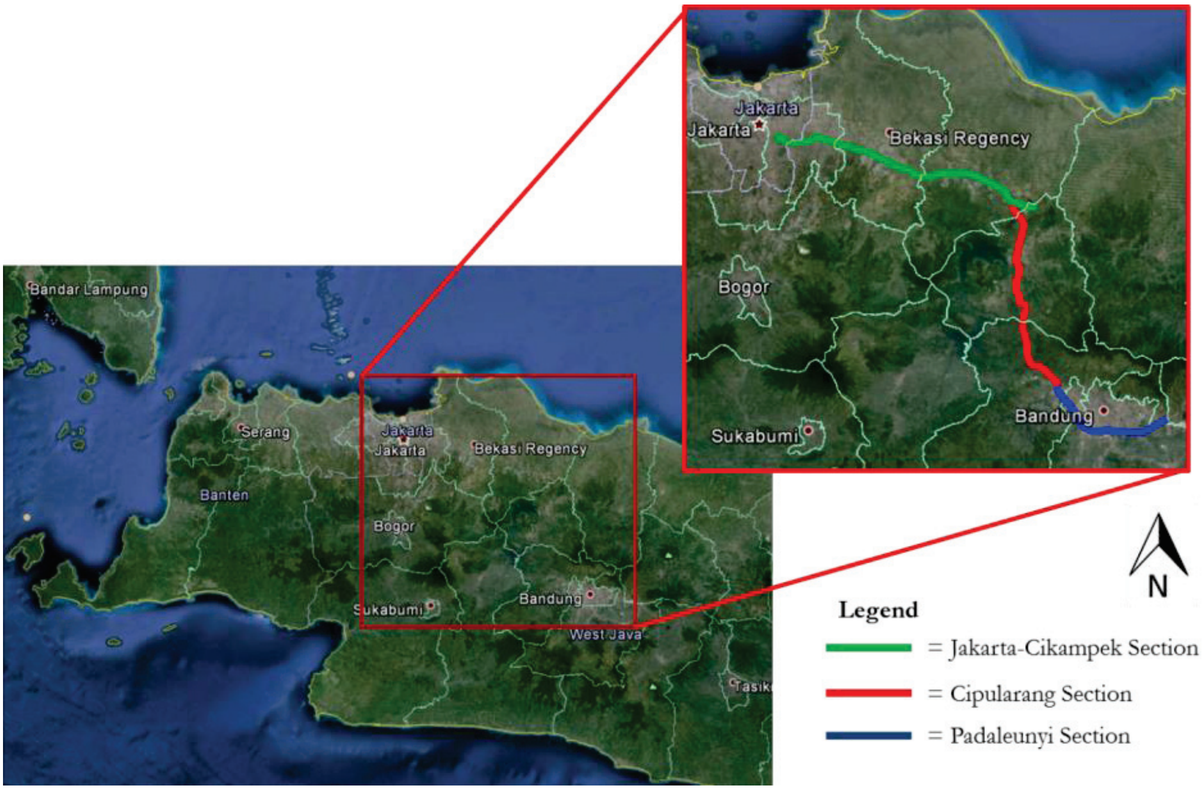


Figure 4 Three sections of toll road which connects Jakarta and Bandung (Source: Google Earth, 2014)

Padaleunyi section is the busiest section of Purbaleunyi toll road. It is located around the borderline of Bandung City and its neighbouring municipalities. According to the toll road operator, the annual average daily traffic (AADT) of Padaleunyi toll road was of approximately 165,000 vehicles per day in 2012 (Jasa Marga, 2013).

There are five interchanges on Padaleunyi section that lead the traveller to Bandung city. They are Pasteur, Pasirkoja, Kopo, Moh.Toha and Buah Batu (Figure 5). The travellers preferably choose to exit at Pasteur toll plaza in order to reach city centre and some favourite mountainous nature in the northern part of Bandung. For some periods of time, Pasteur toll gate becomes the most congested outlet due to a disproportionate distribution of traffic queuing in comparison to other toll plazas. In January 2012, the queue of vehicles reached 3 kilometres of length (Hardi, 2012).

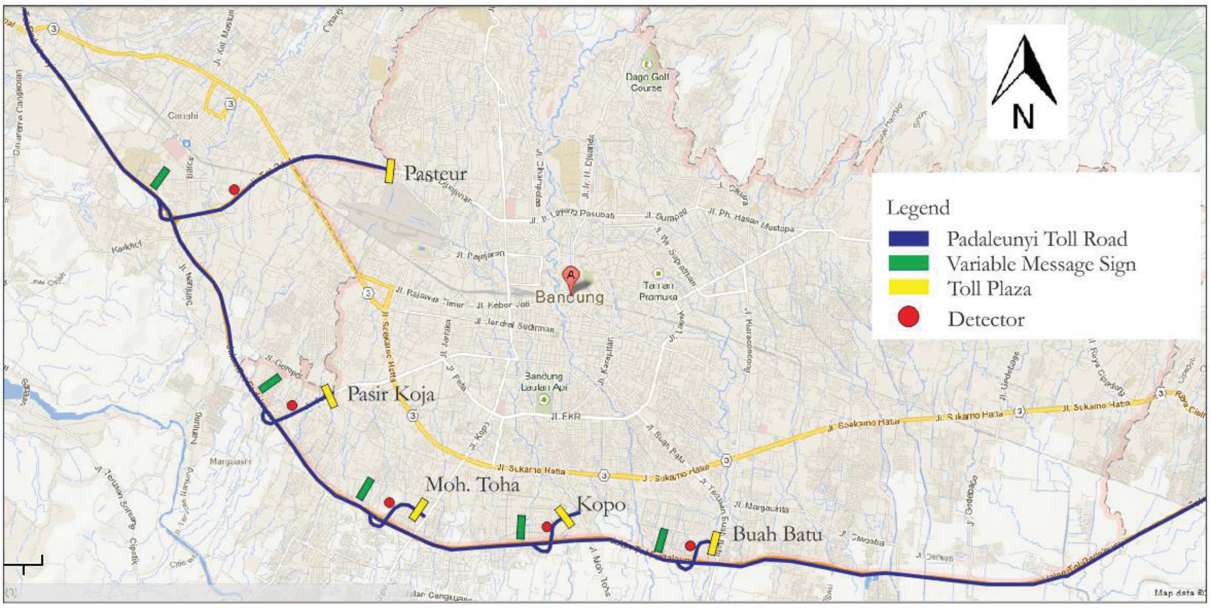


Figure 5 VMS and Detectors Placement on Padaleunyi section (Source: Google Maps, 2013)

In 2012, all five outlets are equipped with VMS prior to its interchanges. These VMS are displaying the information of traffic condition based on visual observation of toll booth operators. By connecting the VMS system to the server, the operator from each toll plaza sends the message to the central office to report the traffic condition at a certain point of time. Usually, they were reporting the length of queued vehicles exiting the toll road. Accordingly, the operator from the central office input the information manually to be displayed on VMS to inform travellers.

Since there is a time interval between the assessment of traffic conditions and VMS reaching the travellers, they may be facing a different downstream conditions compared to the information they perceive earlier on the VMS, and this is called flawed information. Arnott et al. (1991) indicated that flawed information generated by intuitively inputted VMS, result in the drivers exacerbating the congestions.

Since there is no detector deployed between the interchanges, the current VMS were only able to display the traffic conditions solely on particular outlet where the VMS was placed on its interchange. Furthermore, detected traffic volumes at each outlet are the combination of traffic volumes that come from westbound and eastbound of the toll road to enter Bandung City. These data gaps imply limitations on the simulation to be developed.

To remedy the above situation, different strategies are possible. This research in particular proposes to address the problems using a traffic management approach, by looking at the use of VMS based on analysis of traffic data. The expected outcome of this research is to provide accurate information on the VMS that will improve the distribution of traffic towards each toll outlet of Bandung. This information derived from the prediction of queuing vehicles at the toll plaza. The simulation will be implemented at the exit of Pasteur toll plaza, as this outlet presumably the busiest outlets and has been known as a strategic access to Bandung city.

4. METHODOLOGY

This research has been done by a quantitative approach in order to deal with the available quantitative data in three steps. The three steps contain the data extraction and analysis, the queuing simulation, and dissemination of simulation results.

This following chapter explored possible method in order to treat a large amount of traffic datasets. Extracting datasets which is built by several attributes was the first step should be taken in order to consider only in relevant attributes for further analysis. Having two datasets from the inflow and outflow traffic was a challenge in making sure that those separate time series data will be perfectly matched to each other and connected to the same attribute(s). The fact that there were errors in automatically captured data, adjusting those errors should be done by rigorous efforts in order to meet the criteria as complete and consistent training datasets.

Simulation of queued vehicles initiated with analytical processes named the test of statistical distribution from a certain group of observation. Sets of formula were used to calculate whether group of data follows a particular statistical distribution. Lastly, calculation of accumulated vehicles at toll plaza was done to assign the input of messages on VMS.

4.1. Data Extraction and analysis

Given the time of the research, the data extraction and analysis is conducted by using the desk study approach. The desk study is aimed to extract data from the available datasets. This chapter tries to provide a description about the data source and data structure. The data source part covers the explanation of detectors, VMS and the sensor data processing. While the data structure describe the extraction of the data attributes.

In the operationalization of dual virtual loops and optical sensor at each toll booth, there are conditions which caused the system not to work properly. In fact, since the detectors send traffic data via SMS to the main server, sometimes one or two detectors failed to send the data because of many reasons, such as the power outage or no signal acquired due to bad weather. Moreover, since the inflow detectors worked as image analyser, they sometimes failed to detect oncoming traffic due to visual limitation (fog, glare, or storm).

4.1.1 Data source

A. Detectors

The data is derived from the Ministry of Public Works, Republic of Indonesia. The inflow traffic data of 2012 were collected through the utilization of dual virtual loops which are the inflow detector and outflow detector. The data acquisition was acquired during seven consecutive months. Total number of traffic volumes, average vehicles headways and speeds were being collected. In addition, the occupancy of each exit toll booth was collected by locating optical beam detectors. These detectors counted the number of vehicle exiting toll road at each toll booth of five toll plazas. Moreover, the secondary data from the operator of Padaleunyi such as the extent of reservoir area prior the toll gates and the standard for service time per vehicle were also being collected.

Inflow detectors

There are 5 inflow detectors placed on 5 toll road outlets towards Bandung city. The detectors utilized on Pasteur, Pasir Koja, Moh. Toha, Kopo, and Buah Batu outlet as can be seen on Figure 5. Even though there is another outlet between Pasteur interchange and Pasteur toll gate, this outlet leads to Cimahi City which is not part of the study area (Figure 6, red circled). The control unit of each detector runs by DC power (battery) and charged automatically with the solar panel. These inflow detectors only captured the traffic over two lanes from four lanes of the toll road which is only the exit lanes, while other two lanes are the entrance lane in the opposite direction and it is out of the inflow detectors can reach.

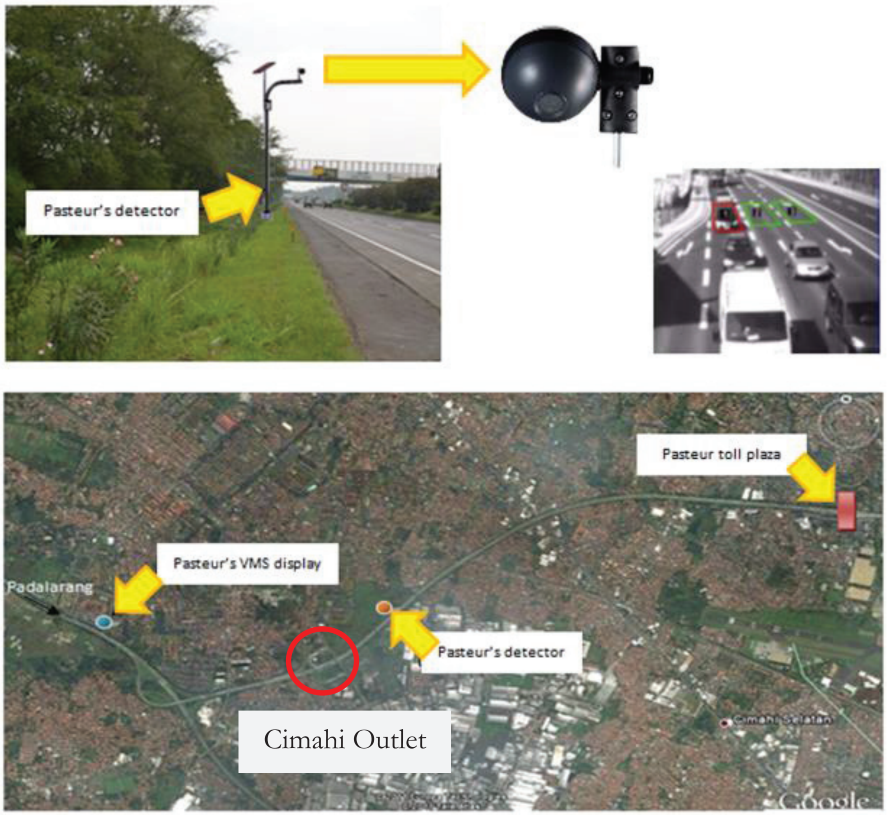


Figure 6 VMS display, road detector, and toll plaza location at Pasteur outlet towards Bandung city (Source: Google maps, 2013 and www.traficon.com, 2013)

The inflow detectors work as virtual loop detectors (VLD) or virtual induction loop (VIL) in form of camera or image detection system, which emitted the signals when vehicles traversed on defined virtual zones (Gramaglia et al., 2013). In this case, there are two detection zones placed on each lane of the road. Each detection zone has two virtual loops with 2.5 m by 4 m dimension and 1 m threshold (Figure 7).

Figure 7 shows 4 virtual loops over 2 lanes of carriageway. These 4 zones virtual loop are made based on the patterns of dummy loops drew on each lane's pavement surface with mentioned measurement. From these dummy loops, operator will easily digitize the virtual loops in VLD point of view. Based on motion estimation (Lai & Yung, 2000), each virtual loop emits pulses when there is a vehicle transverse above it. The emitted pulses on one loop make a particular loop as an active loop. From these virtual loops, we can infer:

a. Number of vehicles

   By counting the frequencies of active loop on zone 1 and zone 3

b. Vehicles speed

   Vehicle speed is derived from calculating the ratio of arrival time between zone 2/4 and zone 1/3 with the actual distance between zone 2/4 and zone 1/3.

c. Vehicles headway

The vehicles headway is originated from interval time between active loop of zone 1 and zone 3 also zone 2 and zone 4 respectively.

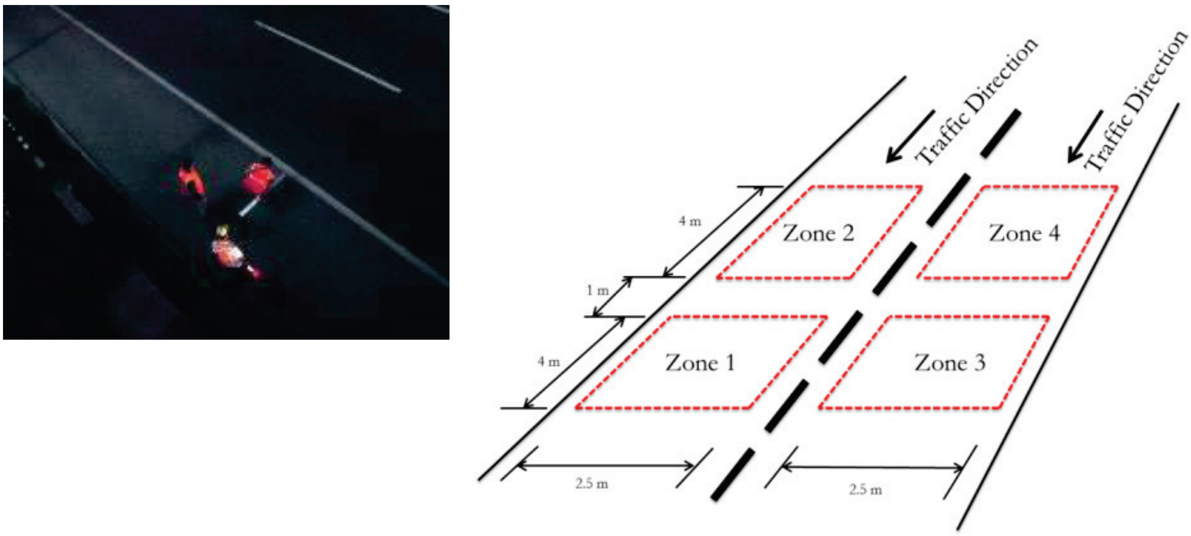


Figure 7 Creating dummy loops on the pavement and placement of virtual loops detector

Outflow detectors

The type of outflow detectors is the optical beam detectors. This detector consists of a pair of devices which is installed confronting each other and perpendicular to the traffic stream at each toll booth. The single infrared beam that is broken by moving vehicle, will count as a presence of the vehicle that leaves the booth (Figure 8). Also, the time difference between two consecutive vehicles can be considered as headway.

There are 8 pairs of outflow detector at Pasteur toll Plaza, 4 couples at Pasir Koja, 3 couples at Moh. Toha, 4 couples at Kopo, and 5 couples of them at Buah Batu toll plaza. The height of the beam is approximately 90 cm from the road surface. This height is representing the optimal height that all types of vehicles can be detected by the device.

Figure 8 Optical beam detector at each of toll booth at Pasteur toll plaza

The type of vehicles can be classified by vehicle's length. It is possible for the inflow detectors to achieve the task, but difficult for the outflow detectors. So, in this research, all vehicle detected by all detectors are assumed to be similar type of vehicles.

B. VMS

4 out of 5 outlets are equipped with variable message sign (VMS). All the VMSs are facing towards the westbound traffic, which means, as this research is conducted, these traffic guidance only used for traffic comes from Jakarta direction. The VMS displays a combination both the name of the outlets and variable information respect to certain outlet. The idea of variable information may contain the traffic state, travel time and length of the queuing vehicles exiting toll road on the particular outlet towards Bandung City. Each VMS contains the information of 3 respective outlets, and placed prior to the outlet's interchange. For instance, before Pasteur interchange, the VMS is displaying the traffic information of Pasteur, Pasir Koja, and Moh. Toha outlet, and so for the rest of the outlets. The exception is on Kopo outlet which has only 2 outlets information that is Kopo and Buah Batu outlet. Being the last outlet that leads the driver to Bandung City, Buah Batu interchange is not equipped with VMS. The variable informations displayed on all VMSs are the interpretation of traffic parameters calculation results.

C. Detector data processing

Both inflow and outflow detectors were gathering real time traffic data from each outlet and each toll booth exit. Each detector has a control unit which can do the calculation of total number of vehicles, average speeds per lane, and average vehicle headways per lane. Based on the time bin setting, this controller transmitted the traffic data periodically by using short message service (SMS) with General Packet Radio Service (GPRS) protocol to the main server located at Pasteur toll plaza (Figure 9). The main server retrieves the traffic data from all the detectors, and stacked them in a sequence manner. In the future, the ideal is that the server will calculate all the possibilities of traffic state at all the outlets, and send the information through SMS to each VMS. This system will work as one control system, rules by one main server. It means, as if one of the outlets fail to send the traffic data, the system will continue working by sending traffic information to the rest of VMSs. As a consequence, the traveller will not get any information of traffic condition where the malfunction detector(s) occurs.

