

Development of GIS-based Traffic Simulation on the Jakarta's Highway

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ABSTRACT

One serious problem in Jakarta megacity is the daily traffic jam. Recently, according to the ever increasing amount of newly registered vehicles in Jakarta, the time interval needed to across some districts in Jakarta tends to be longer. The main reason for the traffic jam is the condition in which the road capacity and the arrival rate of vehicles are not staying in balance. Well planned traffic rules can be used to control the traffic flow so that the overload condition should never happen. To assist in the planning of these traffic rules, a traffic simulator has been developed at the Center for Information and Communication Technology in BPPT. By integrating a GIS-based digital road map into the above traffic simulator, the visualization of the simulation results can be enhanced significantly. In this paper some of the simulation results which are performed on the Semanggi's highway section are presented. Further, the capability of this software-tool to support the management of Jakarta's highway will also be figured out.

Keywords: traffic simulation, traffic jam, geographic information system, digital road map

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1. INTRODUCTION

A serious problem in Jakarta megacity is the daily traffic jam. In the year 2000 a distance of 14.6 km between Kalideres (West Jakarta) and the district of Jalan Gajah Mada (Central Jakarta) should be passed through in 51.7 minutes [7]. According to the ever increasing amount of newly registered vehicles in Jakarta, the time interval needed to across some districts in Jakarta tends to be longer.

In the rush hours traffic in Jakarta city can only move forward at 12 km/h. Strong rainfalls would immediately make the whole city stuck. This conditions cause high operational costs and non-negligible loss in time. The social cost paid for this traffic jam is estimated to be more than USD 1.83 billions per year [7]. Traffic jams in the

surroundings of Jakarta, like Depok and Bogor, were reported to cost IDR 1.7 billions per day [3]. Besides, traffic jam has severely deteriorated the air quality of Jakarta city.

The main reason for the traffic jam is the condition in which the road capacity and the arrival rate of vehicles are not staying in balance. Well planned traffic rules can be used to control the traffic flow so that the overload conditions should never happen. To assist in the planning of satisfying traffic rules, a traffic simulator has been developed in the Scientific Computing workgroup at the Center for Information and Communication Technology, BPPT.

A further goal of this work is to obtain a suitable traffic model that can be easily put on the real existing traffic situations in Jakarta. Using this model several simple analyses of traffic situations could be performed [1,5]. A model used in this traffic simulator is shown in figure 1. It was shown that a simple model of queuing system can be used to simulate traffic conditions on the Jakarta's streets and highways [4,5].

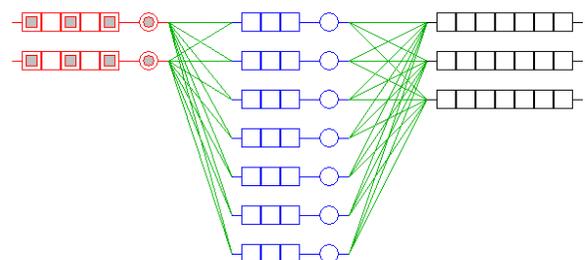


Figure 1. A model of queuing system at the toll-gate

Previous results of the traffic simulation at the Jakarta's highways and toll-gates have shown that total number of operating toll-gates and the service time at that gate have given big influence for the traffic flow [6]. When the number of currently operated toll-gates are not staying in balance with the huge current of vehicles, it will lead to long queues in front of the toll-gate. The previous simulation results have also shown that the application of the so-called open-close strategy in operating the toll-gates was sufficient in anticipating time-varying arrival rate of the vehicles. Moreover, the dynamics of the open-close strategy

and the arrival rate of vehicles could be well represented using the normalized traffic density curve [6].

By integrating a GIS-based digital road map into the above traffic simulator, the visualization of the simulation results can be enhanced significantly.

2. METHOD

Basically a vehicle queue at the toll-gate can be modeled by a simple queuing system consisting of the queue element and the processing element [1,4]. The element queue can then be divided into three queuing subsystems, i.e. the queuing subsystem before, within and after the toll-gate.

In this queuing model various vehicle types within the queue are represented by objects with different colors (see figure 1). The length or capacity of the queue is represented by a number of small boxes laying in a row, whereas a processing element is symbolized by a circle at the end of these box series. The object movement among the subsystems is visualized by the green lines connecting one queuing subsystem on the left side to the next queuing subsystem on the right side.

There are at least three parameters that significantly characterize a queuing system. The first one is the service or processing time. The service time determines how long a vehicle will remain within a queue. In the case of a queue at the toll-gate this service time is affected by the speed of the processing machine and the promptness of the operators at the toll-gate serving the users of the highway.

