LINTAS-LC 1.0: Modeling and Simulation of Traffic in Lingkar Cileuniyi Bandung Indonesia

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Abstract. Smooth traffic is one of the parameters of the government's good performance in managing the transportation system. The smoothness of traffic plays an important role in improving community development which covers the fields of economy, social, culture, education and technology. Along with the increase in population, traffic becomes more congested and occurs in various places. This situation will reduce the level of productivity, economy, social and welfare of the community, while increasing air pollution and waste of fuel.

One of the congested locations that make concern is the path of Cinunuk road, which is located in the Cibiru sub-district and Cileunyi district bordering Bandung City and the Regency, Indonesia. The traffic congestion occurs starting from the starting point of Cinunuk road to the end by length 2.9 Km. The Cinunuk road is the only non-highway road that connects traffic in the northern region the south and east region. This resulted in a high volume of vehicles going through the route, so that traffic congestions occur every day from 6am to 11pm, and it’s getting worst on the day before weekend or holiday. An alternative solution that is relatively appropriate, effective, and efficient to solve the congestion problem is to build an alternative route known as the circle lane of Cileunyi (lingkar cileunyi - LC). This route is a new road that planned by government through a different area with the Cinunuk road for the purpose of breaking down the traffic congestion. In this article, we propose a traffic simulation system to preview the traffic situation on the Cinunuk and the LC road, which is named as "LINTAS-LC 1.0". The simulator is intended to analyse and simulate the level of congestion that occurs in the Cinunuk road, and make a feasibility study on the discourse on the development of the LC road. Through the LINTAS-LC simulator, it is expected to predict the effectiveness of LC road development in describing congestion in the Cinunuk road. The LINTAS-LC simulator is compiled using the SimEvents-MATLAB toolbox on the basis of Mathematics, specifically the queuing theory.

1. Introduction

Congestion occurs because of obstructed vehicle traffic which results in long queues. The factors that cause queue length are limited road capacity or too many vehicles [1]. In general, the solution to solve this congestion problem is to increase road capacity or reduce the number of vehicles [2]. However, increasing road capacity requires enormous costs, in addition to very complex bureaucratic mechanisms [3]. On the other hand, reducing the number of vehicles is also not easy, because it is related to government policy and community dependence on means of transportation [4].
Congestion generally occurs in big cities, including in the Cinunuk road as depicted in Figure 1, where traffic congestion is significantly increasing every year [1]. Congestion generally occurs because of some factors e.g.: no so well in traffic management [5] [6], the low level discipline of traffic users [7], and the imbalance in the number of vehicles with road capacity [1]. Congestion-prone locations are including the location of markets, schools, bus terminals, and other similar locations. Congestion can also occur at intersections of traffic lanes, such as traffic light intersections, railroad intersections, or accidents, and also due to natural disasters such as floods, landslides, road fires, residential fires, and others. Traffic congestion is very important to overcome because it is very detrimental, including waste of time, waste of fuel, increasing air pollution, increasing stress and emotional road users, and disrupting the smooth operation of emergency transportation such as ambulances and fire vehicles.

Figure 1. Traffic congestion at the Cinunuk road

The Bandung city government has implemented several alternatives and plans to reduce traffic congestion, especially in the Cinunuk road. Among them are the planned construction of the cileunyi ring road (lingkar cileunyi - LC). It has been socialized for a long time [8]. The LC plan and its development discourse was positively welcomed by a number of community leaders in Cileunyi sub-district and road users, including the Chairman of the Bandung Regency.

We propose a simulation application, namely LINTAS-LC, that can predict and evaluate the traffic situations [9-19]. Through the LINTAS-LC application, a feasibility study can be carried out on the discourse of LC development, such as the level of its contribution in reducing congestion in the Cinunuk road, the causes of traffic congestion, the number of the vehicle arrival, another factors that cause congestion. LINTAS-LC was built using SimEvents-MATLAB [20,21] and works based on one field of Mathematics, namely Queuing Theory [22-25].