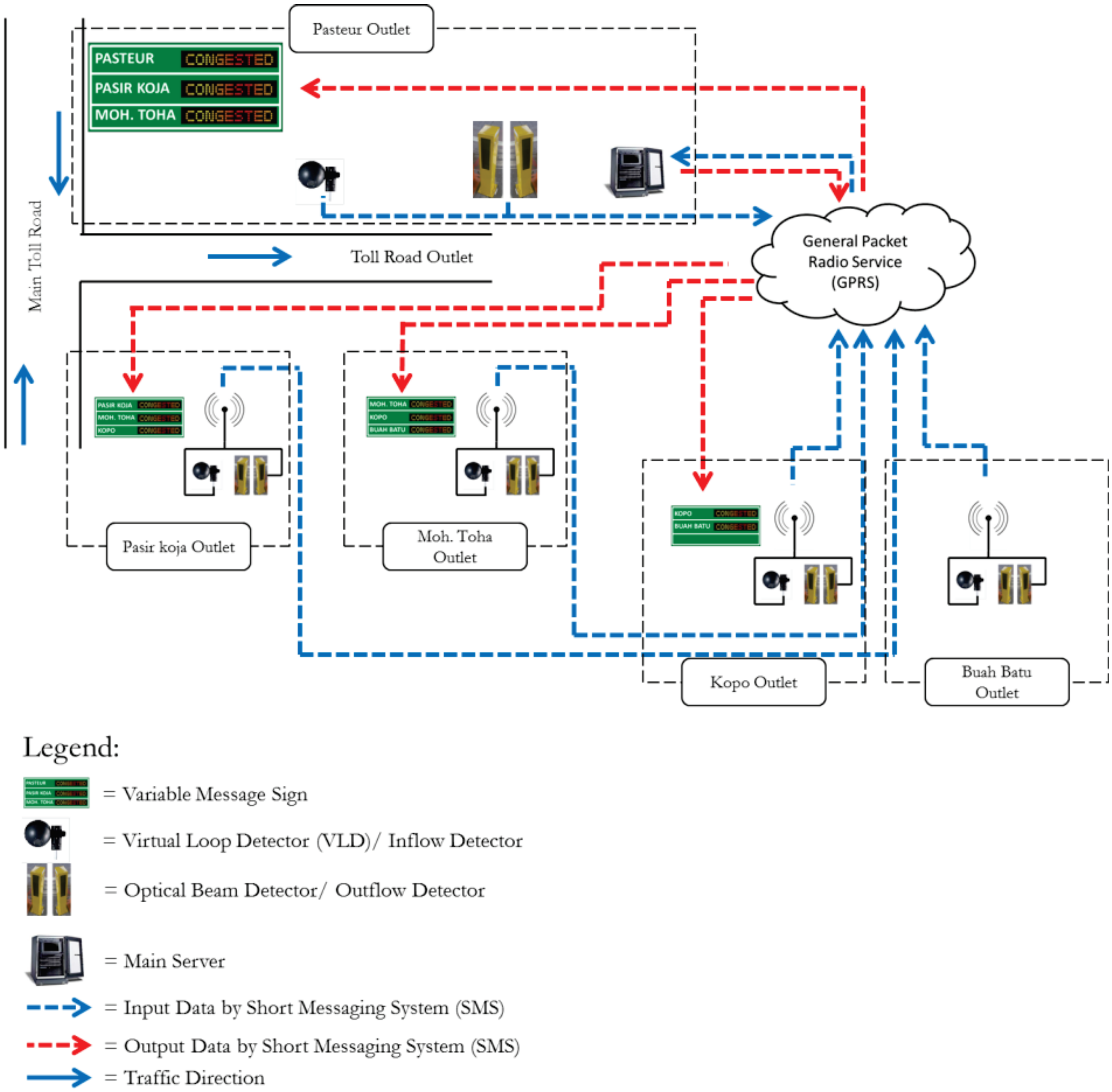


Figure 9 The scheme of Advance Traffic Information Systems (ATIS) on Padaleunyi Toll Road.

4.1.2 Data Structure

Data were downloaded from the server, and converted from Microsoft access format into Microsoft excel format. In the beginning, there were two spreadsheets within the file, which are the 'sms in" and "sms out" (Table 2 and Table 3). These two spreadsheets contain the inflow data and the outflow data respectively. From all attributes showed in the inflow and outflow datasets, only the relevant attributes are selected from the spreadsheets for further analysis.

Table 2 lists all the attributes that can be found in the "sms_in" spreadsheet. These attributes are constituted to the parameters that can be used as calculating the traffic volume towards the certain toll road outlet. The "in_speed_1" is the average speed that the control unit calculated in time bin period by comparing the time and distance between the virtual loop zone 3 and zone 4, and so for "in_speed_2" with the virtual loop zone 1 and zone 2.

"in_hw_1" is being calculated by the control unit by averaging the headway time for all the detected vehicles per time bin on left, with the similar ways to be done in "in_hw_2" for right lane.

"sms_out" spreadsheet attributes can be found on Table 3. "out_ctr_1" is total number of vehicles are passing through booth number 1, and so on. Also, "out_hw_1" is the average headways have been calculated by the controller in certain time bin. If the average headways is exceeding the time bin setting, then the system will consider as closed booth(s). This "out_hw_1" values can be 0, explains that booth number 1 is inactive or might not have been used for a certain period of time. Since the maximum number of booth is 8, then "out_hw_9 to out_hw_12" is always empty.

Table 2 Inflow attributes

Attribute Name	Remarks	Unit	Selected
in_no	Record number in a sequence manner received by a main server	-	
in_recv_date	Time and date of data captured by the detectors	mm/dd/yyyy hh/mm/ss	√
in_sender	SIM Card identification number		
in_dev_id	Identification code of inflow detector, based on the outlet	i.e. 21 : Pasteur Outlet 22 : Pasir Koja Outlet 23 : Moh. Toha Outlet 24 : Kopo Outlet 25 : Buah Batu Outlet	√
in_samp_rate	Time bins	Minute(s)	√
in_total	Total number of vehicles per time bin	Vehicle(s)	√
in_speed_1	Speed per time bin on left lane	Km/Hour	
in_hw_1	Average headway time per time bin on left lane	Second	
in_speed_2	Average speed per time bin on left lane	Km/Hour	
in_hw_2	Average headway time per time bin on right lane	Seconds	

in_date	Time and date when the server receive data from the inflow detector	mm/dd/yyyy hh/mm/ss
in_bat	Battery status	Ampere
in_temp	Temperature of device	Degree Celsius

Table 3 Outflow attributes

Attribute Name	Remarks	Unit	Selected
out_no	Record number captured by server in sequence manner received by a main server		
out_recv_date	Time and date of data captured by the detectors	mm/dd/yyyy hh/mm/ss	√
out_sender	SIM Card identification number		
out_dev_id	Identification code of outflow detector, based on the outlet	i.e. 31 : Pasteur Gate 32 : Pasir Koja Gate 33 : Moh. Toha Gate 34 : Kopo Gate 35 :Buah Batu Gate	√
out_samp_rate	Time bin	Minutes	√
out_booth	Number of exit Booth(s) open	Booth(s)	√
out_ctr_1	Total number of vehicle(s) count by an output detector on Booth number 1	Vehicle(s)	√
out_hw_1	Average headway time per time bin on Booth number 1	Milliseconds	
…			
out_ctr_12	Total number of vehicle(s) count by an output detector on Booth number 12	Vehicle(s)	√
out_hw_12	Average headway time per time bin on Booth number 12	Milliseconds	
out_date	Time and date when the server receive data from the inflow detector	mm/dd/yyyy hh/mm/ss	
out_bat	Battery status	Ampere	
out_temp	Temperature of device	Degree Celsius	

The relevant attributes for further analysis are total number of vehicles, and average vehicle headway from in the inflow spreadsheet. Respectively, the number of open booth(s), number of vehicles per booth, and vehicle headway per booth in the outflow spreadsheet are taken into account to the analysis (Table 4). As can be seen from Table 4, the time interval/time bin varied from 1 to 60 minutes. It means that both inflow and outflow detectors were capturing the traffic flow based on that time interval and send them to the main server. Of course, this time bin variation will make an irregular pattern to the number of records if those time interval are implemented in one day. These irregularities will be explained in the upcoming paragraphs.

Both inflow and outflow spreadsheet coded by the outlet ID, so the next step was separating them into each outlet in the sequence manner based on the date and time when the detectors captured the traffic data. In the spreadsheets revealed that there were two different time stamps coded in the server. One is the time when the detector captured the traffic flow and sends it to the server, and another is the time when server reports the received traffic volume from the detector. The time delay between two time stamps varied between 12 and 15 minutes. In this case, the choice is to take the time stamp written in the detector than the server's time stamp, as this will give more realistic condition of what actually happened in a certain period of time. Clear representation of all the above processes depicted in Figure 10 .

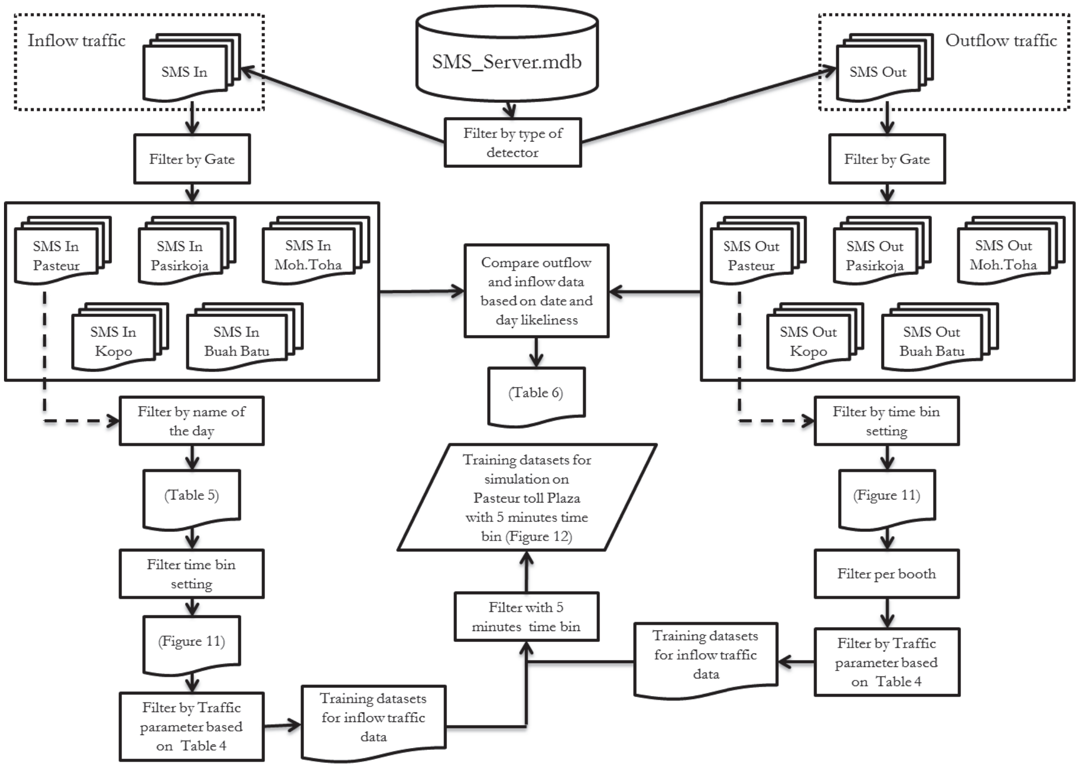


Figure 10 Work flow to determine the training datasets

Table 4 Relevant attributes in the spreadsheet for data analysis

Inflow data	Outflow data
• Date and hour of received data	• Date and hour of received data
• Outlet code for inflow	• Outlet code for outflow
• Time bin (1, 5, 15, 60 minutes)	• Time bin (1, 5, 15, 60 minutes)
• Total number of vehicles per time bin	• Number of booth(s) open
• Average vehicle speed per lane per time bin	• Number of vehicles per booth per time bin
• Average vehicle headway per lane per time bin	• Vehicle headway per booth per time bin (service time)

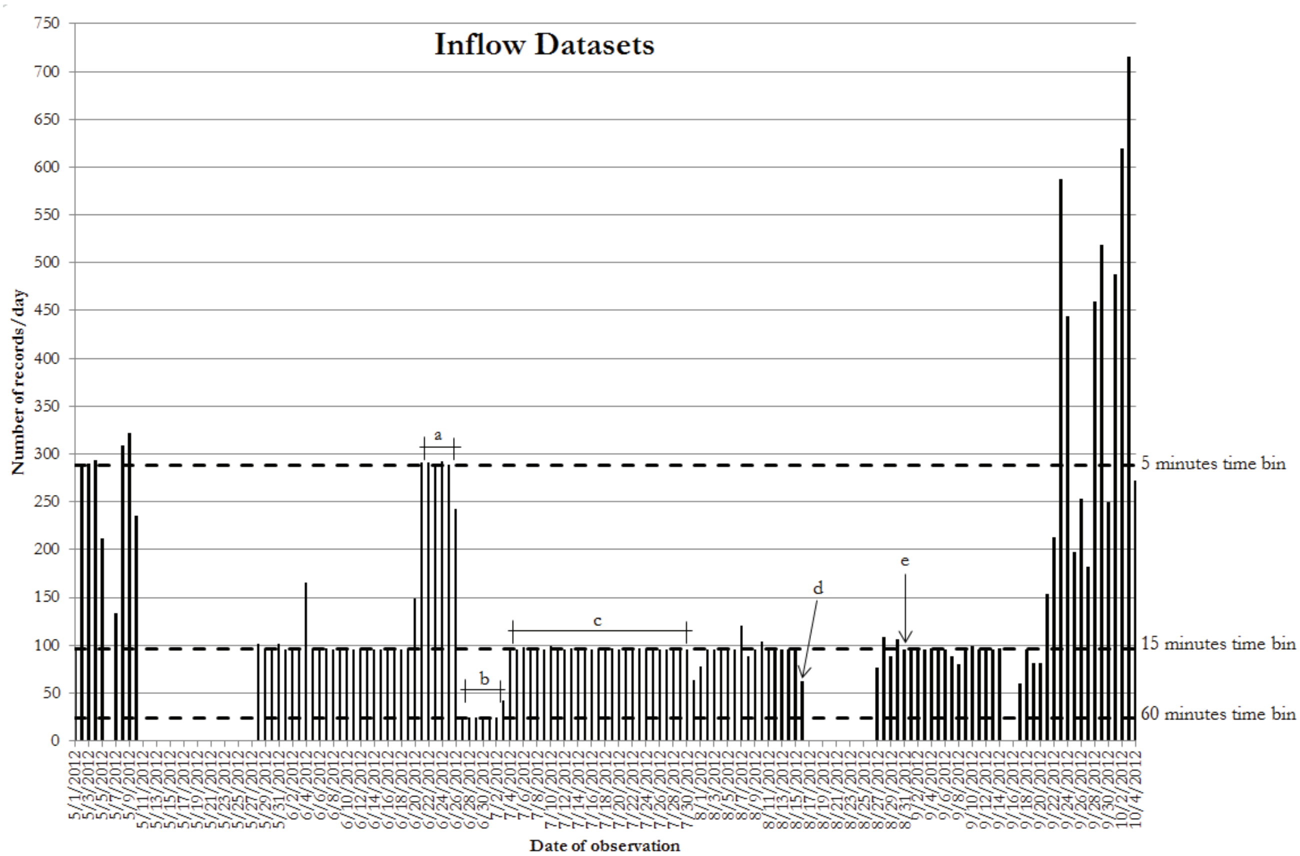
The total number of observed datasets according to the name of the day per month is showed in Table 5. Both inflow and outflow data collection from 5 outlets of Padaleunyi toll road began on Tuesday, first of May 2012 and ended on Thursday, 4th of October 2012. In average, filtered with the name of the day, there are 19 datasets in a same name of day from which the estimation of traffic flow pattern can be inferred. However, from this number of days, critical attention should be made on each day time series, in order to make sure the availability of data in 24 hours period. The incomplete datasets, in terms of captured data within 24 hours, should be excluded from the analysis.

Table 5 Number of datasets according to day calculated from traffic detectors

Months/Days	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Total
May	2	2	3	4	4	3	3	21
June	4	4	4	4	4	5	5	30
July	5	5	5	4	4	4	4	31
August	2	3	3	4	4	3	2	21
September	5	4	4	4	4	4	5	30
October		1	1	1	1			4
Total	18	19	20	21	21	19	19	137

Both inflow and outflow detectors captured 24 records for 1 hour interval, 96 records for 15 minutes intervals, and 288 records for 5 minutes interval per day of observation. Figure 11 depicts the fluctuation number of records over seven months on Pasteur outlet. At some points, the time interval in one day may vary due to the setting that was made by the toll operator. For instance, in some days, 24 hours of traffic data might be binned into 15, and 60 minutes interval that makes the intermediate points in between 24 and 96 records in the graph (datasets d on Figure 11).

The datasets irregularities are defined as a mixture of time intervals within a day caused by operator's setting or system's error. Sometimes, when operator set the time bin into certain time interval, the system is not necessarily put the data in the correct manner.



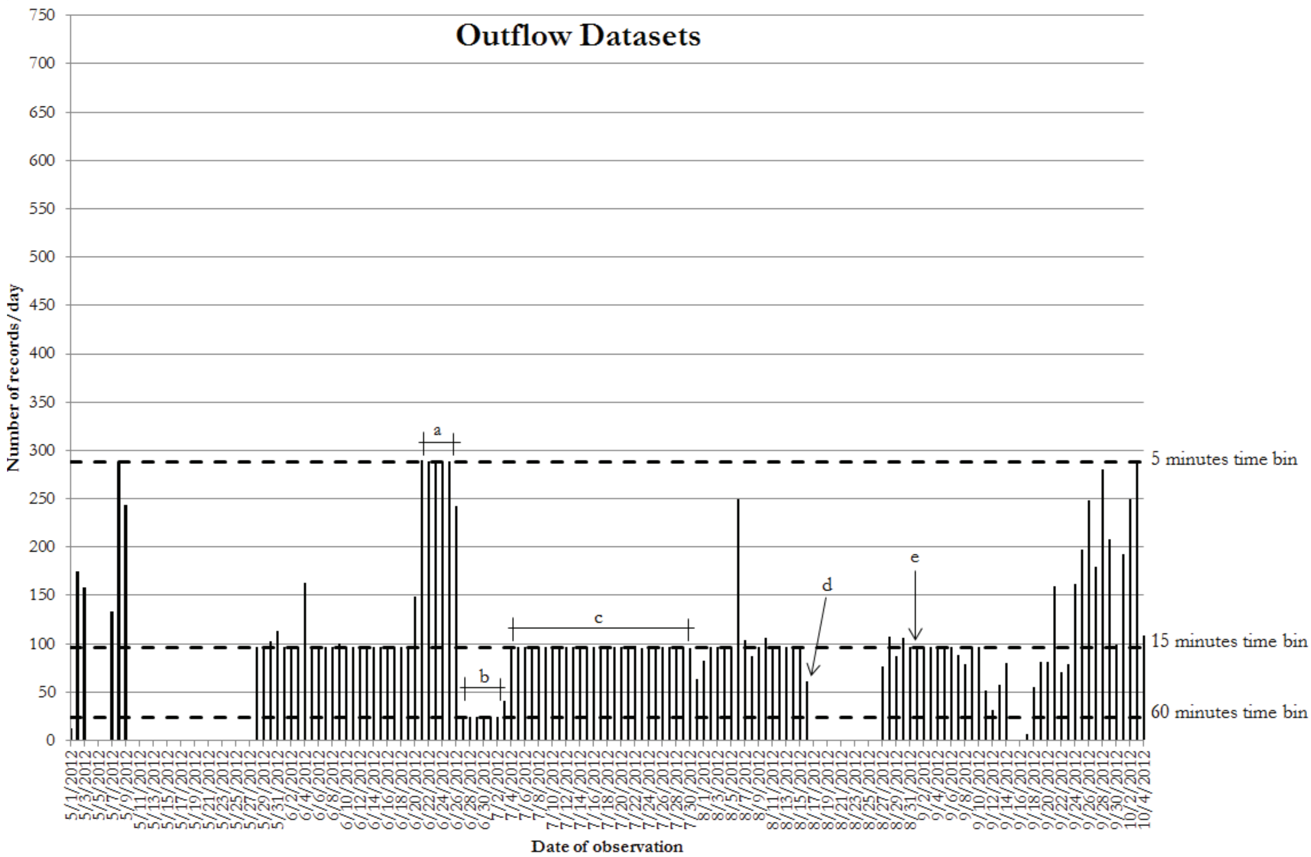


Figure 11 The amount of records captured by inflow and outflow detectors on Pasteur toll plaza

In Figure 11, there are three subsets from the dataset that show fewer irregularities. They are 27 days of 15 minutes time bins from 4th of July to 30th July 2012 (c); 5 days of 5 minutes time bins from 21st of June to 25 June 2012 (a) and 60 minutes time bins from 27th of June to 1st of July 2012 (b). However, by taking a closer look at daily data, these subsets also show variation number of records captured by the detectors. To deal with these irregularities, Table 6 depicts the matching matrices between datasets from all outlets, filtered by date and number of records per day.

Table 6 Comparison of Inflow and Outflow datasets

Toll Plaza	Number of Observations (days)	Number of matched days and date (days)	Number of days with the same interval per day (days)	Percentage of the datasets with the same date and records per day
(1)		(2)	(3)	(3)/(2) x100%
Pasteur	137	125	50	40.00%
Pasir Koja	137	126	42	33.33%
Kopo	137	125	45	36.00%
Moh. Toha	137	123	46	37.40%
Buah Batu	137	134	43	32.09%

Table 6 depicts the comparison of 137 days of observation on 5 outlets. Taking an example from Pasteur outlet, only 125 of datasets are showing the same date of observation denote by number of datasets/day with the same date. It is because of some detectors failed to detect, and some of them are switched off due to power outage. Furthermore, only 50 or 40% from all datasets of Pasteur outlet are showing the same amount of records in a same day between inflow and outflow datasets.

It is also worth to mention the variation of timestamp within a pair of inflow and outflow datasets. This situation occurred because of the time lag in activating the unit of detector. The system which includes the server, inflow detectors and outflows detectors were not activated simultaneously. Although in next calculation these pair of datasets were being analysed together, the time stamps within both datasets were not necessarily matched in scale of minute.

The GPRS as a protocol to convey all the data from the detectors to the server sometime failed to send the data according to the pre-set time bin. This problem took place when there are more records captured in an hour observation. For instance, in 5 minutes time bin setting, it should be exactly 12 records in an hour observation. The case that some observations have more than 12 records, it should be suspected that within that hourly data, the detectors send more it should be. Then, an observation should rigorously make in order to manually rearrange the inflow or outflow data according to the timestamp.