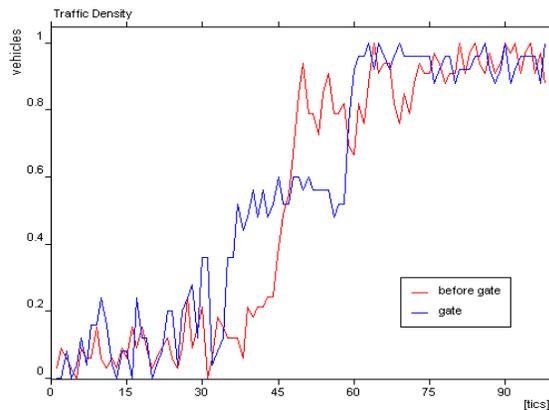


Figure 2. Simulation result depicting the increase of traffic density at the rush hours in the morning [6]

The second parameter is the traffic flow. A traffic flow is defined by the number of vehicles moving into or out of a road section in a certain time interval. A high traffic flow indicates that a certain road section is frequently passed through by several kind of vehicles.

The third parameter of a queuing system is described by the vehicle's arrival rate. The arrival rate of vehicles on the highway is mainly driven by the work hours. At rush hours

in the morning we will perceive a very high arrival rate of vehicles on the highways moving toward the business centres and governmental buildings at the city centre. On the contrary, the arrival rate will reach a minimum value before the morning dawn.

Another variable commonly used apart from the above parameters is the traffic density. Traffic density is defined by a number of present vehicles in a certain part of the queue. This variable is very useful to describe the current situation at the highway section at a certain time. The previous simulation results have shown that the time-varying arrival rate of vehicles can be well recorded by using the normalized traffic density [6]. A case in which the traffic density drastically changes is shown in figure 2. This case is often found at the rush hours in the morning.

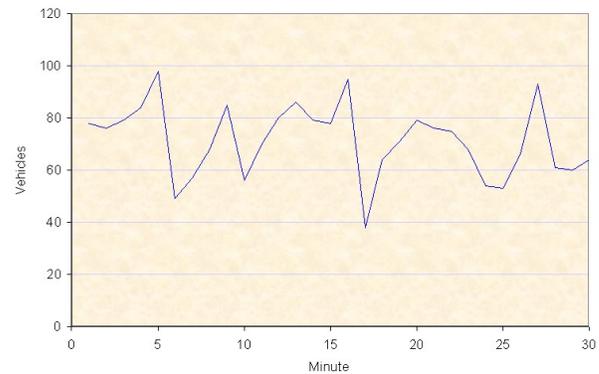


Figure 3. Traffic flow at the Semanggi highway section (course Semanggi-Cawang)

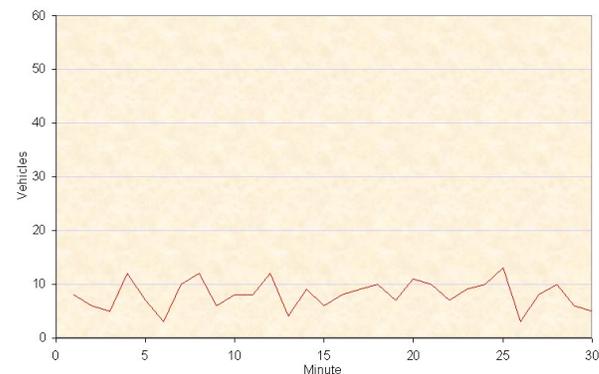


Figure 4. Traffic flow at the Entry of Semanggi toll-gate

To verify all of these simulation results we need to measure the actual traffic flow. As earlier mentioned, the actual traffic flow data is necessary to obtain a real description of the traffic situation on the streets. So the measurement is performed by considering the direction of the traffic flow and the number of available lanes and crossroads at the street section. Data of traffic flow is recorded by counting the number of vehicles passing through a prescribed reference line every single minute. The

recording is continued for the next thirty minutes. In a jam situation vehicles that were not passing through the reference line have not been taken into account.

Measurement data of the traffic flow on the Semanggi highway section taken in the third week in August 2006 are shown in figure 3-6.

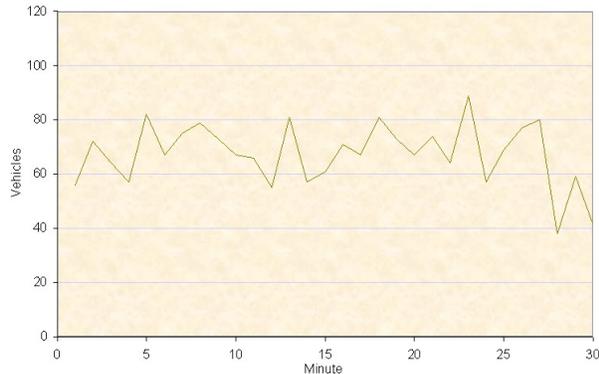


Figure 5. Traffic flow at the Semanggi highway section (course Cawang - Semanggi)