The LINTAS-LC application is very important to implement, where its functions are expected to be supported in the LC development discourse, so that it comes to a very definite conclusion that the LC development is absolutely necessary to achieve smooth traffic in the Cileunyi region, especially at peak times or in the event of a long holiday or national holiday. Research on the solution of Bandung city traffic congestion is part of the 2016-2020 LPPM UNISBA Renstra which is outlined in the research objectives of LPPM UNISBA, namely developing the ability to adapt knowledge and technology to regional development needs, especially for West Java and surrounding areas, and nationally [26].
2. Theoretical background

2.1 LINTAS: state of the art

LINTAS is a system designed to simulate traffic flows that operate based on Mathematics, especially the queuing theory. LINTAS is designed to run simulations based on three types of input parameters, including the average number of vehicle arrivals per unit time, the average length of time the vehicle is in a system (traffic light queue), and road capacity. Based on these three inputs, LINTAS can predict whether traffic congestion occurs, the length of the queue of vehicles, the number of vehicles on a road segment, the length of travel from the starting point to the end point, and other predictions needed for traffic management analysis.

LINTAS can predict traffic situations based on traffic methods or engineering. For example changes in the direction of the current into a direction or two-way, dynamic vehicle transfer [17], balancing the load of traffic flow [14,27], traffic light engineering, and other methods or engineering. Engineering trials through simulations using LINTAS are expected to be able to help and support traffic managers so that the most appropriate engineering methods can be found to create a smooth and congested traffic atmosphere.

2.2 Queuing Theory

Queue is an event where a vehicle waits at an intersection with a traffic light with a red light to light green. Queuing theory is one branch of Mathematics which contains the study of the queuing system as a set of entities, namely in this case the vehicle that runs in traffic, which is equipped with a rule governing arrival and service. Services in the context of traffic can be in the form of obstacles, such as traffic lights, road crossings, narrowing of roads, congested vehicles, and so on.

Queue theory is widely used in applied various fields of science, including the modeling of computer or internet network systems [25,28,29], transportation models [20], and others. In the field of transportation, queuing theory is often used in the analysis of traffic management to understand and monitor congestion through several parameters, such as average vehicle arrivals, queue length, waiting times in queues, and others.

The LINTAS simulator operates based on the queuing theory science field. Some basic concepts of queuing theory used in the LINTAS system are the rate of arrival ($\lambda$), which is the average arrival of vehicles into the system per unit time. The rate of the process or service in the system ($\mu$) is that the average vehicle is processed and exits the queue system or traffic barriers per unit time. In this study it is assumed that the queue model used is $M/M/n$ where $n$ is the number of servers indicated by real numbers. In the $M/M/n$ model, the arrival process is Poisson with the arrival rate following an exponential distribution. Similarly, the rate of service follows an exponential distribution.

Based on the $M/M/n$ queue model, the average queue length of the vehicle ($L$) in steady-state conditions is calculated based on the formula:

$$L = \frac{P_0(\lambda - \mu)^n \lambda / n \mu}{n! (1 - \lambda / n \mu)^2}$$ .... (1)

where

$$P_0 = \sum_{i=0}^{n-1} \frac{(\lambda / \mu)^i}{i!} + \frac{(\lambda / \mu)^n}{i! (1 - \lambda / n \mu)}^{-1}$$ .... (2)

Queue length calculations in the LINTAS simulator system are integrated in the Queue module. In this module, the queue length is calculated for each unit of simulation time. The results of the calculation of the queue length based on the Queue module give convergent results with formula (1) for infinite
simulation time assuming the average rate of arrival and service does not change (steady state). Furthermore, the level of traffic density ($\rho$) is calculated based on the formula:

$$\rho = \frac{\lambda}{\mu} \quad \text{.... (3)}$$

The calculation of traffic density based on formula (3) is to predict traffic density at stable conditions (steady state). Calculation of the level of traffic density for each unit of simulation time is integrated in the Server module on the LINTAS system.

3. Method

In this article, we analyse the queue waiting time at traffic light intersection by modelling and simulation. The modelling is performed based on queuing theory with the $M/M/n$ principle, while the simulation which include the design of traffic simulator and its components, is created using the SimEvents MATLAB-Simulink [20].