Figure 12 shows the fluctuation of traffic volume per day with 5 minute time bin on 5 outlets. It starts from Tuesday, 21st of June 2012 to Monday June 25th 2012. To determine the peak day, the author used datasets of Friday, June 22nd 2012 as most of all outlets show the tendencies of highest traffic volumes, except on Pasirkoja outlet. It is understood that on Friday people rushed to enter Bandung, especially through Pasteur toll plaza. As seen on this capture, similar trend also occurred on Sunday, 24th of June 2012 when the total traffic volumes on all outlets tend to decrease and at its lowest point of a week. It is always the case that in Sunday, people leave Bandung and use all of the outlets of Padaleunyi toll road. This Sunday datasets will be used as off-peak datasets in the queuing simulation. Conclusively, one datasets from peak and one datasets from off-peak period of Pasteur outlet will be the training datasets for further analysis.

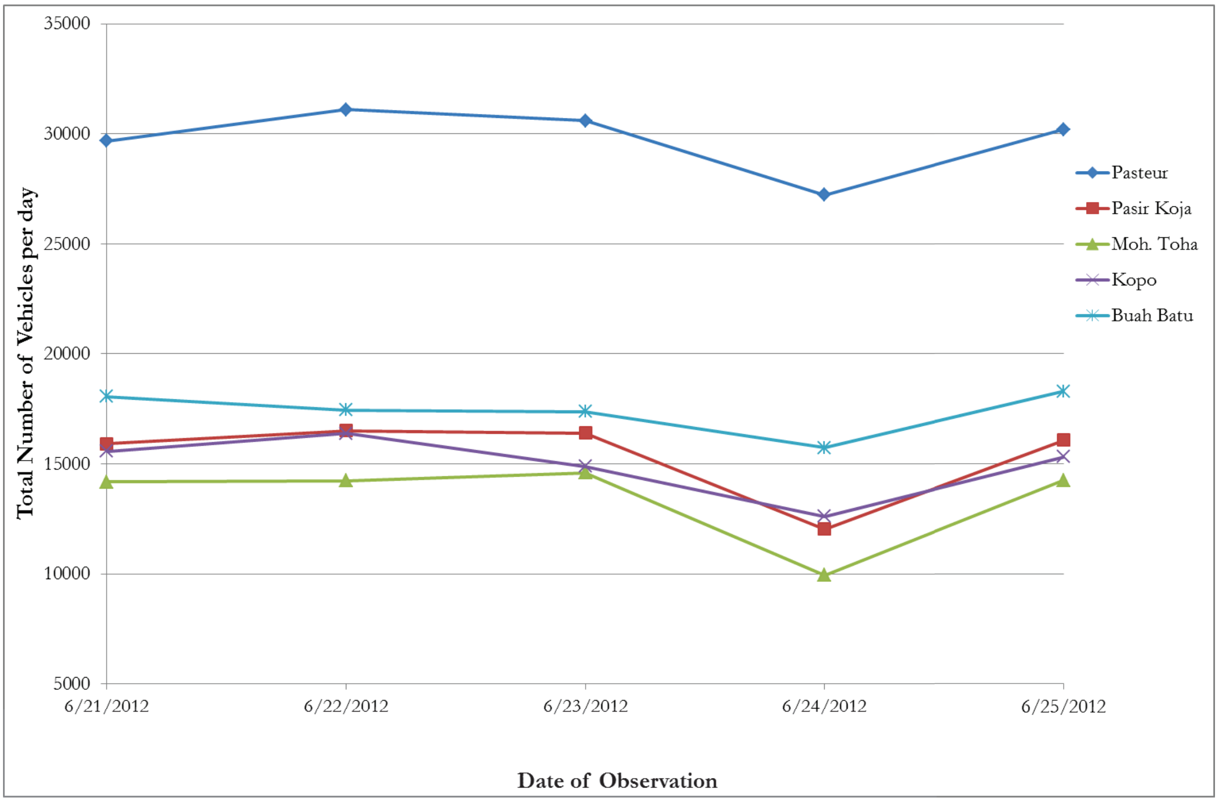


Figure 12 Fluctuation of Traffic Volume on each outlet with 5 minutes time bin

4.2. Measuring the traffic detection accuracy

Before taking the training datasets into further steps of analysis, it is important to make sure that traffic data derived from the detectors were not distorted by noise or error. Several methods to measure the accuracy of captured traffic data are possible. In general, the data estimated by the detectors has to be verified by actual or manual measurement by surveyors. Two datasets which later confronted each other will tell whether the estimation has a similar value from the manually counted traffic data.

If Y_t is the actual data measured by surveyors at period t , and Y'_t is the estimation value from the detectors, then there will be n data to be compared each other in order to get the differences.

The test to measure the statistical dispersion of data is done by calculating the mean absolute deviation (MAD) of group of data. MAD measurement is used to denote the average distance of each data from the mean. If big value shown in the result, it is less likely that the measurement is accurate, and vice versa. MAD can be calculated by the following formula:

$$MAD = \frac{1}{n}\sum_{t=1}^{n}|Y_t - Y'_t| \tag{1}$$

The second test is to measure the randomness of two groups of data. It is mean squared error (MSE) which describes the variance value of automatically captured traffic data. The calculation can be done with such formula:

$$MSE = \frac{1}{n}\sum_{t=1}^{n}(Y_t - Y'_t)^2 \tag{2}$$

The fact that MSE constitute as variance, it puts more weight on the outliers (Bermejo & Cabestany, 2001) while mean absolute percentage error (MAPE) is based on median. As depicted in the formula, MSE provides a quadratic loss function Unlike MAPE, mean percentage error (MPE) shows offset of negative and positive values in measuring bias of traffic flow estimation. The later method is the easiest way to spot the difference between actual and estimated traffic flow (Makridakis, 1993). The calculation of error of MAPE and MPE used these following formulas:

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\frac{|Y_t - Y'_t|}{Y_t} \tag{3}$$

$$MPE = \frac{1}{n}\sum_{t=1}^{n}\frac{(Y_t - Y'_t)}{Y_t} \tag{4}$$

4.3. Queuing simulation to predict the congestion

There are some factors correlated to form the queue of vehicles exiting the toll road. The numbers of available service booths, incoming traffic, and average service time in each toll booth are considered as parameters. Also, capacity of the reservoir before the toll plaza (A), the average of vehicles that can be served at the toll booths (D), and distance between the detector and the toll plaza (S) are taking into account (Figure 13)

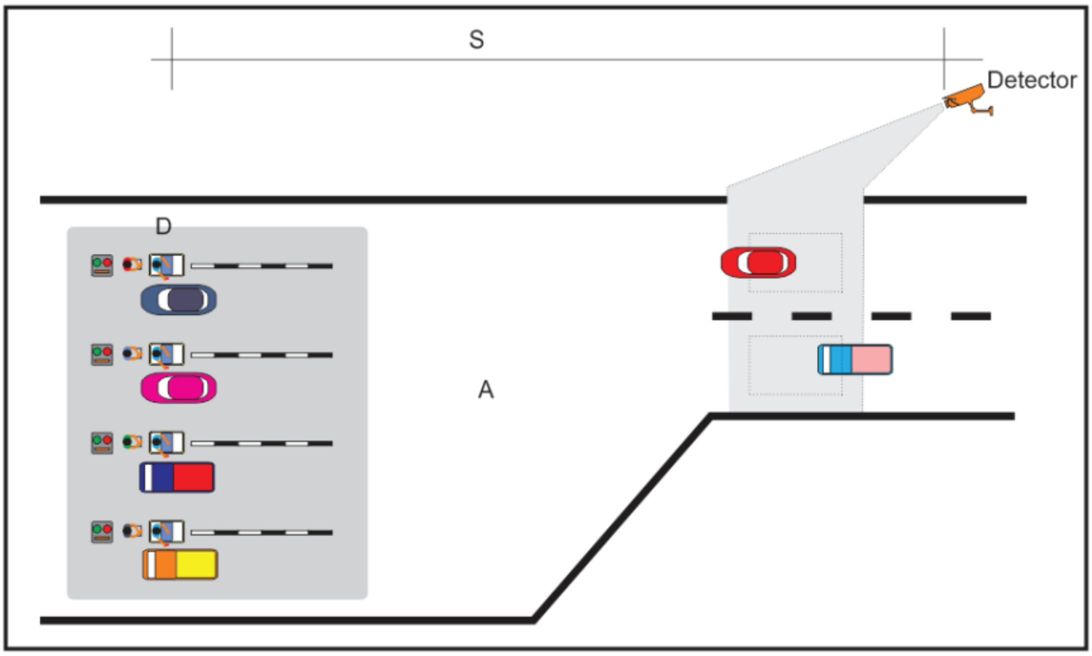
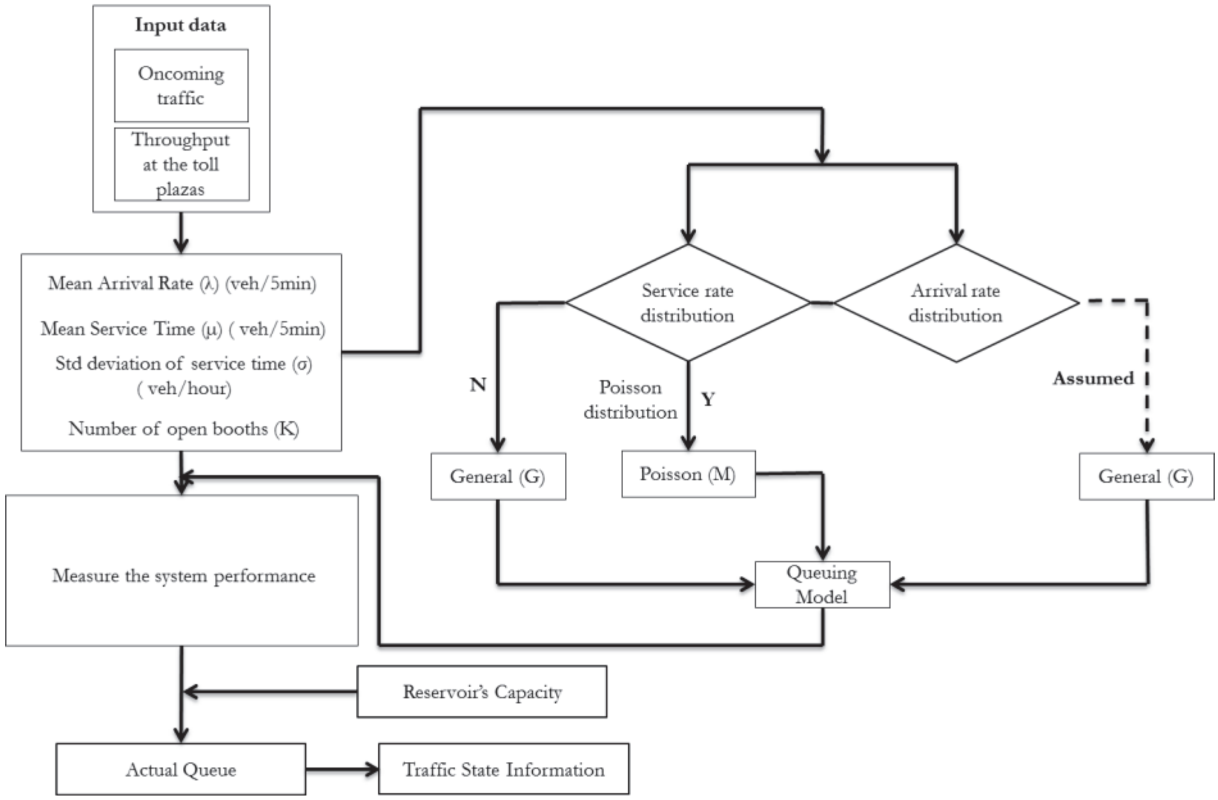


Figure 13 Layout of the congestion prediction factors

Irregularity of the vehicle arrival pattern at the toll plaza makes the traffic rates between two consecutive time slices becomes a random variable. Similarly, the service time at the toll booth for each vehicle is different. Therefore, to determine the type of statistical distribution of an event (arrival pattern and average service time) is essential before analysing the data. Figure 14 gives a brief description of ways to determine the type of statistical distribution for both service rate and arrival rate.



Adapted from (Nugraha et al., 2013)

Figure 14 Flow chart of queue prediction at toll plaza

4.3.1. Developing the statistical distribution

Statistical distributions can be classified in two general categories that are discrete or counting distributions and continuous or interval distributions. This section will discuss only discrete distributions both for arrival rate at the outlet of toll roads and for service rate at the toll gate. The following formulas of two statistical distributions are taken from "*Transportation and Traffic Engineering Handbook*" by Homburger et al. (1982).

Poisson distribution

Poisson distribution is used to describe a random discrete event, and the first distribution applied to analyse the traffic flow. Poisson distribution gives the probability value for the number of successful events in a certain interval of observation. This trial is using single parameter *m*, the average number of vehicle during period of duration *t*, and later is called λ_t .

Poisson distribution can be denoted as:

$$P(x) = \frac{e^{-\lambda_t} {\lambda_t}^x}{x!} \tag{5}$$

$$x = 0,1,2,3...$$

Where:

$P(x)$ = probability that x vehicles will arrive during a counting interval t

λ_t = arrival rate of vehicle per t period

e = natural base of logarithms = 2.7183

For the Poisson distribution, the mean and the variance are nearly equal, so that the ratio mean/variance ≈ 1.0.

Binomial distribution

The uniform flow can be seen in congestion situation. In this state, the variance of the number of vehicles per time interval is decreased. Thus, the ratio mean/variance is bigger than 1.0.

The binomial distribution gives the probability of x events in n trials and may be stated as:

$$P(x) = \frac{n!}{n!\,(n-x)!} p^x q^{n-x} \tag{6}$$

$$x = 0,1,2,3...$$

Where:

$P(x)$ = probability that x events in n trials

n = number of trial (each t interval is a trial)

x = number of events in n trials

p = probability of an event on any given trial = probability that any t interval will contain vehicle(s)

q = probability of a failure on any given trial = 1-p = probability that t interval does not contain a vehicle

The two parameters of the binomial distribution are estimated as follows:

$$p = \frac{\bar{x} - s^2}{\bar{x}} \tag{7}$$

$$\text{and } n = \frac{\bar{x}^2}{\bar{x} - s^2} \tag{8}$$

Where:

$\bar{x}$ =mean number of events per t interval

s^2 = variance in the number of events per t interval

Testing goodness of fit

Hypothesis testing is a mathematical procedure that uses empirical data to decide whether a group of observations justifies the proposed hypothesis in particular, whether the set of data conforms to a statistical distribution (Greenshields et al., 1978). Hypothesis testing using Chi-square value has two common statistical applications:

1. To know and to test whether a given population to follow or approach a certain theoretical distribution (goodness of fit test).
2. To determine whether two or more data may come from the same distribution (homogeneity test)

The Chi-square (χ^2) distribution follows the equation:

$$\chi^2 = \sum_{1}^{g} \frac{(f_0 - f_t)^2}{f_t} \tag{9}$$

With:

f_o = frequency of observation for each observation / observation class.

f_t = frequency calculations / theoretical frequency for each observation / observation class.

g = number of groups of observations.

The Value of χ^2 for the significance level (α) or different degree of freedom (υ) can be found in table of Chi-square value (χ^2), as degree of freedom (υ) can be calculated by:

$$\upsilon = (g-1) - A \tag{10}$$

With:
g = number of groups of observations
A = number of parameters (see Table 7)

Table 7 Number of parameters and degree of freedom for Poisson and Binomial statistical distribution

Statistical Distribution	Parameter	A	υ
Poisson	m	1	g-2
Binomial	π,n	2	g-3

Source: Statistics with Applications to Highway Traffic Analysis by Greenshields et al. (1978)

In order to test one population follows a certain statistic distribution, or tend to resemble theoretical distribution tested by degree of freedom = 1- significance level, the value of $\chi^2_{critical}$ should be less then $\chi^2_{\alpha,\upsilon}$, or $\chi^2_{critical} < \chi^2_{\alpha,\upsilon}$.

4.3.2. Application of statistical model

Figure 15 is a flow chart used in selecting the appropriate discrete statistical distribution of traffic flow. The type of distribution was based on ratio of average arrival rate and variance of hourly data. This section presents the application of statistical models to a set of observed vehicle arrivals on Friday 22nd and Sunday 24th June 2012. These two days are being picked as the data consist of 24 hours period with 5 minutes time bins. In order to recognize hourly fluctuation of traffic flow, the calculation is being done by dividing the 24 hours data into 1 hour time slices.

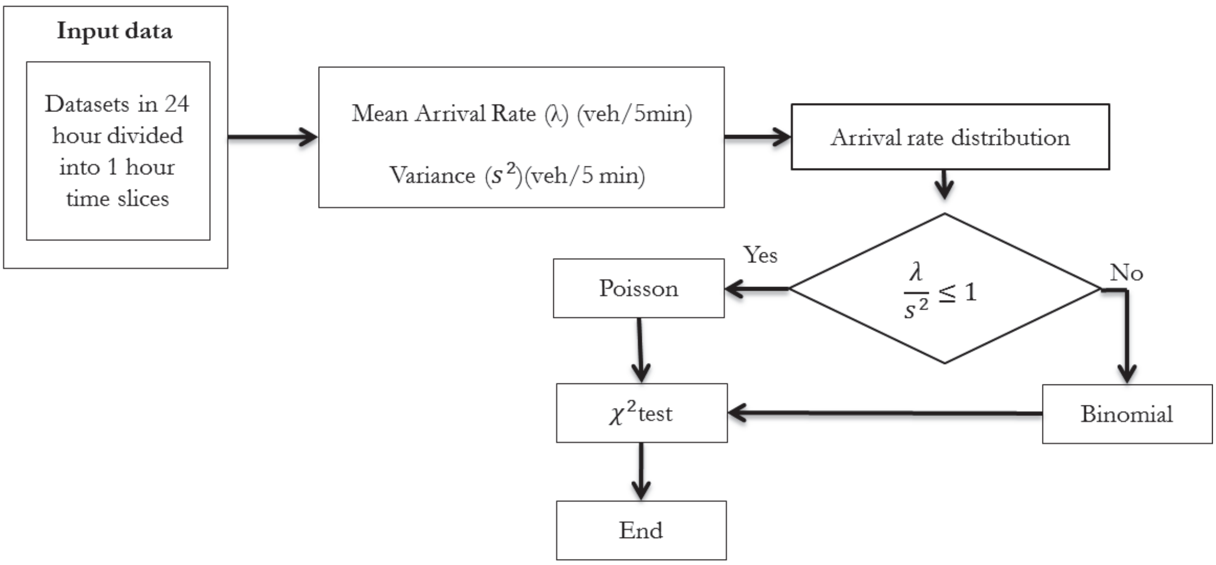


Figure 15 Discrete Statistical distribution testing with chi-square test

4.3.3. Measure the system performance

Single service queue

For a single service, if the statistical distribution of arrival distribution is Poisson and exponential distribution for services, also queues are unlimited (M/M/1/∞), the model has several operating characteristics based on Homburger et al. (1982), as follows:

The steady state condition (ρ) applies if the ratio between arrival rate (λ) and mean service rate (μ) is less than 1, and can be expressed as:

$$\rho = \frac{\lambda}{\mu} < 1 \tag{11}$$

1. Probability of no vehicles in the system, $p(0)$, i.e. the probability that the system is in a state where there are no vehicle serviced or waiting.

$$p(0) = 1 - \frac{\lambda}{\mu} \tag{12}$$

With: λ = arrival rate (vehicles/minute)

μ = mean service rate (vehicles/minute)

2. The average number of vehicles in the queue, L_q, i.e. the average number of waiting vehicles to be serviced.

$$L_q = \frac{\lambda^2}{\mu(\mu - \lambda)} \tag{13}$$

Multiple-channels queue.

According to Homburger et al. (1982), basic components of queuing are arrival rate, service rate, and queuing. Suggested K service channels, the service rate μK of each of the K channels is assumed identical. Arrivals rate follows Markovian distribution λ and ρ=λ/ μK. The value of ρ for multiple-channels case may be bigger than 1, but the following formulas apply only for the case where ρ/K<1.

$$P(0) = \frac{1}{\sum_{n=0}^{k-1} \frac{\rho^n}{n!} + \frac{\rho^K}{K!\,(1 - \rho/K)}} \tag{14}$$

$$E(m) = \frac{P(0)\rho^{K+1}}{K!\,K}\left[\frac{1}{(1 - \rho/K)^2}\right] \tag{15}$$

To calculate the queue length, number of steps depicted in Figure 14 are done based on Kim (2009). The formula was used with the arrival rate follows Poisson distribution and assumption was taken as service time follows General distribution (M/G/1). Kim (2009) argued that most of the calculation of service time using the exponential distribution always ended up with overestimated result. By using the general distribution, he proved that the result was more likely with the real condition. L_i represent the length of the queue expressed with number of vehicles. Suppose that mean arrival rate within a certain time interval is distributed evenly to every open service booth, than $\lambda_i$is calculated as mean arrival rate per booth. μ_i is the average service rate per booth calculated from all $n_i$booths. Thus, the variance or squared standard deviation is derived from the service rate of all operationalized toll booths.