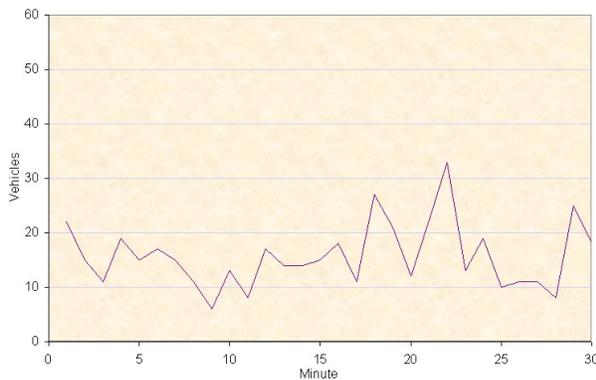


Figure 6. Traffic flow at the Exit of Semanggi toll-gate

Using the measurement data of traffic flow we can now perform a more realistic traffic simulation on the Semanggi highway section. However, to achieve the prescribed goal we still need to complete this preparation phase by transferring the data of simulation results onto the actual road map. For this purpose a digitization of the road map is necessary (figure 7-8).

Digital map of road mesh is needed to display the results of computation and traffic simulation. By means of this digital road map the simulation of the car movements on the highway can be visualized on the computer display. That way a non-expert can better understand the result and the meaning of a traffic simulation.

Based on a method used in the GIS (geographic information system) technology, we need to add some attributes to the previously created digital map when running the simulation on a digital road map. These data

attributes will comprise e.g. number of the lanes, direction of the traffic flow and crossroads available on the road section. An example of data attributes embedded to the digital map is shown in figure 8.



Figure 7. Satellite image of the highway section [2]

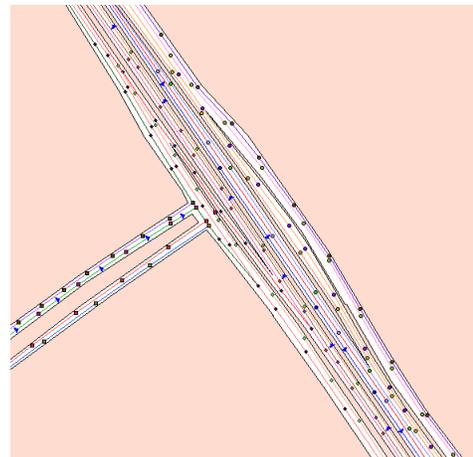


Figure 8. Digital map of the Semanggi highway section

3. DISCUSSION

From figure 3 it is recognized that in a normal condition the traffic flow on the highway section moving forward from Semanggi to Cawang varies in a range of 40–98 vehicles per minute. In the opposite direction the flow is found to be variable in a range of 40–85 vehicles per minute (figure 5). Among the vehicles passing through the Semanggi highway section there are some that come out of and into the toll-gate.

Data of traffic flow through the toll-gate is shown in figure 4 and 6. Figure 6 shows that the traffic flow exiting the Semanggi toll-gate varies from 8 up to 32 vehicles per minute with a mean of 18 vehicles per minute. Meanwhile

the traffic flow entering the toll-gate is found to be 5–12 vehicles per minute, or average 8 vehicles per minute (figure 4).

vehicle's arrival rate will vary in a wide range of values highly driven by the work patterns and hours in Jakarta city and the surroundings.

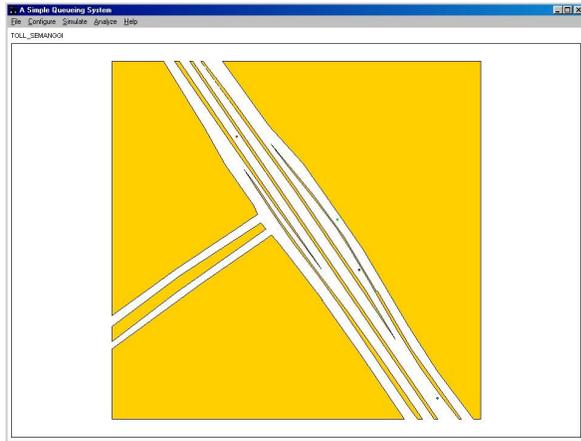


Figure 9. Graphical user interface of the traffic simulator

A result of the traffic simulation conducted on the digital road map enhanced with the above mentioned attributes is presented in figure 9. The latest simulation result reveals the potential of this traffic simulator to be utilized as a valuable software-tool in the daily monitoring of the traffic situation on the highways. This advance can be very useful in supporting the management of the Jakarta's highway. Based on the data input to this traffic simulator the operator of the highway can e.g. predict the next traffic jam that will occur on that day.

Nevertheless, long-term traffic flow measurements are obviously still needed at several observation points for different time periods. These are caused by the facts that the

4. CONCLUSION

A traffic simulator based on a simple queuing system is presented. By sufficiently integrating complementary data attributes thereto, a GIS-based digital road map could be used to visualize the simulation results. That way a layperson can better understand the result and the meaning of a traffic simulation. Especially, if the digital road map is extended and data of the traffic flow is advanced to comprise the traffic pattern in the region of Jakarta city for one year period, then this traffic simulator will be a valuable tool to monitor the traffic situation in Jakarta day by day.

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