The SimEvents-MATLAB application has been used as a tool to simulate a system in various fields, including Transportation and Internet [21] which involves data flow methods on Content Delivery Networks (CDN) technology and Service-oriented Routers [22,28,29]. Several methods can be used in vehicle distribution simulations, including load balancing as well as artificial intelligence Bayesian networks [30,31]. Besides SimEvents, another simulator that is commonly used is ns3 [27]. The components of the simulator system using SimEvents are modules in the form of an entity generator as a medium for generating entity (vehicles), server modules as media services, gate modules as representations of traffic intersections, links as representations of transportation routes, and sink modules for entity removal.

4. Result and Discussion

4.1 Components of the simulation

The implementation of the LINTAS-LC 1.0 simulator will be implemented at Cinunuk and LC road depicted in Figure 2.

Simulation model is created for the Cinunuk and Lingkar Cileunyi (LC) road. Long queues along the Cinunuk road often occur during rush hour morning or early evening. General data for Cinunuk road are listed in table 1.
### Table 1. Data of Cinunuk Road

|                        |                |
|------------------------|----------------|
| **Road Class**         | Secondary Artery |
| **Road Type**          | 3 / 2 directions |
| **Path width**         | 9 meters (two sides) |
| **Number of the lane in one path** | 2 lane |
| **Waypoint Description** | West to East (A to C) |
| **Average Number of vehicles (per hour at 06.00 – 09.00)** | 2,426 Vehicles/h |
| **Average Velocity**   | 10 Km/h        |
| **Distance (A to B)**  | 2.9 Km         |

Furthermore, for the parameters of the arrival rate data ($\lambda$) and service rate ($\mu$) are taken from observation. Arrival data ($\lambda$) is obtained based on the average number of vehicle arrivals. Service rate data ($\mu$) is obtained based on the duration of traffic. For the calculation of $\mu$, it is assumed that the number of servers (obstacles/congestion) at the both Cinunuk and Lingkar Cileunyi road are 2, as the number of lane. Thus, based on the $M/M/n$ queue model, the average length of time waiting in the system ($T$) is formulated by:

$$
T = \frac{P_0(n\rho)^n\mu + (n\mu - \lambda)}{n! \(1 - \rho\)\mu(n\mu - \lambda)} \quad \ldots (4)
$$

where $P_0$ is obtained from (2) and $\rho$ is obtained from (3).

### 4.2 The implementation of simulation

The LINTAS-LC 1.0 simulator model for Cinunuk road is depicted in Figure 3, yang merupakan model representasi dari gambar 2 khususnya untuk jalan Cinunuk.

**Figure 3. Model LINTAS-LC 1.0 for Cinunuk road**

The arrival of vehicles is assumed to follow the Poisson process with the arrival of the average vehicle $\lambda$ per minute. The vehicle enters the Cinunuk road with a maximum width of 2 vehicles. The road condition is very congested, especially during rush hour which is in the morning 6 to 9 and late afternoon starting at 3pm to 7pm. Based on observations, the main factors that cause congestion are in and out of vehicles to and from residential areas that cross to another side of the road. Other factors are public transportation stopping at random, careless parking, crossing activities, and too many vehicles.
Figure 4. Model LINTAS-LC 1.0 for Cinunuk and LC road

The alternative solution for traffic congestion in the Cinunuk Road is the government builds a new road, namely the LC road as shown in Figure 2. LC is built to break down the congestion which currently the Cinunuk road has a maximum capacity. In order to analyse the usefulness of the LC path, a simulation model is created as shown in Figure 4.

5. Conclusion

In this paper a model and simulation of traffic at Cinunuk and Lingkar Cileunyi (LC) road are analyzed. The model is based on the queuing theory and the simulation is performed using SimEvents. SimEvents application is used to calculate the queue waiting time for given parameters. Theoretically, this model can be used at various situation of traffic to be a solution for the one that cause very long vehicle queues. Modeling the vehicle in the queue at the traffic is expected to be used to determine the setting of the capacity of the road so that it can avoid the queue that is too long and consumed time.

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