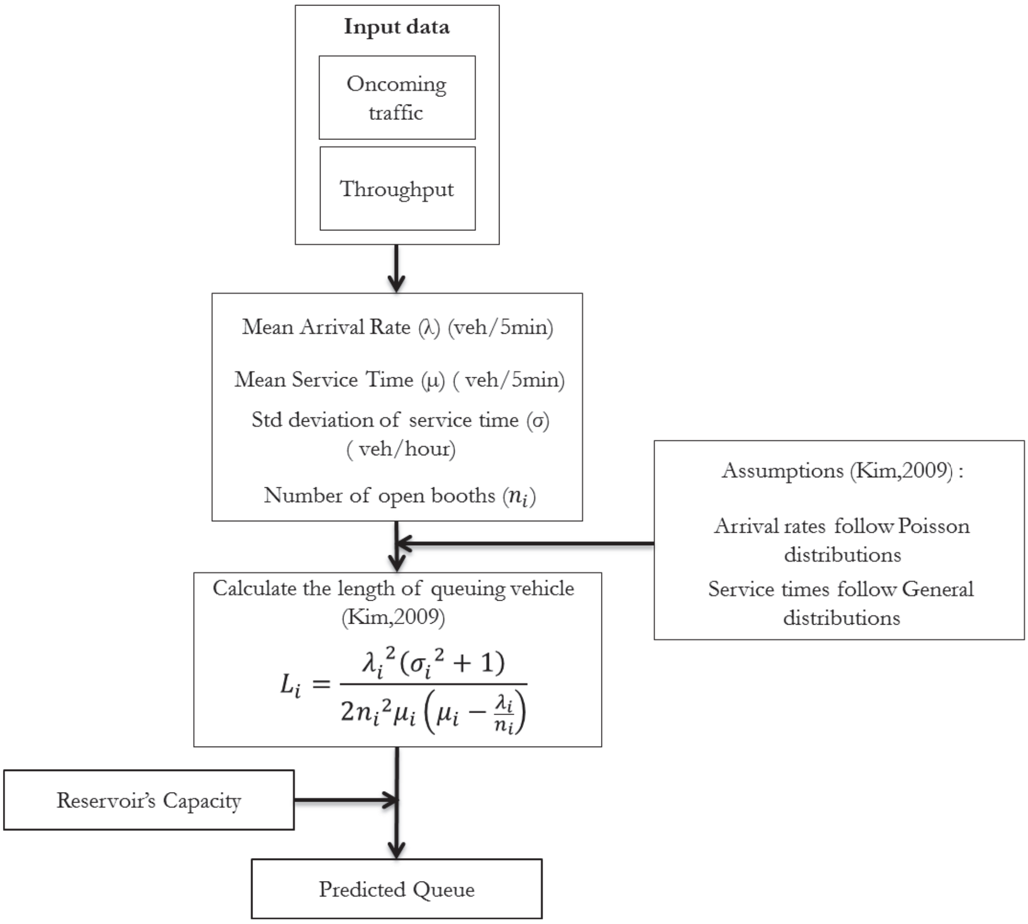


Figure 16 Flowchart to predict the vehicle queue based on empirical data

4.4. Dissemination of simulation results

Since the research is heavily data driven, existing data used in this research are going to be treated and will be used to calibrate and validate the model (Huisken & van Maarseveen, 2006). The validation of congestion at toll plaza will incorporate traffic volumes and the level of throughputs of the system. The queuing storage's occupancy as a result of simulation is compared with the difference between toll plaza's throughputs and traffic volumes.

According to Xu et al. (2013) there are three categories of traffic state that could be describe and evaluate based on observation Macroscopic Fundamental Diagram (MFD) model. These traffic states are: free flow conditions, optimal accumulation, and congestion. However, to simplify it, the concept of disseminating the information through the VMS is constructed by estimated thresholds to define "smooth", "queuing", and "congested" condition displayed on VMS. Such thresholds come from assumptions and the standard used by the toll road operator compared with the quantified measurement from the queuing simulation.

The study of Erke et al. (2007) showed a surprising result of how the traveller react to the information on VMS. Even though the recommended routes are 70% longer, but if they offer shorter travel time, travellers tend of using the routes to reach their destination. However, this condition can be achieved if the traveller familiar with the surrounding networks. For this research, since most of Padaleunyi toll road users are living in the cities adjacent to Bandung city, they are more likely know the day-by-day traffic situations of the toll section. This opportunity can contributes to the ways of toll road users react and change their behaviour after they are seeing the information through the VMS, based on predicted queuing simulation at each toll plaza on Padaleunyi toll road.

In Pasteur toll plaza, 8 exit booths are being utilized. Suppose all these booths are open, therefore, there will be maximum 8 vehicle lines toward the plaza. According to minimum standard of service regulation (PP No. 15 year 2005) adjacent with Ministry of Public Works decree (Permen PU No. 392/PRT/M/2005), Jasa Marga, as the operator of Padaleunyi toll road section, has to meet particular criteria in servicing its costumer. Jasa Marga has its own standard to define the congested situation. 200 meters is the maximum queue length that can be tolerated by operator as a normal length. Above that threshold, the queuing system will be marked as a congested condition. Assumed that all the vehicles in the system are passenger car, and the dimension as stated on Aashto (2001) per vehicle is 5.79m. If the clearance distances both in front and behind the vehicle are 2 x 3 feet, than 1 vehicular dimension would be approximately 7 meter. Taking back to Jasa Marga standard, there would be approximately 29 of vehicles in 200 m queue. So, the capacity of the queuing storage at the exit of Pasteur toll plaza can be calculated as 232 vehicles.

The system should be able to give an alert for the congestion. The "SMOOTH" condition is a state that all the inflow traffic is being served by each operated toll booth. In other words, it is the state where the outflow is more than the inflow. As mentioned, the congestion will be defined as 100% occupancy of the queuing storage. So, several assumptions should be taken in order to give clear thresholds to determine the traffic condition. If the predicted queue length reaches 232 vehicles, the system will announce "CONGESTED" state. Since the travellers spend travel time between VMS and toll plaza, the "CONGESTED" alert should be stated earlier before it happens. The "CONGESTED" state should be announced when the condition of inflow is going to fill more than 80% of the reservoir area, so that the traffic who read the message will suddenly divert the direction and got to the next exit. At the certain point, there will be a state which is not expressing either "SMOOTH" or "CONGESTED" based on predefined criteria. The "QUEUING" state is being taken as a condition where the inflow is about to occupy before 50% of the storage.

5. RESULTS AND DISCUSSION

5.1. Introduction

This chapter presents the result of the congestion simulation on Pasteur outlet of Padaleunyi toll road. As a prior step of the analysis, the test conducted whether both inflow and outflow detectors worked properly. The testing result showed insignificant error produced by the detectors. It means, all the training datasets derived from the server are not necessarily corrected to a certain value of error.

As mentioned on previous chapter, the arrival rate was analysed by using chi-square test in order to determine such rate follows exponential distribution (Poisson and Binomial) or general distribution. Tin addition, it was assumed that statistical distribution for service rate is following general distribution to avoid the over estimation of queue length (Kim, 2009).

By using the same procedure, other four outlets as mentioned on the first chapter can be expected have a similar kind of result that is the graph that shows the fluctuation of queuing vehicles over time.

5.2. Measuring the error detection

This step was conducted to test the accuracy of both inflow and outflow detectors. The measurement was done by comparing the number of vehicles counted manually by operators and those which were automatically detected by the detectors.

There were two arrangements in accuracy testing, first is to test the accuracy of virtual loop detector on the outlet, and second is to check optical sensors' precision in detecting numbers of vehicle passing through each booth of toll plaza.

The test took place on Pasirkoja outlet on Saturday, 1st of September 2012. A video camera was placed next to the inflow sensor, facing at the same direction as virtual loop detectors detect the traffic. The arrival rate comparison was done in 3 hours from 8.10 AM to 11.10 with 15 minutes time bin setting of calculating number of vehicles. Traffic volumes were being calculated manually by operators at the office based on the recording of video camera.

At the beginning, the surveys were going to conduct on Pasteur outlet. There were two major reasons Pasirkoja chose as a survey location instead of Pasteur. First, since it is the main entrance to Bandung, 8 exit booths at Pasteur toll plaza are most of the time occupied by travellers doing their transaction. In order to count the number of vehicles exiting toll plaza manually, it was difficult to place a camera which covers the entire toll booths. Second, in the weekends travellers are often encountered congestion after exiting toll road. This reason was also exacerbate the process of manual counting, because all the idle vehicles blocked the camera's sight distance.

From all the rest of the outlet on Padaleunyi toll road, Pasirkoja has some similar characteristics with Pasteur. For instance, Pasteur and Pasirkoja are the first and the second longest outlet measured from the main toll road interchange, and both outlets are connecting the toll plaza straight to the centre of business activities.

The video camera used to calculate service rate was placed outside the toll road and facing the toll plaza in such a way that the camera can observe all the vehicles exiting toll road through each exit booth. The video start recorded at 8.10 AM and finished at 11.55 AM. At that time, 4 exit booths are operationalized. As the same as calculating the arrival rate, the service rate are also being done at the office with manually counted by operators. The service rate was calculated per booth and per minute, and later were combined into 15 minutes bin as the same as automatic setting from optical sensor.

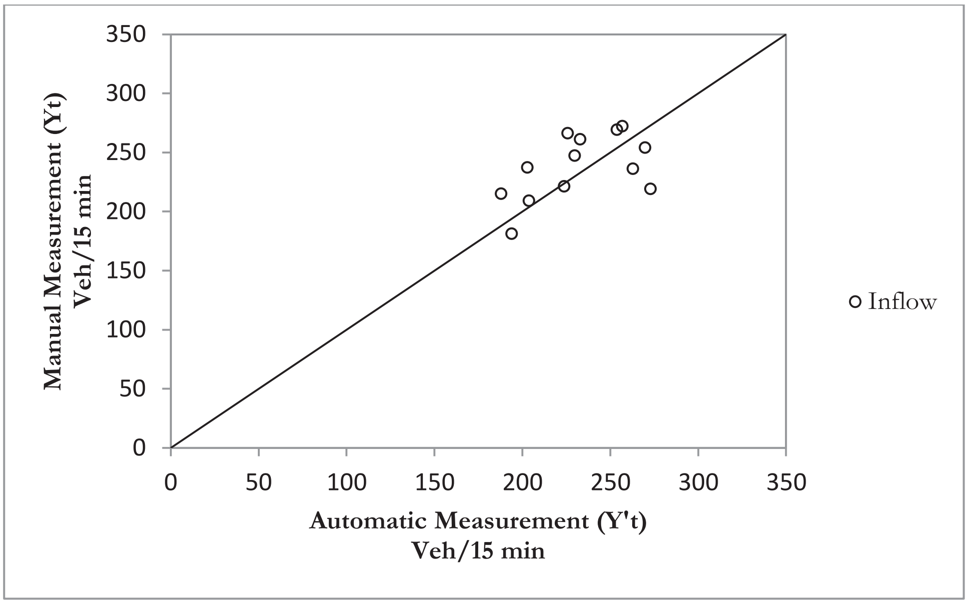


Figure 17 Comparison of arrival rate of traffic flow between automatic and manual measurement at Pasirkoja outlet for 3 hours period with 15 minutes time bin.

Figure 17 shows the result of inflow detector's accuracy compared to manually counted traffic flow data. The oblique line is representing the tendency line. The more observed data close to the tendency line, the more accurate the estimation will be. Most of all measurements lie above the tendency line, which means the result from the detector's measurements value is underestimate because it is below the manually counted traffic data. These errors are suspected due to vehicle detection error in which two or more intermingled vehicles are detected as one vehicle. Moreover, visual limitation such as the dark, heavy rain and fog are also affecting the correctness of this image analyser detector. Ideally, this kind of detector is equipped with addition sensor such as vehicle axle detector in order to verify the number of vehicle based on number of its axles.

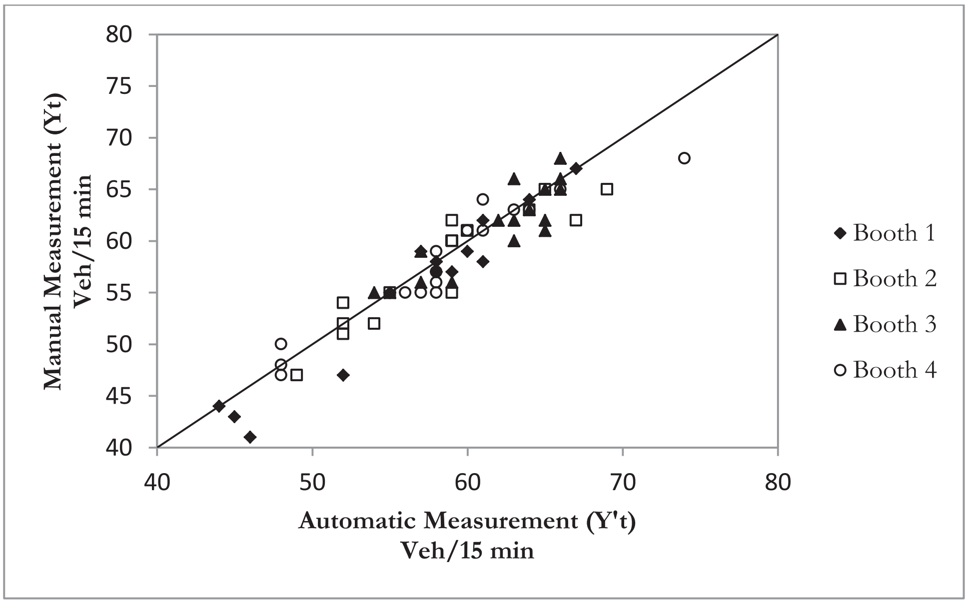


Figure 18 Comparison of service rate of each booth between automatic and manual measurement at Pasir Koja outlet for 3 hours period with 15 minutes time bin.

Optical detectors which are placed on each toll booth of Pasteur toll plaza showed almost a same result in capturing outflow data automatically. It can be seen in Figure 18 which most all of the measurements lay near the tendency line. However, the difference with the inflow measurements, this outflow measurement from the optical detector is overestimate. The automatic counting shows more vehicles exiting toll plaza than the actual condition. It happened because when detected the flow, these optical detectors sometimes failed to sense articulated vehicles and counted them as two vehicles instead of one.

From the error measurement, Table 8 (and more in ANNEX 1) shows the values of errors based on MAD, MSE, MAPE and MPE calculations at each toll booth at Pasirkoja toll plaza. It is concluded that there were no significant error occurred on the detections, so that the training datasets can be taken to the next analysis without being applied by any error correction.

Table 8 The error measurement between actual and forecasted service rate on each booth at Pasir Koja toll plaza on 1st September 2012 with 15 minutes time bin

	MAD	MSE	MAPE	MPE
Booth 1	1.563	5.188	3.246	-1.706
Booth 2	1.750	5.250	3.018	-1.124
Booth 3	1.563	4.063	2.561	-0.974
Booth 4	1.563	4.563	2.646	-1.143

5.3. Statistical distribution testing for mean arrival rate at Pasteur toll plaza

The statistical distribution analysis was done by calculating the group of data in 1 hour time slice. These hourly sub-datasets was used in order to indicate in which time of observation the queue occurs. Table 9 and Table 10 show the example of how analysis of statistical distribution was calculated. Also, chi-square test was executed to test whether a certain group of hourly data is following expected statistical distribution. By confirming the type of statistical distribution by chi-square test, the next step was choosing the right formula to simulate the queue length. Moreover, ANNEX 2 shows the variation of collected inflow data within 1 hour period for 2 x 24 hours observations.

The steps to calculate each attributes for Table 9 and Table 10 as follows:

1. Separate arrival rate datasets into 1 hour time slice for 24 hours observation.
2. Calculate the mean arrival rate per hour (λ_t). In this particular hour, λ_t=42.33 vehicles/5 minutes
3. Calculate the variance of arrival rate per hour (s^2), that is s^2=125.879
4. Compare between mean and variance. If the ratio between mean and variance is less than 1, than such group of data is hypothetically following Poisson distribution. If the ratio is greater than 1, than it should be considered as Binomial distribution.

   In this case $\frac{\lambda_t}{s^2} = \frac{42.33}{125.879} = 0.336 < 1$ →Poisson distribution
5. Based on Table 9 for Poisson distribution analysis, the calculation as follows:
   a. Column 1: sort the data from the smallest to the biggest value of number of arrival =x (veh/5min)
   b. Column 2: Calculate the frequency of arrival rate x in 1 hour
   c. Column 3: Calculate probability of x using Poisson distribution formula.

$$P(x) = \frac{e^{-\lambda_t}\lambda_t^{\ x}}{x!} \qquad (5)\text{repeated}$$

d. Column 4: Calculate the theoretical frequency (f_t) based on the formula:

$$f_t = P(x) \times \sum f_0 \tag{16}$$

e. Column 5: Widen the interval of arrival rate (x) by combining its theoretical frequencies which has value below 0.1. This step should be done in order to prevent the big value of chi-square (χ2).

f. Column 6: Calculate the percentage of combined theoretical frequency (f_t) using the formula:

$$\frac{\text{Combined } f_t}{\sum \text{Combine } f_t} \times 100\% \tag{17}$$

g. Column 7: Fill with the difference between f_0 and f_t

h. Column 8: Squared value of column 7

Column 9: Divide the value from column 8 with the value from column 7, and became the formula chi-square test:

$$\chi^2 = \sum_{1}^{g} \frac{(f_0 - f_t)^2}{f_t} \qquad \text{(9)repeated}$$

i. Sum of all value in column 9, it became the value of $\chi^2{}_{critical}$

6. The degree of freedom was derived from subtracting number of observations (g) by 1 and value of parameter(A).

$$\upsilon = (g - 1) - A \qquad \text{(10)repeated}$$

Based on Table 7, the value of parameter (A) for Poisson distribution is =1

So degree of freedom for Poisson distribution is,

$$\upsilon = g - 2$$

In the example of Table 9, the value of g is equal to the number of successful events based on theoretical frequencies that is 28 events. So, by using the formula (10), the degree of freedom from this group of data is 26.

7. H_0 or null hypothesis means that the group of data is constitute as postulated distribution (Poisson or Binomial). In contrary, alternate hypothesis or Ha is the distribution such group of data that is not very likely following the postulated distribution.

In other words, Null hypothesis (H_0) = follows Poisson distribution

Alternate hypothesis (Ha) = not to follow Poisson distribution

8. There are two values of significance level used in this calculation. They are 0.05 and 0.01. It is actually not necessary to provide two level of significance in the same calculation, unless the test was about to expect the hypothesis is accepted in one of the significance level and rejected in the other.

The value of 0.05 itself means that 5% of rejected postulated distribution is match with the true distribution (Gerlough & Schuhl, 1955). In less accurate precision, 0.01 or 1%significance level is also having the same definition.

9. In order to accept null hypothesis, means that the observed data can be composed as a sample derived from theoretical distribution, the value of critical chi-square should be fewer than chi-square value on a certain degree of freedom.

For example: the sum of values in column 9 indicates the critical chi-square

$\chi^2{}_{critical} < \chi^2{}_{\alpha,\upsilon}$

$\leftrightarrow \chi^2{}_{critical} < \chi^2{}_{0.05,26}$

$\leftrightarrow 31.791 < 38.885$

Therefore this group of observed data in 1 hour at 00.00AM to 01.00AM on 24th of June 2012 is following Poisson distribution with mean arrival rate = λ_t=42.33 vehicles/5 minutes at 95% confidence level.

Similar calculation also applied in Table 10. The main difference is that the probability used in this table was using the Binomial distribution probability function. Also, the result showed that particular group of data was rejected at both levels of significance. It means that the observed distribution did not follow Binomial distribution. Assumed in the previous chapter, rejected observed distribution was treated as if such group of data follows General distribution. These calculations also applied for the rest of 22 hours of the day, and so in the peak day on 22nd of June 2012. The complete calculation for 2 x 24 hour period can be seen in ANNEX 2.

Table 9 Analysis of counting distribution data and hypothesis testing using chi-square on Pasteur outlet at 00.00AM to 01.00AM on 24th of June 2012 with 5 minutes time bin

Vehicles/5 min interval	Observed Frequency	Poisson Dist.				Chi-Square Test		
x	f_0	P(x)	f_t	Combined f_t	f_t (%)	f_0-f_t	$(f_0-f_t)^2$	$(f_0-f_t)^2/f_t$
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
21	1	0.000	0.001					
22	0	0.000	0.003					
23	0	0.000	0.005					
24	0	0.001	0.009					
25	0	0.001	0.015					
26	0	0.002	0.024					
27	0	0.003	0.038					
28	0	0.005	0.057					
29	0	0.007	0.083	0.235	1.963	0	0.055	0.662
30	0	0.010	0.118	0.118	0.983	0	0.014	0.118
31	0	0.013	0.161	0.161	1.342	0	0.026	0.161
32	0	0.018	0.213	0.213	1.776	0	0.045	0.213
33	1	0.023	0.273	0.273	2.278	1	0.529	1.938
34	0	0.028	0.340	0.340	2.836	0	0.115	0.340
35	0	0.034	0.411	0.411	3.430	0	0.169	0.411
36	2	0.040	0.483	0.483	4.034	2	2.301	4.762
37	1	0.046	0.553	0.553	4.615	0	0.200	0.362
38	0	0.051	0.616	0.616	5.142	-1	0.379	0.616
39	0	0.056	0.668	0.668	5.581	-1	0.447	0.668
40	1	0.059	0.707	0.707	5.907	0	0.086	0.121
41	1	0.061	0.730	0.730	6.099	0	0.073	0.099
42	0	0.061	0.736	0.736	6.147	-1	0.542	0.736
43	0	0.060	0.725	0.725	6.052	-1	0.525	0.725
44	1	0.058	0.697	0.697	5.823	0	0.092	0.131
45	0	0.055	0.656	0.656	5.477	-1	0.430	0.656
46	0	0.050	0.604	0.604	5.041	-1	0.365	0.604
47	0	0.045	0.544	0.544	4.540	-1	0.296	0.544
48	0	0.040	0.480	0.480	4.004	0	0.230	0.480
49	0	0.035	0.414	0.414	3.460	0	0.172	0.414
50	0	0.029	0.351	0.351	2.929	0	0.123	0.351
51	2	0.024	0.291	0.291	2.431	2	2.920	10.027
52	0	0.020	0.237	0.237	1.979	0	0.056	0.237
53	0	0.016	0.189	0.189	1.581	0	0.036	0.189
54	0	0.012	0.148	0.148	1.239	0	0.022	0.148
55	0	0.010	0.114	0.114	0.954	0	0.013	0.114
56	1	0.007	0.086	0.282	2.357	1	0.515	5.963
57	0	0.005	0.064					
58	0	0.004	0.047					
59	0	0.003	0.034					
60	0	0.002	0.024					
61	0	0.001	0.016					
62	1	0.001	0.011					
Total	12	0.99812	11.97748	11.97748	100			31.791

g	28	Df	26
	Sig.level	0.05	0.01
	Chi-square	**38.885**	**45.642**
		Do not reject H0	**Do not reject H0**

Table 10 Analysis of counting distribution data and hypothesis testing using chi-square on Pasteur outlet at 03.00AM to 04.00AM on 24th of June 2012 with 5 minutes time bin

Vehicles/5 min interval	Observed Frequency	Binomial Dist.				Chi-Square Test			
x	f_0	P(x)	f_t	Combined f_t	f_t (%)	f_0-f_t	$(f_0\text{-}f_t)^2$	$(f_0\text{-}f_t)^2/f_t$	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	
9	3	0.075	0.898	0.898	8.762	2.102	4.418	4.920	
10	0	0.095	1.141	1.141	11.131	-1.141	1.301	1.141	
11	2	0.109	1.313	1.313	12.813	0.687	0.472	0.359	
12	3	0.115	1.381	1.381	13.476	1.619	2.621	1.898	
13	1	0.111	1.336	1.336	13.040	-0.336	0.113	0.085	
14	0	0.100	1.197	1.197	11.678	-1.197	1.432	1.197	
15	1	0.083	0.997	0.997	9.729	0.003	0.000	0.000	
16	0	0.065	0.776	0.776	7.573	-0.776	0.602	0.776	
17	0	0.047	0.567	0.567	5.530	-0.567	0.321	0.567	
18	0	0.032	0.390	0.390	3.801	-0.390	0.152	0.390	
19	2	0.021	0.253	0.253	2.467	1.747	3.053	12.073	
Total	12		10.24905	10.24905	100			23.404	
p	0.039735099				g	11 Df		9	
1-p	0.960264901						Sig.level	0.05	0.01
n	316.6805556						Chi-square	**16.919**	**21.666**
								Reject Ho	**Reject Ho**

5.4. Predicting the queued vehicles

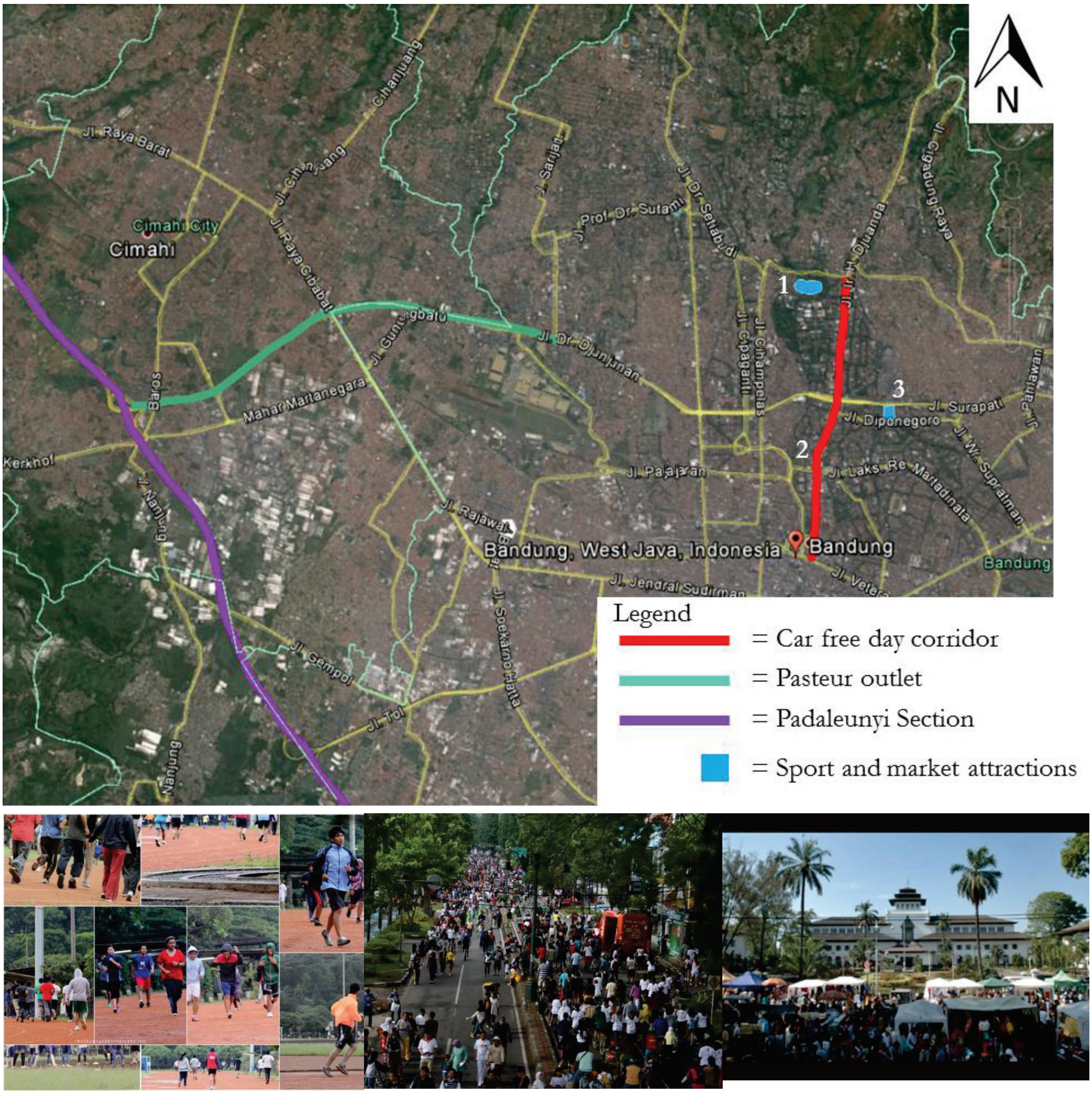
This model was done in order to spot the time when the queue in the reservoir was building up. Moreover, this analysis was also being able to recognize the dull moment. The dull moment is the condition when the arrival rate was approximately having the same amount with the service rate, so that vehicles which came into the storage were directly served by the operating booths. Noticing the dull moment is the easiest way to test whether the prediction of queued vehicle is likely to occur. If it is assumed that in the dull moment there was null vehicle in the queue, and the approximate predicted queue showed similar value, than the prediction is more likely accurate. The next discussion showed that the starting point of a dull moment is at 3 AM in the morning.

There are 2 x 24 hour datasets from Pasteur toll plaza with 5 minutes time bin on Friday 22nd of June 2012 as a peak day and Sunday, June 24th 2012 as off-peak day. From the datasets, traffic volumes on the outlet (inflow) and from the toll booths (outflow) were taken at the same time as two different time series. The reservoir capacity prior the exit of toll plaza is being measured as number of vehicles that the area can accommodate. As we may know, numbers of open toll booths were changing even in 15 minutes time interval. Therefore, the graphs of queued vehicle were drawn based on the maximum booths that actively serviced the incoming traffic at a certain time interval.

Figure 20 depicts the fluctuation of queuing vehicles at Pasteur toll plaza for 24 hours period at peak day. This first figure of fluctuated vehicle queue happened on Friday, 22nd of June 2012. It is hard to determine the peak hour concluded from this graph, as in 15 minutes interval the length of queued vehicle in the reservoir were changing from morning to evening. The coarse time interval was applied; it is hourly aggregated both for mean arrival rate and mean service time. The result shows that there were two significant peaks of vehicle queue. The first peak occurred in the morning from 06.02 AM to 06.57 AM, noted by 67 vehicles as the average vehicle in the queue line. The queue dropped at 34 vehicles until 07.57 AM. It is understood on this period as the morning peak hour where commuters were going to their works. These commuters were using Pasteur exit plaza as this exit is strategically located near the central business district. Most of these commuters came from neighbouring city of Bandung, such as Padalarang and Cimahi. Some of the commuters from the eastern part of Bandung were also using this toll plaza. They usually tried to avoid the traffic jam in the city road networks as they reach their destination to the city centre. The second peak can be seen as evening peak hour occurred at 20.19PM to 20.59PM.

Although there was no strong evidence, it is assumed that start from this time interval people from outside Bandung were coming to spend their weekend.

In the second figure, as can be seen in Figure 21, the first peak occurred in the morning from 07.02 AM to 07.58 AM and slightly rose up until 08.58 AM. Although it was a holiday period, high volume traffic were suspected happening because there were some attraction around the city centre. Depicted in Figure 19, people used Pasteur outlet to reach three major attractions. There are car free day on one of the corridor in the city centre, Sunday market, and sport arena.



1. Sabuga, Sport attraction
(Source: imeldamega.blogspot.nl)

2. Ir. H. Juanda street, Car free day
(Source: sterilpoltekkesbdgfiles.wordpress.com)

3. Gasibu, Sunday flea market
(Source: www.tempo.co)

Figure 19 Three major attractions occurred every Sunday in Bandung

Start from 13.53PM he traffic flows continued to flood Bandung. There were always accumulations of vehicles in the reservoir based on predicted condition until it dropped at 17.19PM and 21.45PM. It is suspected that there was congestion outside Pasteur toll plaza that affects the queue in the reservoir.

There were two significant spike of traffic flows occurred in the afternoon. There was no evidence available to explain this situation. But if we take a look at the raw data, these conditions occurred because there were huge differences of standard deviation values on average service rate. These values affect the calculation and showed the enormous number of queued vehicles. As can be seen on the Figure 21, these conditions only happened in 15 minutes time interval. For the next interval, the system succeeds to alleviate the congestion.

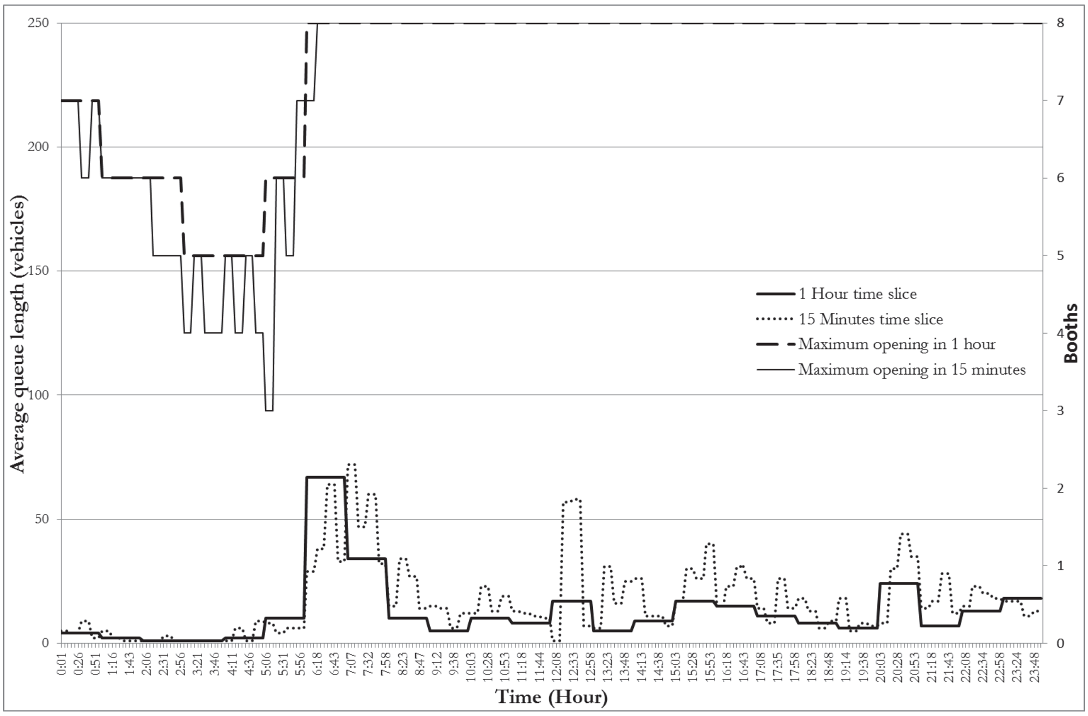


Figure 20 Predicted queued vehicles at Pasteur toll plaza on Friday, 22 June 2012 (Peak)

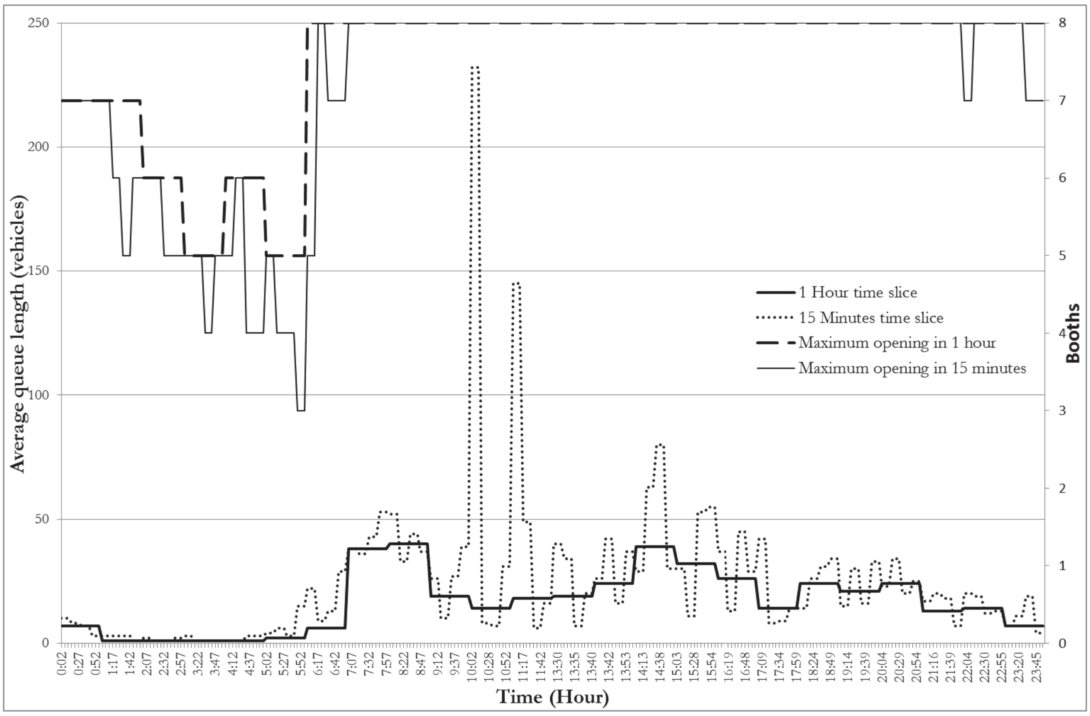


Figure 21 Predicted queued vehicles at Pasteur toll plaza on Sunday, 24 June 2012 (Off-peak)

6. CONCLUSION AND RECOMENDATION

This research aims to predict congestion on the exit of toll plaza towards Bandung city. This prediction is disseminated through VMS placed before the interchange of main toll road and its outlet. By noticing the upstream travellers who come from westbound of the city, it is expected that the travellers who read the message will avoid the congestion of certain outlet and continue to the next exit.

The method applied is to calculate the length of the possible queuing vehicle. Identification of statistical distribution from mean arrival rate (inflow traffic) and gates' throughput (outflow traffic) has become a justification for using a certain set of formulas. These calculations were done by using Microsoft Excel 2010 and IBM SPSS version 21.

The datasets extracted from the server demonstrated number of errors. It was recognised that only maximum 40% of all 7 months data collection on each pair of inflow and outflow datasets has the same date and same number records at the same toll outlet. However, the measurement test conducted to quantify the error of automatically detected traffic flow. Insignificant error from traffic detection also indicates that both inflow and outflow detectors performed nearly accurate. In fact, as a recommendation for future research, the collection of less aggregate data will gives a detail insight of vehicular movement over time.

Although it is seldom to happen, some of the detector sometime failed to send the traffic data to the server according to the pre-set time bin configuration. For instance, in 5 minutes time bin setting, the fact that there are more than 12 records in one hour time slice indicates that there was something wrong with the data transmission. Such detector either sent the data in less than 5 minutes time interval or in most cases, the detector did "double sending" several second or minute after the pre-define time. This situation often requires tedious inspection, by manually sort out the time stamp list in the datasets before combining inflow and outflow datasets into a training datasets.

The fact that there are problems on the connection between server and control unit on the detectors, it is assumed that this is the main drawback of GPRS protocol in transmitting data. Investment in communication infrastructure, such as fibre optic to support constant data transmission from all the detectors to the server is also appropriate as a recommended thing for future research.

Simulation of congestion at toll plaza was done by calculating traffic parameters applied into number of formulas. Although the simulation was built over several assumptions, it is more likely that the prediction of queuing vehicle at the toll plaza is similar to the actual condition. One thing that showed a similar pattern between the simulation and the actual situation can be observed in the dull moment when the minimum traffic flows were detected. The dull moment at 03.00 AM in the morning was very likely that no vehicle present in the reservoir area before toll plaza. It is confirmed with the calculation that the result of queuing vehicle at that moment was closely to zero.

For second instance, this prediction was proven correct by showing the occurrence of morning and afternoon peak hour. These recurrent pattern confirmed by usual activity happened in Bandung whether on weekday (in this case: Friday) and weekend (i.e. Sunday).

A critical attention should be taken to these predictions. The predictions should be considered as a minimum threshold that may be happen in the actual condition. The limitation in defining the reservoir capacity as number of queued vehicle in front of active service booths gives a floating value of reservoir's capacity. As a matter of fact, the capacity of reservoir prior to toll plaza is fixed in a certain geographical boundary. Also, the bottleneck before the reservoir which converts the outlet from two to eight vehicle lanes towards toll plaza will makes the real congestion more severe than it is predicted by the system.

In normal circumstances, the travel time from the location of Pasteur VMS to Pasteur toll plaza is less than 10 minutes. The dissemination of information through VMS for the upstream traveller is better done in 5 minutes interval derived from 15 minutes calculation. In addition, since there are two types of information to be displayed, the possible solution would be shows two types of information simultaneously on the VMS.

The methods delivered in this research consider as an applicative and straight forward in determining the number of queued vehicles at the toll plaza. However, the opportunity to develop this method in the future leaves room for improvement. The possible advancement is to replace the actual traffic flows calculated in the beginning of the process with predicted traffic flow.

The training datasets used in this research are the proper datasets to support the ultimate claim that says Pasteur toll plaza experienced the traffic congestion. From the discussion of results, proofs of evidence of such claim were described. Nonetheless, since the prediction was only done in one outlet, one other claim that Pasteur toll plaza as the most congested toll outlet among other outlets on Padaleunyi toll road section is yet has been proven.

In relevance with geo-information and urban planning, this research helps transportation planner to delineate spatio-temporal traffic condition on the outlets of Padaleunyi toll road. By this result, planner and policy maker are being facilitated to make a discussion of strategic planning by making a decisive intervention.

In the endeavour to relief the traffic congestion on particular outlet, urban planners are also supported by this research. Accessibility to the city centre as the main problem that causes the congestion will give planner an idea of how they are going to allocate the recreational area. The urban development in the eastern part of the city may be the possible solution to distribute the traffic evenly through five toll outlets towards Bandung. Utilization of more detectors, especially on the mid-block between two interchanges within main toll road is also will gives this system more advancement in formulating the reliable VMS.

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ANNEX 1: THE ERROR MEASUREMENT BETWEEN ACTUAL AND AUTOMATICALLY DETECTED ARRIVAL AND SERVICE RATE

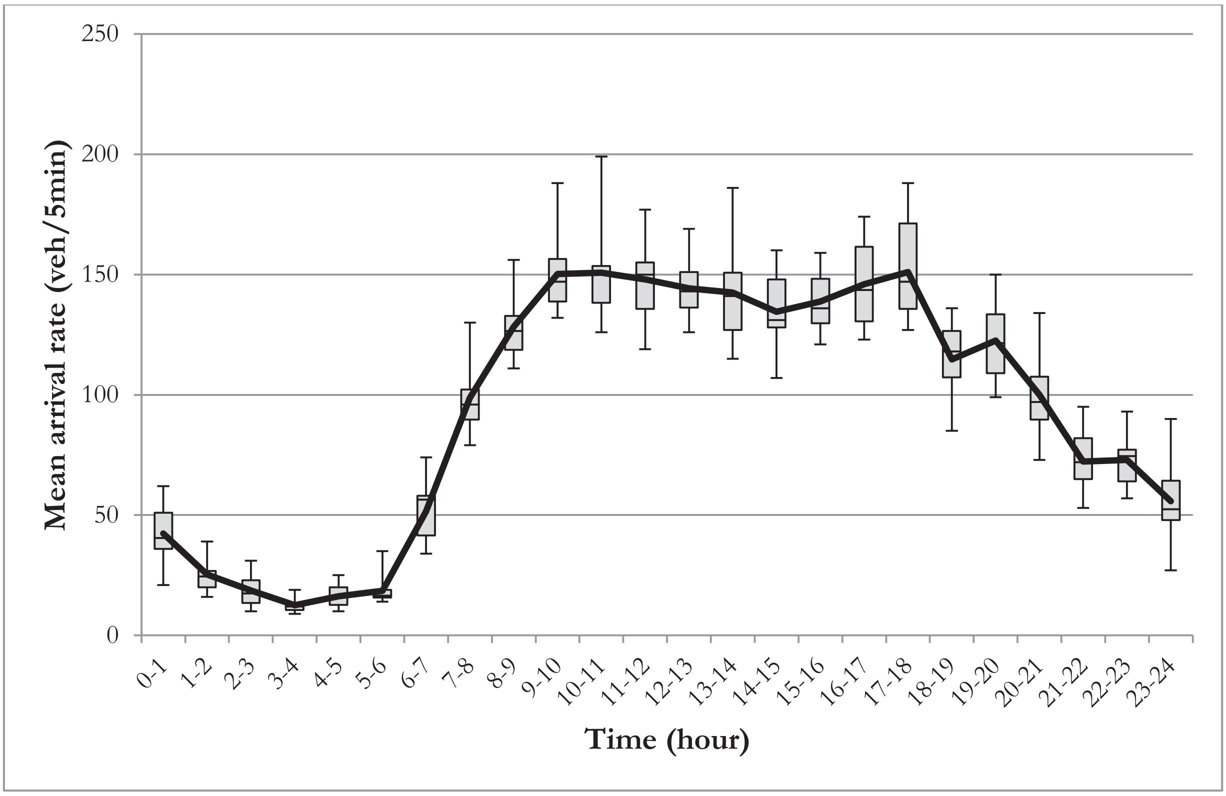
The error measurement between actual and automatically detected arrival rate at Pasirkoja toll plaza on 1st September 2012 with 15 minutes time bin

No	Time	Actual	Forecast	Error	Absolute Error	Squared Error	$\lvert e_t \rvert / Y_t$	e_t / Y_t
	t	Y_{t1}	Y'_{t1}	e_{t1}	$\lvert e_{t1} \rvert$	e_{t1}^2		
0	7:56:08 AM	0	0	0	0	0	0.000	0.000
1	8:11:01 AM	209	204	5	5	25	0.024	0.024
2	8:26:07 AM	181	194	-13	13	169	0.072	-0.072
3	8:41:00 AM	215	188	27	27	729	0.126	0.126
4	8:56:06 AM	221	224	-3	3	9	0.014	-0.014
5	9:11:01 AM	237	203	34	34	1156	0.143	0.143
6	9:26:01 AM	236	263	-27	27	729	0.114	-0.114
7	9:41:00 AM	261	233	28	28	784	0.107	0.107
8	9:56:00 AM	269	254	15	15	225	0.056	0.056
9	10:11:00 AM	219	273	-54	54	2916	0.247	-0.247
10	10:26:01 AM	266	226	40	40	1600	0.150	0.150
11	10:41:00 AM	272	257	15	15	225	0.055	0.055
12	10:56:00 AM	254	270	-16	16	256	0.063	-0.063
13	11:11:01 AM	247	230	17	17	289	0.069	0.069
	Total	3087	3019	68	294	9112	1.240	0.221
			MAD		22.615			
			MSE			700.923		
			MAPE (%)				9.536	
			MPE (%)					1.700

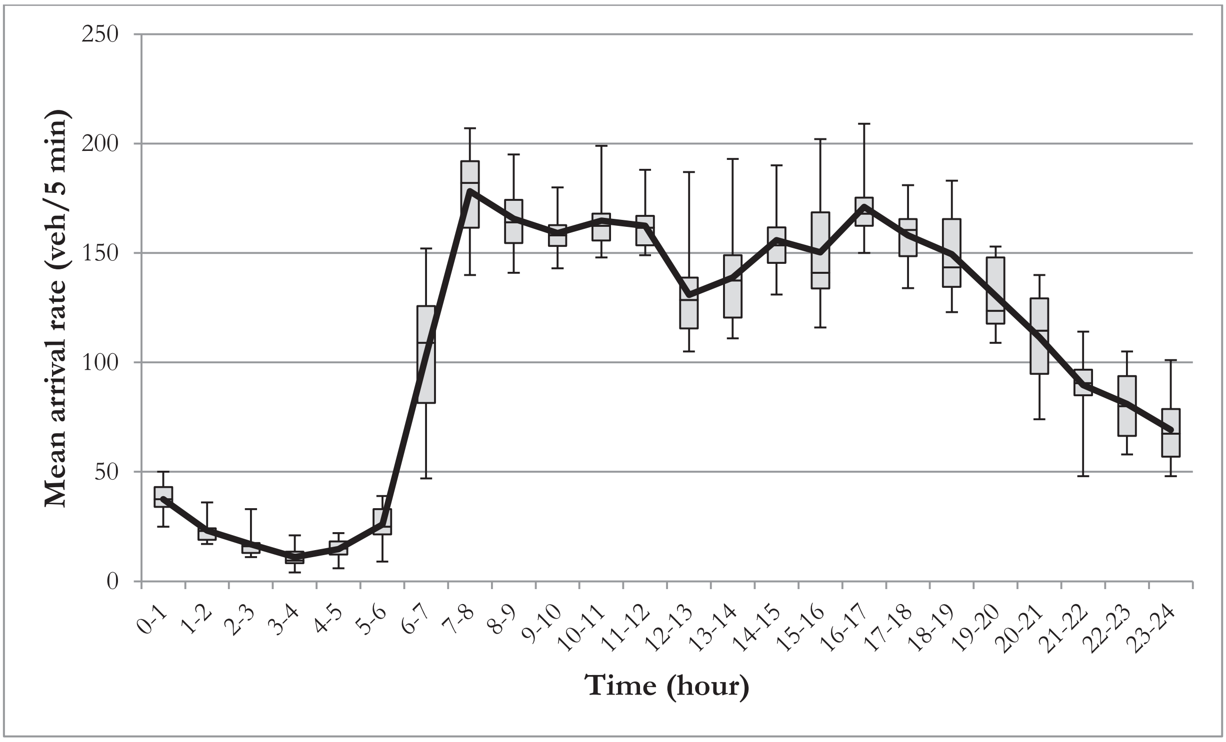
The error measurement between actual and automatically detected service rate on booth 1 at Pasirkoja toll plaza on 1st September 2012 with 15 minutes time bin

No	**Time**	**Actual**	**Forecast**	**Error**	**Absolute Error**	**Squared Error**	Ie_tI / Y_t	e_t / Y_t
	t	Y_{t1}	Y'_{t1}	e_{t1}	$Ie_{t1}I$	e_{t1}^2		
0	7:55:00 AM	0	0	0	0	0	0.000	0.000
1	8:10:48 AM	44	44	0	0	0	0.000	0.000
2	8:25:54 AM	41	46	-5	5	25	0.122	-0.122
3	8:40:48 AM	41	38	3	3	9	0.073	0.073
4	8:55:48 AM	47	52	-5	5	25	0.106	-0.106
5	9:10:47 AM	43	45	-2	2	4	0.047	-0.047
6	9:25:48 AM	59	57	2	2	4	0.034	0.034
7	9:40:48 AM	64	64	0	0	0	0.000	0.000
8	9:55:51 AM	59	60	-1	1	1	0.017	-0.017
9	10:10:47 AM	58	58	0	0	0	0.000	0.000
10	10:25:48 AM	58	58	0	0	0	0.000	0.000
11	10:40:49 AM	57	59	-2	2	4	0.035	-0.035
12	10:55:48 AM	67	67	0	0	0	0.000	0.000
13	11:10:48 AM	58	61	-3	3	9	0.052	-0.052
14	11:25:48 AM	62	61	1	1	1	0.016	0.016
15	11:40:49 AM	57	58	-1	1	1	0.018	-0.018
16	11:55:48 AM	55	55	0	0	0	0.000	0.000
	Total	870	883	-13	25	83	0.519	-0.273
			MAD		1.563			
			MSE			5.188		
			MAPE (%)				3.246	
			MPE (%)					-1.706

ANNEX 2: MEAN ARRIVAL RATE AND ITS VARIATION OF DATA DISTRIBUTION



Mean arrival rate and its variation of data distribution within an hour on Pasteur toll plaza on 24 June 2012



Mean arrival rate and its variation of data distribution within an hour on Pasteur toll plaza on 22 June 2012

ANNEX 3: THE RESULT OF HYPOTHESIS TESTING USING CHI-SQUARE TEST ON ARRIVAL RATE

The result of hypothesis testing using chi-square on Pasteur outlet 24th of June 2012 with 5 minutes time bin for 24 hours

Hour	χ^2	df	$\chi^2_{df,0.05}$	$\chi^2_{df,0.01}$	H_0	0.05	0.01	Remarks
1	15.142	16	26.296	40.289	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
2	17.670	16	26.296	32.000	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
3	10.904	15	24.996	30.578	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
4	25.142	14	23.685	29.141	Poisson Distribution	**Reject Ho**	**Do not reject H0**	General Distribution
5	13.819	14	23.685	29.141	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
6	33.936	21	32.671	38.932	Poisson Distribution	**Reject Ho**	**Do not reject H0**	Poisson Distribution
7	22.243	35	49.802	57.342	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
8	26.428	40	55.758	63.691	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
9	32.691	40	55.758	63.691	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
10	40.376	35	49.802	57.342	Binomial Distribution	**Do not reject H0**	**Do not reject H0**	Binomial Distribution
11	32.882	36	50.998	58.619	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
12	35.096	33	47.400	54.776	Binomial Distribution	**Do not reject H0**	**Do not reject H0**	Binomial Distribution
13	27.231	37	52.192	59.893	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
14	30.491	39	54.572	62.428	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
15	30.058	39	54.572	62.428	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
16	46.685	39	54.572	62.428	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
17	46.025	41	56.942	64.950	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
18	26.574	39	54.572	62.428	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
19	33.137	39	54.572	62.428	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
20	98.721	38	53.384	61.162	Poisson Distribution	**Reject Ho**	**Reject Ho**	General Distribution
21	53.731	36	50.998	58.619	Poisson Distribution	**Reject Ho**	**Do not reject H0**	General Distribution
22	34.336	33	47.400	54.776	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
23	39.748	31	44.985	52.191	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
24	39.120	30	43.773	50.892	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution

The result of hypothesis testing using chi-square on Pasteur outlet 22nd of June 2012 with 5 minutes time bin for 24 hours

Hour	χ^2	df	$\chi^2_{df,0.05}$	$\chi^2_{df,0.01}$	H_0	0.05	0.01	Remarks
1	31.791	26	38.885	45.642	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
2	28.704	20	31.410	37.566	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
3	27.874	18	28.869	34.805	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
4	22.746	9	16.919	21.666	Binomial Distribution	**Reject Ho**	**Reject Ho**	General Distribution
5	21.112	14	23.685	29.141	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
6	11.884	14	23.685	29.141	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
7	41.190	28	41.337	48.278	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
8	24.539	35	49.802	57.342	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
9	41.987	36	50.998	58.619	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
10	42.212	38	53.384	61.162	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
11	35.400	39	54.572	62.428	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
12	48.367	41	56.942	64.950	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
13	45.791	38	53.384	61.162	Binomial Distribution	**Do not reject H0**	**Do not reject H0**	Binomial Distribution
14	36.092	40	55.758	63.691	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
15	51.974	39	54.572	62.428	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
16	42.462	36	50.998	58.619	Binomial Distribution	**Do not reject H0**	**Do not reject H0**	Binomial Distribution
17	57.052	40	55.758	63.691	Poisson Distribution	**Reject Ho**	**Do not reject H0**	General Distribution
18	32.925	41	56.942	64.950	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
19	35.829	37	52.192	59.893	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
20	53.148	36	50.998	58.619	Poisson Distribution	**Reject Ho**	**Do not reject H0**	General Distribution
21	46.482	35	49.802	57.342	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
22	31.202	31	44.985	52.191	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
23	42.611	30	43.773	50.892	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution
24	30.271	29	42.557	49.588	Poisson Distribution	**Do not reject H0**	**Do not reject H0**	Poisson Distribution

ANNEX 4: VMS STATUS BASED ON PREDICTED QUEUED VEHICLES AT PASTEUR TOLL PLAZA

22nd of June 2012

Time	Li (Vehicle)		Opening	Reservoir Capacity (Vehicle)			VMS Status	
	Predicted	Rounded-up	(Booth)	100%	80%	50%	Qualitative	Quantitative
0:02	4.4	5	7	232	185.6	116	SMOOTH	35 meter queue
0:07	4.4	5	7	232	185.6	116	SMOOTH	35 meter queue
0:12	4.4	5	7	232	185.6	116	SMOOTH	35 meter queue
0:17	3.4	4	7	232	185.6	116	SMOOTH	28 meter queue
0:22	3.4	4	7	232	185.6	116	SMOOTH	28 meter queue
0:27	3.4	4	7	232	185.6	116	SMOOTH	28 meter queue
0:32	8.5	9	6	232	185.6	116	SMOOTH	63 meter queue
0:37	8.5	9	6	232	185.6	116	SMOOTH	63 meter queue
0:42	8.5	9	6	232	185.6	116	SMOOTH	63 meter queue
0:47	1.0	2	7	232	185.6	116	SMOOTH	14 meter queue
0:52	1.0	2	7	232	185.6	116	SMOOTH	14 meter queue
0:57	1.0	2	7	232	185.6	116	SMOOTH	14 meter queue
1:02	4.1	5	6	232	185.6	116	SMOOTH	35 meter queue
1:07	4.1	5	6	232	185.6	116	SMOOTH	35 meter queue
1:12	4.1	5	6	232	185.6	116	SMOOTH	35 meter queue
1:17	1.1	2	6	232	185.6	116	SMOOTH	14 meter queue
1:22	1.1	2	6	232	185.6	116	SMOOTH	14 meter queue
1:27	1.1	2	6	232	185.6	116	SMOOTH	14 meter queue
1:32	0.9	1	6	232	185.6	116	SMOOTH	7 meter queue
1:37	0.9	1	6	232	185.6	116	SMOOTH	7 meter queue
1:42	0.9	1	6	232	185.6	116	SMOOTH	7 meter queue
1:47	0.7	1	6	232	185.6	116	SMOOTH	7 meter queue
1:52	0.7	1	6	232	185.6	116	SMOOTH	7 meter queue
1:57	0.7	1	6	232	185.6	116	SMOOTH	7 meter queue
2:02	0.6	1	6	232	185.6	116	SMOOTH	7 meter queue
2:07	0.6	1	6	232	185.6	116	SMOOTH	7 meter queue
2:12	0.6	1	6	232	185.6	116	SMOOTH	7 meter queue
2:17	0.3	1	5	232	185.6	116	SMOOTH	7 meter queue
2:22	0.3	1	5	232	185.6	116	SMOOTH	7 meter queue
2:27	0.3	1	5	232	185.6	116	SMOOTH	7 meter queue
2:32	2.5	3	5	232	185.6	116	SMOOTH	21 meter queue
2:37	2.5	3	5	232	185.6	116	SMOOTH	21 meter queue
2:43	2.5	3	5	232	185.6	116	SMOOTH	21 meter queue
2:47	0.2	1	5	232	185.6	116	SMOOTH	7 meter queue
2:52	0.2	1	5	232	185.6	116	SMOOTH	7 meter queue
2:57	0.2	1	5	232	185.6	116	SMOOTH	7 meter queue
3:02	0.8	1	4	232	185.6	116	SMOOTH	7 meter queue
3:07	0.8	1	4	232	185.6	116	SMOOTH	7 meter queue
3:12	0.8	1	4	232	185.6	116	SMOOTH	7 meter queue
3:17	0.3	1	5	232	185.6	116	SMOOTH	7 meter queue
3:22	0.3	1	5	232	185.6	116	SMOOTH	7 meter queue
3:27	0.3	1	5	232	185.6	116	SMOOTH	7 meter queue
3:32	0.2	1	4	232	185.6	116	SMOOTH	7 meter queue
3:37	0.2	1	4	232	185.6	116	SMOOTH	7 meter queue
3:42	0.2	1	4	232	185.6	116	SMOOTH	7 meter queue
3:47	0.2	1	4	232	185.6	116	SMOOTH	7 meter queue
3:52	0.2	1	4	232	185.6	116	SMOOTH	7 meter queue
3:57	0.2	1	4	232	185.6	116	SMOOTH	7 meter queue
4:02	0.6	1	5	232	185.6	116	SMOOTH	7 meter queue
4:07	0.6	1	5	232	185.6	116	SMOOTH	7 meter queue
4:12	0.6	1	5	232	185.6	116	SMOOTH	7 meter queue
4:17	5.4	6	4	232	185.6	116	SMOOTH	42 meter queue
4:22	5.4	6	4	232	185.6	116	SMOOTH	42 meter queue
4:27	5.4	6	4	232	185.6	116	SMOOTH	42 meter queue
4:32	0.4	1	5	232	185.6	116	SMOOTH	7 meter queue
4:37	0.4	1	5	232	185.6	116	SMOOTH	7 meter queue
4:42	0.4	1	5	232	185.6	116	SMOOTH	7 meter queue
4:47	8.8	9	4	232	185.6	116	SMOOTH	63 meter queue
4:52	8.8	9	4	232	185.6	116	SMOOTH	63 meter queue
4:57	8.8	9	4	232	185.6	116	SMOOTH	63 meter queue
5:02	7.7	8	3	232	185.6	116	SMOOTH	56 meter queue
5:07	7.7	8	3	232	185.6	116	SMOOTH	56 meter queue
5:12	7.7	8	3	232	185.6	116	SMOOTH	56 meter queue
5:17	3.3	4	6	232	185.6	116	SMOOTH	28 meter queue
5:22	3.3	4	6	232	185.6	116	SMOOTH	28 meter queue
5:27	3.3	4	6	232	185.6	116	SMOOTH	28 meter queue
5:32	5.5	6	5	232	185.6	116	SMOOTH	42 meter queue
5:37	5.5	6	5	232	185.6	116	SMOOTH	42 meter queue
5:42	5.5	6	5	232	185.6	116	SMOOTH	42 meter queue
5:47	5.3	6	7	232	185.6	116	SMOOTH	42 meter queue
5:52	5.3	6	7	232	185.6	116	SMOOTH	42 meter queue
5:57	5.3	6	7	232	185.6	116	SMOOTH	42 meter queue

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Time	Li (Vehicle)		Opening	Reservoir Capacity (Vehicle)			VMS Status	
	Predicted	Rounded-up	(Booth)	100%	80%	50%	Qualitative	Quantitative
6:02	28.2	29	7	232	185.6	116	CONGESTED	203 meter queue
6:07	28.2	29	7	232	185.6	116	CONGESTED	203 meter queue
6:12	28.2	29	7	232	185.6	116	CONGESTED	203 meter queue
6:17	37.3	38	8	232	185.6	116	CONGESTED	266 meter queue
6:22	37.3	38	8	232	185.6	116	CONGESTED	266 meter queue
6:27	37.3	38	8	232	185.6	116	CONGESTED	266 meter queue
6:32	63.7	64	8	232	185.6	116	CONGESTED	448 meter queue
6:37	63.7	64	8	232	185.6	116	CONGESTED	448 meter queue
6:42	63.7	64	8	232	185.6	116	CONGESTED	448 meter queue
6:47	32.6	33	8	232	185.6	116	CONGESTED	231 meter queue
6:52	32.6	33	8	232	185.6	116	CONGESTED	231 meter queue
6:57	32.6	33	8	232	185.6	116	CONGESTED	231 meter queue
7:02	71.3	72	8	232	185.6	116	CONGESTED	504 meter queue
7:07	71.3	72	8	232	185.6	116	CONGESTED	504 meter queue
7:12	71.3	72	8	232	185.6	116	CONGESTED	504 meter queue
7:17	46.5	47	8	232	185.6	116	CONGESTED	329 meter queue
7:22	46.5	47	8	232	185.6	116	CONGESTED	329 meter queue
7:27	46.5	47	8	232	185.6	116	CONGESTED	329 meter queue
7:32	60.0	60	8	232	185.6	116	CONGESTED	420 meter queue
7:37	60.0	60	8	232	185.6	116	CONGESTED	420 meter queue
7:42	60.0	60	8	232	185.6	116	CONGESTED	420 meter queue
7:47	31.7	32	8	232	185.6	116	CONGESTED	224 meter queue
7:52	31.7	32	8	232	185.6	116	CONGESTED	224 meter queue
7:57	31.7	32	8	232	185.6	116	CONGESTED	224 meter queue
8:02	14.3	15	8	232	185.6	116	SMOOTH	105 meter queue
8:07	14.3	15	8	232	185.6	116	SMOOTH	105 meter queue
8:12	14.3	15	8	232	185.6	116	SMOOTH	105 meter queue
8:17	33.1	34	8	232	185.6	116	CONGESTED	238 meter queue
8:22	33.1	34	8	232	185.6	116	CONGESTED	238 meter queue
8:27	33.1	34	8	232	185.6	116	CONGESTED	238 meter queue
8:32	27.0	27	8	232	185.6	116	CONGESTED	189 meter queue
8:37	27.0	27	8	232	185.6	116	CONGESTED	189 meter queue
8:42	27.0	27	8	232	185.6	116	CONGESTED	189 meter queue
8:47	13.9	14	8	232	185.6	116	SMOOTH	98 meter queue
8:52	13.9	14	8	232	185.6	116	SMOOTH	98 meter queue
8:57	13.9	14	8	232	185.6	116	SMOOTH	98 meter queue
9:02	14.7	15	8	232	185.6	116	SMOOTH	105 meter queue
9:07	14.7	15	8	232	185.6	116	SMOOTH	105 meter queue
9:12	14.7	15	8	232	185.6	116	SMOOTH	105 meter queue
9:17	13.7	14	8	232	185.6	116	SMOOTH	98 meter queue
9:23	13.7	14	8	232	185.6	116	SMOOTH	98 meter queue
9:27	13.7	14	8	232	185.6	116	SMOOTH	98 meter queue
9:32	5.4	6	8	232	185.6	116	SMOOTH	42 meter queue
9:37	5.4	6	8	232	185.6	116	SMOOTH	42 meter queue
9:42	5.4	6	8	232	185.6	116	SMOOTH	42 meter queue
9:47	11.9	12	8	232	185.6	116	SMOOTH	84 meter queue
9:52	11.9	12	8	232	185.6	116	SMOOTH	84 meter queue
9:57	11.9	12	8	232	185.6	116	SMOOTH	84 meter queue
10:02	11.2	12	8	232	185.6	116	SMOOTH	84 meter queue
10:07	11.2	12	8	232	185.6	116	SMOOTH	84 meter queue
10:12	11.2	12	8	232	185.6	116	SMOOTH	84 meter queue
10:17	22.1	23	8	232	185.6	116	QUEUING	161 meter queue
10:22	22.1	23	8	232	185.6	116	QUEUING	161 meter queue
10:28	22.1	23	8	232	185.6	116	QUEUING	161 meter queue
10:32	12.6	13	8	232	185.6	116	SMOOTH	91 meter queue
10:37	12.6	13	8	232	185.6	116	SMOOTH	91 meter queue
10:44	12.6	13	8	232	185.6	116	SMOOTH	91 meter queue
10:47	18.9	19	8	232	185.6	116	QUEUING	133 meter queue
10:52	18.9	19	8	232	185.6	116	QUEUING	133 meter queue
10:57	18.9	19	8	232	185.6	116	QUEUING	133 meter queue
11:02	12.6	13	8	232	185.6	116	SMOOTH	91 meter queue
11:07	12.6	13	8	232	185.6	116	SMOOTH	91 meter queue
11:12	12.6	13	8	232	185.6	116	SMOOTH	91 meter queue
11:17	11.9	12	8	232	185.6	116	SMOOTH	84 meter queue
11:23	11.9	12	8	232	185.6	116	SMOOTH	84 meter queue
11:27	11.9	12	8	232	185.6	116	SMOOTH	84 meter queue
11:32	10.4	11	8	232	185.6	116	SMOOTH	77 meter queue
11:37	10.4	11	8	232	185.6	116	SMOOTH	77 meter queue
11:42	10.4	11	8	232	185.6	116	SMOOTH	77 meter queue
13:28	9.0	10	8	232	185.6	116	SMOOTH	70 meter queue
13:28	9.0	10	8	232	185.6	116	SMOOTH	70 meter queue
13:28	9.0	10	8	232	185.6	116	SMOOTH	70 meter queue
13:29	0.8	1	8	232	185.6	116	SMOOTH	7 meter queue
13:30	0.8	1	8	232	185.6	116	SMOOTH	7 meter queue
13:30	0.8	1	8	232	185.6	116	SMOOTH	7 meter queue
13:31	56.1	57	8	232	185.6	116	CONGESTED	399 meter queue
13:34	56.1	57	8	232	185.6	116	CONGESTED	399 meter queue
13:34	56.1	57	8	232	185.6	116	CONGESTED	399 meter queue
13:35	57.3	58	8	232	185.6	116	CONGESTED	406 meter queue
13:36	57.3	58	8	232	185.6	116	CONGESTED	406 meter queue
13:37	57.3	58	8	232	185.6	116	CONGESTED	406 meter queue
13:38	6.0	7	8	232	185.6	116	SMOOTH	49 meter queue
13:38	6.0	7	8	232	185.6	116	SMOOTH	49 meter queue
13:40	6.0	7	8	232	185.6	116	SMOOTH	49 meter queue

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Time	Li (Vehicle)		Opening	Reservoir Capacity (Vehicle)			VMS Status	
	Predicted	Rounded-up	(Booth)	100%	80%	50%	Qualitative	Quantitative
13:40	5.5	6	8	232	185.6	116	SMOOTH	42 meter queue
13:41	5.5	6	8	232	185.6	116	SMOOTH	42 meter queue
13:42	5.5	6	8	232	185.6	116	SMOOTH	42 meter queue
13:42	30.3	31	8	232	185.6	116	CONGESTED	217 meter queue
13:42	30.3	31	8	232	185.6	116	CONGESTED	217 meter queue
13:50	30.3	31	8	232	185.6	116	CONGESTED	217 meter queue
13:50	15.6	16	8	232	185.6	116	SMOOTH	112 meter queue
13:51	15.6	16	8	232	185.6	116	SMOOTH	112 meter queue
13:52	15.6	16	8	232	185.6	116	SMOOTH	112 meter queue
13:53	24.7	25	8	232	185.6	116	QUEUING	175 meter queue
13:54	24.7	25	8	232	185.6	116	QUEUING	175 meter queue
13:59	24.7	25	8	232	185.6	116	QUEUING	175 meter queue
14:03	25.4	26	8	232	185.6	116	QUEUING	182 meter queue
14:08	25.4	26	8	232	185.6	116	QUEUING	182 meter queue
14:13	25.4	26	8	232	185.6	116	QUEUING	182 meter queue
14:18	10.2	11	8	232	185.6	116	SMOOTH	77 meter queue
14:23	10.2	11	8	232	185.6	116	SMOOTH	77 meter queue
14:28	10.2	11	8	232	185.6	116	SMOOTH	77 meter queue
14:33	11.0	11	8	232	185.6	116	SMOOTH	77 meter queue
14:38	11.0	11	8	232	185.6	116	SMOOTH	77 meter queue
14:43	11.0	11	8	232	185.6	116	SMOOTH	77 meter queue
14:49	6.9	7	8	232	185.6	116	SMOOTH	49 meter queue
14:53	6.9	7	8	232	185.6	116	SMOOTH	49 meter queue
14:58	6.9	7	8	232	185.6	116	SMOOTH	49 meter queue
15:03	16.6	17	8	232	185.6	116	QUEUING	119 meter queue
15:09	16.6	17	8	232	185.6	116	QUEUING	119 meter queue
15:13	16.6	17	8	232	185.6	116	QUEUING	119 meter queue
15:18	29.8	30	8	232	185.6	116	CONGESTED	210 meter queue
15:23	29.8	30	8	232	185.6	116	CONGESTED	210 meter queue
15:28	29.8	30	8	232	185.6	116	CONGESTED	210 meter queue
15:33	25.9	26	8	232	185.6	116	QUEUING	182 meter queue
15:38	25.9	26	8	232	185.6	116	QUEUING	182 meter queue
15:47	25.9	26	8	232	185.6	116	QUEUING	182 meter queue
15:53	39.4	40	8	232	185.6	116	CONGESTED	280 meter queue
15:54	39.4	40	8	232	185.6	116	CONGESTED	280 meter queue
15:59	39.4	40	8	232	185.6	116	CONGESTED	280 meter queue
16:04	14.4	15	8	232	185.6	116	SMOOTH	105 meter queue
16:09	14.4	15	8	232	185.6	116	SMOOTH	105 meter queue
16:14	14.4	15	8	232	185.6	116	SMOOTH	105 meter queue
16:19	22.7	23	8	232	185.6	116	QUEUING	161 meter queue
16:24	22.7	23	8	232	185.6	116	QUEUING	161 meter queue
16:29	22.7	23	8	232	185.6	116	QUEUING	161 meter queue
16:34	30.7	31	8	232	185.6	116	CONGESTED	217 meter queue
16:39	30.7	31	8	232	185.6	116	CONGESTED	217 meter queue
16:48	30.7	31	8	232	185.6	116	CONGESTED	217 meter queue
16:49	25.5	26	8	232	185.6	116	QUEUING	182 meter queue
16:54	25.5	26	8	232	185.6	116	QUEUING	182 meter queue
16:59	25.5	26	8	232	185.6	116	QUEUING	182 meter queue
17:04	13.3	14	8	232	185.6	116	SMOOTH	98 meter queue
17:09	13.3	14	8	232	185.6	116	SMOOTH	98 meter queue
17:14	13.3	14	8	232	185.6	116	SMOOTH	98 meter queue
17:19	7.9	8	8	232	185.6	116	SMOOTH	56 meter queue
17:24	7.9	8	8	232	185.6	116	SMOOTH	56 meter queue
17:29	7.9	8	8	232	185.6	116	SMOOTH	56 meter queue
17:34	25.4	26	8	232	185.6	116	QUEUING	182 meter queue
17:40	25.4	26	8	232	185.6	116	QUEUING	182 meter queue
17:44	25.4	26	8	232	185.6	116	QUEUING	182 meter queue
17:49	13.7	14	8	232	185.6	116	SMOOTH	98 meter queue
17:57	13.7	14	8	232	185.6	116	SMOOTH	98 meter queue
17:59	13.7	14	8	232	185.6	116	SMOOTH	98 meter queue

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Time	Li (Vehicle)		Opening	Reservoir Capacity (Vehicle)			VMS Status	
	Predicted	Rounded-up	(Booth)	100%	80%	50%	Qualitative	Quantitative
18:04	17.1	18	8	232	185.6	116	QUEUING	126 meter queue
18:09	17.1	18	8	232	185.6	116	QUEUING	126 meter queue
18:14	17.1	18	8	232	185.6	116	QUEUING	126 meter queue
18:20	12.3	13	8	232	185.6	116	SMOOTH	91 meter queue
18:24	12.3	13	8	232	185.6	116	SMOOTH	91 meter queue
18:29	12.3	13	8	232	185.6	116	SMOOTH	91 meter queue
18:34	5.6	6	8	232	185.6	116	SMOOTH	42 meter queue
18:39	5.6	6	8	232	185.6	116	SMOOTH	42 meter queue
18:45	5.6	6	8	232	185.6	116	SMOOTH	42 meter queue
18:49	8.6	9	8	232	185.6	116	SMOOTH	63 meter queue
18:54	8.6	9	8	232	185.6	116	SMOOTH	63 meter queue
19:02	8.6	9	8	232	185.6	116	SMOOTH	63 meter queue
19:04	17.6	18	8	232	185.6	116	QUEUING	126 meter queue
19:09	17.6	18	8	232	185.6	116	QUEUING	126 meter queue
19:14	17.6	18	8	232	185.6	116	QUEUING	126 meter queue
19:19	4.0	5	8	232	185.6	116	SMOOTH	35 meter queue
19:24	4.0	5	8	232	185.6	116	SMOOTH	35 meter queue
19:29	4.0	5	8	232	185.6	116	SMOOTH	35 meter queue
19:34	7.5	8	8	232	185.6	116	SMOOTH	56 meter queue
19:39	7.5	8	8	232	185.6	116	SMOOTH	56 meter queue
19:44	7.5	8	8	232	185.6	116	SMOOTH	56 meter queue
19:49	6.2	7	8	232	185.6	116	SMOOTH	49 meter queue
19:54	6.2	7	8	232	185.6	116	SMOOTH	49 meter queue
19:59	6.2	7	8	232	185.6	116	SMOOTH	49 meter queue
20:04	7.6	8	8	232	185.6	116	SMOOTH	56 meter queue
20:09	7.6	8	8	232	185.6	116	SMOOTH	56 meter queue
20:14	7.6	8	8	232	185.6	116	SMOOTH	56 meter queue
20:19	29.5	30	8	232	185.6	116	CONGESTED	210 meter queue
20:24	29.5	30	8	232	185.6	116	CONGESTED	210 meter queue
20:29	29.5	30	8	232	185.6	116	CONGESTED	210 meter queue
20:35	43.6	44	8	232	185.6	116	CONGESTED	308 meter queue
20:39	43.6	44	8	232	185.6	116	CONGESTED	308 meter queue
20:44	43.6	44	8	232	185.6	116	CONGESTED	308 meter queue
20:50	34.3	35	8	232	185.6	116	CONGESTED	245 meter queue
20:54	34.3	35	8	232	185.6	116	CONGESTED	245 meter queue
20:59	34.3	35	8	232	185.6	116	CONGESTED	245 meter queue
21:04	13.9	14	8	232	185.6	116	SMOOTH	98 meter queue
21:09	13.9	14	8	232	185.6	116	SMOOTH	98 meter queue
21:14	13.9	14	8	232	185.6	116	SMOOTH	98 meter queue
21:16	16.9	17	8	232	185.6	116	QUEUING	119 meter queue
21:20	16.9	17	8	232	185.6	116	QUEUING	119 meter queue
21:25	16.9	17	8	232	185.6	116	QUEUING	119 meter queue
21:31	27.5	28	8	232	185.6	116	CONGESTED	196 meter queue
21:35	27.5	28	8	232	185.6	116	CONGESTED	196 meter queue
21:39	27.5	28	8	232	185.6	116	CONGESTED	196 meter queue
21:45	11.3	12	8	232	185.6	116	SMOOTH	84 meter queue
21:50	11.3	12	8	232	185.6	116	SMOOTH	84 meter queue
21:54	11.3	12	8	232	185.6	116	SMOOTH	84 meter queue
22:00	14.5	15	8	232	185.6	116	SMOOTH	105 meter queue
22:04	14.5	15	8	232	185.6	116	SMOOTH	105 meter queue
22:10	14.5	15	8	232	185.6	116	SMOOTH	105 meter queue
22:16	22.1	23	8	232	185.6	116	QUEUING	161 meter queue
22:20	22.1	23	8	232	185.6	116	QUEUING	161 meter queue
22:25	22.1	23	8	232	185.6	116	QUEUING	161 meter queue
22:30	19.9	20	8	232	185.6	116	QUEUING	140 meter queue
22:36	19.9	20	8	232	185.6	116	QUEUING	140 meter queue
22:40	19.9	20	8	232	185.6	116	QUEUING	140 meter queue
22:47	17.2	18	8	232	185.6	116	QUEUING	126 meter queue
22:50	17.2	18	8	232	185.6	116	QUEUING	126 meter queue
22:55	17.2	18	8	232	185.6	116	QUEUING	126 meter queue
23:00	16.4	17	8	232	185.6	116	QUEUING	119 meter queue
23:05	16.4	17	8	232	185.6	116	QUEUING	119 meter queue
23:09	16.4	17	8	232	185.6	116	QUEUING	119 meter queue
23:15	16.2	17	8	232	185.6	116	QUEUING	119 meter queue
23:20	16.2	17	8	232	185.6	116	QUEUING	119 meter queue
23:25	16.2	17	8	232	185.6	116	QUEUING	119 meter queue
23:30	10.3	11	8	232	185.6	116	SMOOTH	77 meter queue
23:35	10.3	11	8	232	185.6	116	SMOOTH	77 meter queue
23:40	10.3	11	8	232	185.6	116	SMOOTH	77 meter queue
23:45	12.2	13	8	232	185.6	116	SMOOTH	91 meter queue
23:50	12.2	13	8	232	185.6	116	SMOOTH	91 meter queue
23:55	12.2	13	8	232	185.6	116	SMOOTH	91 meter queue

22nd of June 2012

Time	Li (Vehicle)		Opening	Reservoir Capacity (Vehicle)			VMS Status	
	Predicted	Rounded-up	(Booth)	100%	80%	50%	Qualitative	Quantitative
0:02	9.7	10	7	232	185.6	116	SMOOTH	70 meter queue
0:07	9.7	10	7	232	185.6	116	SMOOTH	70 meter queue
0:12	9.7	10	7	232	185.6	116	SMOOTH	70 meter queue
0:17	7.6	8	7	232	185.6	116	SMOOTH	56 meter queue
0:22	7.6	8	7	232	185.6	116	SMOOTH	56 meter queue
0:27	7.6	8	7	232	185.6	116	SMOOTH	56 meter queue
0:32	6.3	7	7	232	185.6	116	SMOOTH	49 meter queue
0:37	6.3	7	7	232	185.6	116	SMOOTH	49 meter queue
0:42	6.3	7	7	232	185.6	116	SMOOTH	49 meter queue
0:47	2.8	3	7	232	185.6	116	SMOOTH	21 meter queue
0:52	2.8	3	7	232	185.6	116	SMOOTH	21 meter queue
0:57	2.8	3	7	232	185.6	116	SMOOTH	21 meter queue
1:02	2.4	3	7	232	185.6	116	SMOOTH	21 meter queue
1:07	2.4	3	7	232	185.6	116	SMOOTH	21 meter queue
1:12	2.4	3	7	232	185.6	116	SMOOTH	21 meter queue
1:17	2.3	3	6	232	185.6	116	SMOOTH	21 meter queue
1:22	2.3	3	6	232	185.6	116	SMOOTH	21 meter queue
1:27	2.3	3	6	232	185.6	116	SMOOTH	21 meter queue
1:32	2.0	3	5	232	185.6	116	SMOOTH	21 meter queue
1:37	2.0	3	5	232	185.6	116	SMOOTH	21 meter queue
1:42	2.0	3	5	232	185.6	116	SMOOTH	21 meter queue
1:47	0.9	1	6	232	185.6	116	SMOOTH	7 meter queue
1:52	0.9	1	6	232	185.6	116	SMOOTH	7 meter queue
1:57	0.9	1	6	232	185.6	116	SMOOTH	7 meter queue
2:02	1.4	2	6	232	185.6	116	SMOOTH	14 meter queue
2:07	1.4	2	6	232	185.6	116	SMOOTH	14 meter queue
2:12	1.4	2	6	232	185.6	116	SMOOTH	14 meter queue
2:17	0.6	1	6	232	185.6	116	SMOOTH	7 meter queue
2:22	0.6	1	6	232	185.6	116	SMOOTH	7 meter queue
2:27	0.6	1	6	232	185.6	116	SMOOTH	7 meter queue
2:32	0.9	1	5	232	185.6	116	SMOOTH	7 meter queue
2:37	0.9	1	5	232	185.6	116	SMOOTH	7 meter queue
2:43	0.9	1	5	232	185.6	116	SMOOTH	7 meter queue
2:47	1.5	2	5	232	185.6	116	SMOOTH	14 meter queue
2:52	1.5	2	5	232	185.6	116	SMOOTH	14 meter queue
2:57	1.5	2	5	232	185.6	116	SMOOTH	14 meter queue
3:02	2.9	3	5	232	185.6	116	SMOOTH	21 meter queue
3:07	2.9	3	5	232	185.6	116	SMOOTH	21 meter queue
3:12	2.9	3	5	232	185.6	116	SMOOTH	21 meter queue
3:17	0.4	1	5	232	185.6	116	SMOOTH	7 meter queue
3:22	0.4	1	5	232	185.6	116	SMOOTH	7 meter queue
3:27	0.4	1	5	232	185.6	116	SMOOTH	7 meter queue
3:32	0.4	1	4	232	185.6	116	SMOOTH	7 meter queue
3:37	0.4	1	4	232	185.6	116	SMOOTH	7 meter queue
3:42	0.4	1	4	232	185.6	116	SMOOTH	7 meter queue
3:47	0.3	1	5	232	185.6	116	SMOOTH	7 meter queue
3:52	0.3	1	5	232	185.6	116	SMOOTH	7 meter queue
3:57	0.3	1	5	232	185.6	116	SMOOTH	7 meter queue
4:02	0.5	1	5	232	185.6	116	SMOOTH	7 meter queue
4:07	0.5	1	5	232	185.6	116	SMOOTH	7 meter queue
4:12	0.5	1	5	232	185.6	116	SMOOTH	7 meter queue
4:17	0.4	1	6	232	185.6	116	SMOOTH	7 meter queue
4:22	0.4	1	6	232	185.6	116	SMOOTH	7 meter queue
4:27	0.4	1	6	232	185.6	116	SMOOTH	7 meter queue
4:32	2.3	3	4	232	185.6	116	SMOOTH	21 meter queue
4:37	2.3	3	4	232	185.6	116	SMOOTH	21 meter queue
4:42	2.3	3	4	232	185.6	116	SMOOTH	21 meter queue
4:47	2.7	3	4	232	185.6	116	SMOOTH	21 meter queue
4:52	2.7	3	4	232	185.6	116	SMOOTH	21 meter queue
4:57	2.7	3	4	232	185.6	116	SMOOTH	21 meter queue
5:02	3.4	4	5	232	185.6	116	SMOOTH	28 meter queue
5:07	3.4	4	5	232	185.6	116	SMOOTH	28 meter queue
5:12	3.4	4	5	232	185.6	116	SMOOTH	28 meter queue
5:17	5.7	6	4	232	185.6	116	SMOOTH	42 meter queue
5:22	5.7	6	4	232	185.6	116	SMOOTH	42 meter queue
5:27	5.7	6	4	232	185.6	116	SMOOTH	42 meter queue
5:32	2.9	3	4	232	185.6	116	SMOOTH	21 meter queue
5:37	2.9	3	4	232	185.6	116	SMOOTH	21 meter queue
5:42	2.9	3	4	232	185.6	116	SMOOTH	21 meter queue
5:47	14.7	15	3	232	185.6	116	SMOOTH	105 meter queue
5:52	14.7	15	3	232	185.6	116	SMOOTH	105 meter queue
5:57	14.7	15	3	232	185.6	116	SMOOTH	105 meter queue

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Time	Li (Vehicle)		Opening	Reservoir Capacity (Vehicle)			VMS Status	
	Predicted	Rounded-up	(Booth)	100%	80%	50%	Qualitative	Quantitative
6:02	21.3	22	5	232	185.6	116	QUEUING	154 meter queue
6:07	21.3	22	5	232	185.6	116	QUEUING	154 meter queue
6:12	21.3	22	5	232	185.6	116	QUEUING	154 meter queue
6:17	9.0	9	8	232	185.6	116	SMOOTH	63 meter queue
6:22	9.0	9	8	232	185.6	116	SMOOTH	63 meter queue
6:27	9.0	9	8	232	185.6	116	SMOOTH	63 meter queue
6:32	12.9	13	7	232	185.6	116	SMOOTH	91 meter queue
6:37	12.9	13	7	232	185.6	116	SMOOTH	91 meter queue
6:42	12.9	13	7	232	185.6	116	SMOOTH	91 meter queue
6:47	28.3	29	7	232	185.6	116	CONGESTED	203 meter queue
6:52	28.3	29	7	232	185.6	116	CONGESTED	203 meter queue
6:57	28.3	29	7	232	185.6	116	CONGESTED	203 meter queue
7:02	37.4	38	8	232	185.6	116	CONGESTED	266 meter queue
7:07	37.4	38	8	232	185.6	116	CONGESTED	266 meter queue
7:12	37.4	38	8	232	185.6	116	CONGESTED	266 meter queue
7:17	35.0	36	8	232	185.6	116	CONGESTED	252 meter queue
7:22	35.0	36	8	232	185.6	116	CONGESTED	252 meter queue
7:27	35.0	36	8	232	185.6	116	CONGESTED	252 meter queue
7:32	42.7	43	8	232	185.6	116	CONGESTED	301 meter queue
7:37	42.7	43	8	232	185.6	116	CONGESTED	301 meter queue
7:42	42.7	43	8	232	185.6	116	CONGESTED	301 meter queue
7:47	52.0	53	8	232	185.6	116	CONGESTED	371 meter queue
7:52	52.0	53	8	232	185.6	116	CONGESTED	371 meter queue
7:57	52.0	53	8	232	185.6	116	CONGESTED	371 meter queue
8:02	51.9	52	8	232	185.6	116	CONGESTED	364 meter queue
8:07	51.9	52	8	232	185.6	116	CONGESTED	364 meter queue
8:12	51.9	52	8	232	185.6	116	CONGESTED	364 meter queue
8:17	32.9	33	8	232	185.6	116	CONGESTED	231 meter queue
8:22	32.9	33	8	232	185.6	116	CONGESTED	231 meter queue
8:27	32.9	33	8	232	185.6	116	CONGESTED	231 meter queue
8:32	43.5	44	8	232	185.6	116	CONGESTED	308 meter queue
8:37	43.5	44	8	232	185.6	116	CONGESTED	308 meter queue
8:42	43.5	44	8	232	185.6	116	CONGESTED	308 meter queue
8:47	36.3	37	8	232	185.6	116	CONGESTED	259 meter queue
8:52	36.3	37	8	232	185.6	116	CONGESTED	259 meter queue
8:57	36.3	37	8	232	185.6	116	CONGESTED	259 meter queue
9:02	25.8	26	8	232	185.6	116	QUEUING	182 meter queue
9:07	25.8	26	8	232	185.6	116	QUEUING	182 meter queue
9:12	25.8	26	8	232	185.6	116	QUEUING	182 meter queue
9:17	10.0	10	8	232	185.6	116	SMOOTH	70 meter queue
9:23	10.0	10	8	232	185.6	116	SMOOTH	70 meter queue
9:27	10.0	10	8	232	185.6	116	SMOOTH	70 meter queue
9:32	26.8	27	8	232	185.6	116	CONGESTED	189 meter queue
9:37	26.8	27	8	232	185.6	116	CONGESTED	189 meter queue
9:42	26.8	27	8	232	185.6	116	CONGESTED	189 meter queue
9:47	38.9	39	8	232	185.6	116	CONGESTED	273 meter queue
9:52	38.9	39	8	232	185.6	116	CONGESTED	273 meter queue
9:57	38.9	39	8	232	185.6	116	CONGESTED	273 meter queue
10:02	231.6	232	8	232	185.6	116	CONGESTED	1624 meter queue
10:07	231.6	232	8	232	185.6	116	CONGESTED	1624 meter queue
10:12	231.6	232	8	232	185.6	116	CONGESTED	1624 meter queue
10:17	7.5	8	8	232	185.6	116	SMOOTH	56 meter queue
10:22	7.5	8	8	232	185.6	116	SMOOTH	56 meter queue
10:28	7.5	8	8	232	185.6	116	SMOOTH	56 meter queue
10:32	7.0	7	8	232	185.6	116	SMOOTH	49 meter queue
10:37	7.0	7	8	232	185.6	116	SMOOTH	49 meter queue
10:44	7.0	7	8	232	185.6	116	SMOOTH	49 meter queue
10:47	30.4	31	8	232	185.6	116	CONGESTED	217 meter queue
10:52	30.4	31	8	232	185.6	116	CONGESTED	217 meter queue
10:57	30.4	31	8	232	185.6	116	CONGESTED	217 meter queue
11:02	144.4	145	8	232	185.6	116	CONGESTED	1015 meter queue
11:07	144.4	145	8	232	185.6	116	CONGESTED	1015 meter queue
11:12	144.4	145	8	232	185.6	116	CONGESTED	1015 meter queue
11:17	48.2	49	8	232	185.6	116	CONGESTED	343 meter queue
11:23	48.2	49	8	232	185.6	116	CONGESTED	343 meter queue
11:27	48.2	49	8	232	185.6	116	CONGESTED	343 meter queue
11:32	5.2	6	8	232	185.6	116	SMOOTH	42 meter queue
11:37	5.2	6	8	232	185.6	116	SMOOTH	42 meter queue
11:42	5.2	6	8	232	185.6	116	SMOOTH	42 meter queue
13:28	15.4	16	8	232	185.6	116	SMOOTH	112 meter queue
13:28	15.4	16	8	232	185.6	116	SMOOTH	112 meter queue
13:28	15.4	16	8	232	185.6	116	SMOOTH	112 meter queue
13:29	39.0	40	8	232	185.6	116	CONGESTED	280 meter queue
13:30	39.0	40	8	232	185.6	116	CONGESTED	280 meter queue
13:30	39.0	40	8	232	185.6	116	CONGESTED	280 meter queue
13:31	33.9	34	8	232	185.6	116	CONGESTED	238 meter queue
13:34	33.9	34	8	232	185.6	116	CONGESTED	238 meter queue
13:34	33.9	34	8	232	185.6	116	CONGESTED	238 meter queue
13:35	6.4	7	8	232	185.6	116	SMOOTH	49 meter queue
13:36	6.4	7	8	232	185.6	116	SMOOTH	49 meter queue
13:37	6.4	7	8	232	185.6	116	SMOOTH	49 meter queue
13:38	19.1	20	8	232	185.6	116	QUEUING	140 meter queue
13:38	19.1	20	8	232	185.6	116	QUEUING	140 meter queue
13:40	19.1	20	8	232	185.6	116	QUEUING	140 meter queue

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Time	Li (Vehicle)		Opening	Reservoir Capacity (Vehicle)			VMS Status	
	Predicted	Rounded-up	(Booth)	100%	80%	50%	Qualitative	Quantitative
13:40	26.0	26	8	232	185.6	116	QUEUING	182 meter queue
13:41	26.0	26	8	232	185.6	116	QUEUING	182 meter queue
13:42	26.0	26	8	232	185.6	116	QUEUING	182 meter queue
13:42	41.2	42	8	232	185.6	116	CONGESTED	294 meter queue
13:42	41.2	42	8	232	185.6	116	CONGESTED	294 meter queue
13:50	41.2	42	8	232	185.6	116	CONGESTED	294 meter queue
13:50	15.4	16	8	232	185.6	116	SMOOTH	112 meter queue
13:51	15.4	16	8	232	185.6	116	SMOOTH	112 meter queue
13:52	15.4	16	8	232	185.6	116	SMOOTH	112 meter queue
13:53	36.2	37	8	232	185.6	116	CONGESTED	259 meter queue
13:54	36.2	37	8	232	185.6	116	CONGESTED	259 meter queue
13:59	36.2	37	8	232	185.6	116	CONGESTED	259 meter queue
14:03	28.4	29	8	232	185.6	116	CONGESTED	203 meter queue
14:08	28.4	29	8	232	185.6	116	CONGESTED	203 meter queue
14:13	28.4	29	8	232	185.6	116	CONGESTED	203 meter queue
14:18	62.5	63	8	232	185.6	116	CONGESTED	441 meter queue
14:23	62.5	63	8	232	185.6	116	CONGESTED	441 meter queue
14:28	62.5	63	8	232	185.6	116	CONGESTED	441 meter queue
14:33	79.9	80	8	232	185.6	116	CONGESTED	560 meter queue
14:38	79.9	80	8	232	185.6	116	CONGESTED	560 meter queue
14:43	79.9	80	8	232	185.6	116	CONGESTED	560 meter queue
14:49	29.5	30	8	232	185.6	116	CONGESTED	210 meter queue
14:53	29.5	30	8	232	185.6	116	CONGESTED	210 meter queue
14:58	29.5	30	8	232	185.6	116	CONGESTED	210 meter queue
15:03	29.5	30	8	232	185.6	116	CONGESTED	210 meter queue
15:09	29.5	30	8	232	185.6	116	CONGESTED	210 meter queue
15:13	29.5	30	8	232	185.6	116	CONGESTED	210 meter queue
15:18	10.2	11	8	232	185.6	116	SMOOTH	77 meter queue
15:23	10.2	11	8	232	185.6	116	SMOOTH	77 meter queue
15:28	10.2	11	8	232	185.6	116	SMOOTH	77 meter queue
15:33	52.5	53	8	232	185.6	116	CONGESTED	371 meter queue
15:38	52.5	53	8	232	185.6	116	CONGESTED	371 meter queue
15:47	52.5	53	8	232	185.6	116	CONGESTED	371 meter queue
15:53	54.5	55	8	232	185.6	116	CONGESTED	385 meter queue
15:54	54.5	55	8	232	185.6	116	CONGESTED	385 meter queue
15:59	54.5	55	8	232	185.6	116	CONGESTED	385 meter queue
16:04	36.6	37	8	232	185.6	116	CONGESTED	259 meter queue
16:09	36.6	37	8	232	185.6	116	CONGESTED	259 meter queue
16:14	36.6	37	8	232	185.6	116	CONGESTED	259 meter queue
16:19	12.3	13	8	232	185.6	116	SMOOTH	91 meter queue
16:24	12.3	13	8	232	185.6	116	SMOOTH	91 meter queue
16:29	12.3	13	8	232	185.6	116	SMOOTH	91 meter queue
16:34	44.4	45	8	232	185.6	116	CONGESTED	315 meter queue
16:39	44.4	45	8	232	185.6	116	CONGESTED	315 meter queue
16:48	44.4	45	8	232	185.6	116	CONGESTED	315 meter queue
16:49	28.4	29	8	232	185.6	116	CONGESTED	203 meter queue
16:54	28.4	29	8	232	185.6	116	CONGESTED	203 meter queue
16:59	28.4	29	8	232	185.6	116	CONGESTED	203 meter queue
17:04	41.0	42	8	232	185.6	116	CONGESTED	294 meter queue
17:09	41.0	42	8	232	185.6	116	CONGESTED	294 meter queue
17:14	41.0	42	8	232	185.6	116	CONGESTED	294 meter queue
17:19	8.0	8	8	232	185.6	116	SMOOTH	56 meter queue
17:24	8.0	8	8	232	185.6	116	SMOOTH	56 meter queue
17:29	8.0	8	8	232	185.6	116	SMOOTH	56 meter queue
17:34	8.3	9	8	232	185.6	116	SMOOTH	63 meter queue
17:40	8.3	9	8	232	185.6	116	SMOOTH	63 meter queue
17:44	8.3	9	8	232	185.6	116	SMOOTH	63 meter queue
17:49	13.3	14	8	232	185.6	116	SMOOTH	98 meter queue
17:57	13.3	14	8	232	185.6	116	SMOOTH	98 meter queue
17:59	13.3	14	8	232	185.6	116	SMOOTH	98 meter queue

continued…

Time	Li (Vehicle)		Opening	Reservoir Capacity (Vehicle)			VMS Status	
	Predicted	Rounded-up	(Booth)	100%	80%	50%	Qualitative	Quantitative
18:04	14.0	14	8	232	185.6	116	SMOOTH	98 meter queue
18:09	14.0	14	8	232	185.6	116	SMOOTH	98 meter queue
18:14	14.0	14	8	232	185.6	116	SMOOTH	98 meter queue
18:20	25.2	26	8	232	185.6	116	QUEUING	182 meter queue
18:24	25.2	26	8	232	185.6	116	QUEUING	182 meter queue
18:29	25.2	26	8	232	185.6	116	QUEUING	182 meter queue
18:34	30.3	31	8	232	185.6	116	CONGESTED	217 meter queue
18:39	30.3	31	8	232	185.6	116	CONGESTED	217 meter queue
18:45	30.3	31	8	232	185.6	116	CONGESTED	217 meter queue
18:49	33.0	34	8	232	185.6	116	CONGESTED	238 meter queue
18:54	33.0	34	8	232	185.6	116	CONGESTED	238 meter queue
19:02	33.0	34	8	232	185.6	116	CONGESTED	238 meter queue
19:04	14.3	15	8	232	185.6	116	SMOOTH	105 meter queue
19:09	14.3	15	8	232	185.6	116	SMOOTH	105 meter queue
19:14	14.3	15	8	232	185.6	116	SMOOTH	105 meter queue
19:19	29.6	30	8	232	185.6	116	CONGESTED	210 meter queue
19:24	29.6	30	8	232	185.6	116	CONGESTED	210 meter queue
19:29	29.6	30	8	232	185.6	116	CONGESTED	210 meter queue
19:34	15.1	16	8	232	185.6	116	SMOOTH	112 meter queue
19:39	15.1	16	8	232	185.6	116	SMOOTH	112 meter queue
19:44	15.1	16	8	232	185.6	116	SMOOTH	112 meter queue
19:49	32.5	33	8	232	185.6	116	CONGESTED	231 meter queue
19:54	32.5	33	8	232	185.6	116	CONGESTED	231 meter queue
19:59	32.5	33	8	232	185.6	116	CONGESTED	231 meter queue
20:04	22.9	23	8	232	185.6	116	QUEUING	161 meter queue
20:09	22.9	23	8	232	185.6	116	QUEUING	161 meter queue
20:14	22.9	23	8	232	185.6	116	QUEUING	161 meter queue
20:19	33.9	34	8	232	185.6	116	CONGESTED	238 meter queue
20:24	33.9	34	8	232	185.6	116	CONGESTED	238 meter queue
20:29	33.9	34	8	232	185.6	116	CONGESTED	238 meter queue
20:35	19.0	20	8	232	185.6	116	QUEUING	140 meter queue
20:39	19.0	20	8	232	185.6	116	QUEUING	140 meter queue
20:44	19.0	20	8	232	185.6	116	QUEUING	140 meter queue
20:50	24.5	25	8	232	185.6	116	QUEUING	175 meter queue
20:54	24.5	25	8	232	185.6	116	QUEUING	175 meter queue
20:59	24.5	25	8	232	185.6	116	QUEUING	175 meter queue
21:04	16.4	17	8	232	185.6	116	QUEUING	119 meter queue
21:09	16.4	17	8	232	185.6	116	QUEUING	119 meter queue
21:14	16.4	17	8	232	185.6	116	QUEUING	119 meter queue
21:16	19.3	20	8	232	185.6	116	QUEUING	140 meter queue
21:20	19.3	20	8	232	185.6	116	QUEUING	140 meter queue
21:25	19.3	20	8	232	185.6	116	QUEUING	140 meter queue
21:31	17.3	18	8	232	185.6	116	QUEUING	126 meter queue
21:35	17.3	18	8	232	185.6	116	QUEUING	126 meter queue
21:39	17.3	18	8	232	185.6	116	QUEUING	126 meter queue
21:45	6.7	7	8	232	185.6	116	SMOOTH	49 meter queue
21:50	6.7	7	8	232	185.6	116	SMOOTH	49 meter queue
21:54	6.7	7	8	232	185.6	116	SMOOTH	49 meter queue
22:00	19.5	20	7	232	185.6	116	QUEUING	140 meter queue
22:04	19.5	20	7	232	185.6	116	QUEUING	140 meter queue
22:10	19.5	20	7	232	185.6	116	QUEUING	140 meter queue
22:16	18.4	19	8	232	185.6	116	QUEUING	133 meter queue
22:20	18.4	19	8	232	185.6	116	QUEUING	133 meter queue
22:25	18.4	19	8	232	185.6	116	QUEUING	133 meter queue
22:30	12.0	12	8	232	185.6	116	SMOOTH	84 meter queue
22:36	12.0	12	8	232	185.6	116	SMOOTH	84 meter queue
22:40	12.0	12	8	232	185.6	116	SMOOTH	84 meter queue
22:47	12.5	13	8	232	185.6	116	SMOOTH	91 meter queue
22:50	12.5	13	8	232	185.6	116	SMOOTH	91 meter queue
22:55	12.5	13	8	232	185.6	116	SMOOTH	91 meter queue
23:00	6.9	7	8	232	185.6	116	SMOOTH	49 meter queue
23:05	6.9	7	8	232	185.6	116	SMOOTH	49 meter queue
23:09	6.9	7	8	232	185.6	116	SMOOTH	49 meter queue
23:15	10.7	11	8	232	185.6	116	SMOOTH	77 meter queue
23:20	10.7	11	8	232	185.6	116	SMOOTH	77 meter queue
23:25	10.7	11	8	232	185.6	116	SMOOTH	77 meter queue
23:30	18.0	19	7	232	185.6	116	QUEUING	133 meter queue
23:35	18.0	19	7	232	185.6	116	QUEUING	133 meter queue
23:40	18.0	19	7	232	185.6	116	QUEUING	133 meter queue
23:45	3.0	4	7	232	185.6	116	SMOOTH	28 meter queue
23:50	3.0	4	7	232	185.6	116	SMOOTH	28 meter queue
23:55	3.0	4	7	232	185.6	116	SMOOTH	28 meter queue