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REVIEW OF MICROSCOPIC MODEL FOR TRAFFIC FLOW

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ABSTRACT

Today, the problem of cities urban transportation is becoming something we have to face in our daily life. In Indonesia, traffic congestion is increasingly serious. Several economic and social motivations can be related to the need to minimize the time spent in vehicles for transportation and consequently their related pollution problems. Due to these motivations, the literature on traffic phenomena is already vast and characterized by contributions covering modeling aspects, statement of problems, qualitative analysis, and particularly developed simulation generated by applications. This paper will provides a several literature review of microscopic model based on their utilities, including the critical review about the modeling approaches. Furthermore, some practical issues such as potential for future model improvement using existing and emerging data collection technologies is identified based on Indonesian traffic characteristics and will be presented as a contribution from this paper.

Keywords: microscopic model, traffic flow.

INTRODUCTION

Today, the problem of cities urban transportation is becoming something we have to face in our daily life. In Indonesia, traffic congestion is increasingly serious. Several economic and social motivations can be related to the need to minimize the time spent in vehicles for transportation and consequently their related pollution problems. An additional problem worth mentioning is the need to reduce traffic accidents, a human and social cost that is related not only inadequate driving, but also to the planning of the flow conditions [1]. Due to these motivations, the literature on traffic phenomena is already vast and characterized by contributions covering modeling aspects, statement of problems, qualitative analysis, and particularly developed simulation generated by applications. It can be seen from many researcher of the western developed countries have made considerable progress in the field of traffic simulation since 1980s.

Over more than half a century, traffic flow theorists have been pursuing two goals: 1) simple and efficient models to abstract vehicular traffic flow and 2) a unified framework in which existing traffic flow models fit and relate to each other [3]. Continuing these efforts, there are many literatures of traffic flow theories and models have been developed, but researcher generally agree that modeling has not yet reached a satisfying level. Studies traffic flow is become important since many reason behind that, such as: 1) it is necessary to develop traffic model which can describes the real phenomena 2) traffic model can support for developing intelligent transportation system (ITS) whose related with safety driving system, 3) traffic model support for future issue about intelligent car.

Traffic flow models can be grouped into three categories depending on the level of detail: 1) macroscopic, 2) mesoscopic and 3) microscopic [2]. However, we can group into two main models, macroscopic and microscopic. On the one hand, macroscopic models have application when detailed information about behavior of a single vehicle is not required but only a general evaluation of traffic flows in a network. These models are often used for regional transportation planning. On the other hand, microscopic models describe information about a behavior of each single vehicle. For this reason, they can be applied mainly to narrow-range transportation systems, however, with a much higher level of detail.

Besides, microscopic models are becoming increasingly important and popular tool in the area of transportation. It has been used for wide range applications in network design, analysis of transportation problems, and the evaluation of IT'S and traffic management strategies. One benefit of having simulation model in microscopic is that it is provides traffic information from system to individual level.

Furthermore, one of the microscopic model objectives is not only to deliver estimated, reliable and detailed, but also giving information about a behavior of each single vehicle. Even though there is a large number of microscopic models used in many countries. Unfortunately, none of them can be considered as an ideal or, at least, universal one. It is because that every model has different parameters to describe a different traffic situation.

The contribution in this paper will present a concise summary of the existing microscopic model for traffic flow. A rich variety of modelling approaches developed so far based on their utility will be discussed and compared. This comparison will mainly consider theoretical issues of model derivation and characteristics. A several literature will provide in this paper based on their utilities. Furthermore, some practical issues such as potential for future model improvement using existing and emerging data collection technologies is identified based on Indonesian traffic characteristics and will be presented as a contribution from this paper. Our paper is structured as follows: In section 2, we introduce the general concepts about traffic flow microscopic modeling. Section 3 presents a review of existing traffic flow models derived at the microscopic scale based on their utilities. Finally, we will conclude with this discussion in section 4.

MICROSCOPIC MODELING

Microscopic simulation is a model that describes the behavior and interactions of each driver in a traffic system, which is made more detailed modeling for each movement of the vehicle. Definitions of microscopic simulation was assorted, but in general microscopic simulation can be determined as an effort to develop a driver behavior and vehicle models in order to produce a more realistic simulation.

The early research on traffic simulation was focused on the development of microscopic behavior of vehicle in a traffic environment that is given, especially in maintaining the existing distance with the vehicle in front. The most popular theory to model the distance between the vehicles is car-following models. The developments of the theory of car-following models are being implemented with the added element of rider behavior and other elements that will produced a more realistic simulation. The underlying theories of microscopic modeling are car-following and lane-changing. Car-following theory examines the longitudinal movement of each vehicle. Meanwhile, lane-changing theories were about how to assess motorists to change the lanes.

Car-following model is also becoming an important element in the process of autonomous cruise control system [2] [3]. Furthermore, the car-following was used as a tool to evaluate the intelligent transportation system policies [4] [5]. Thus, the researchers were interested to explore the car-following behavior to improve existing models or to find a new model.

Along with the development of computer science, the expansion also extends to the use of cell automation and multi-agent systems. Where the two systems can provide a more realistic behavior of contact or interaction with riders given traffic conditions [6]. Continuing these efforts, the expansion was being conducted to get a more real behavior model by adding a stochastic method for making decision based on a given environment of the road. In addition, these research areas are related to the psychology studies about driver who have different type of personalities (ex: aggressive, calm, etc.). Furthermore, the commonly research was using Monte Carlo procedure to generate random values to show the behavior of driver on traffic conditions [7].

Microscopic model has advantages in simulating the vehicle more detail, but that does not mean they did not have a weaknesses. Modeling the behavior of each vehicle and tracking in a traffic condition will take a big effort and resource in the required time, cost and high-level computational processes because the simulation process will done in real-time. In addition, the development of a model will be closely related to the end of the process, namely the calibration and validation of the model. The model was built to be accurate, according to existing data or information [8].

REVIEW OF MICROSCOPIC MODEL

SIMULATION BASED ON INTELLIGENT TRASNPORTATION SYSTEM

Todays, the development of Intelligent Transportation System (ITS) was related to streamline road capacity available at this time. Result, various ITS technologies such as adaptive cruise control (ACC) has been widely used in high-tech vehicles. Kesting [9] on his paper tries to simulate the effect of influenced vehicles using the ACC related to the flow of traffic, in order to improve the efficiency of road capacity. Kesting developed a microscopic simulation using intelligent driver model (IDM) in order to simulate the effect of ACC technology. This study develops an existing IDM using the new constant-acceleration heuristic. IDM is applied to the development of traffic simulation with multi-path conditions as well as added features ACC driving strategy. Simulations in this study have been quite successful for strategy driving traffic, although there are still some limitations in IDMs model that makes less realistic simulations.

Besides ACC technology, the development of ITS which currently developing is Advanced Driver Assistance Systems (ADAS). Schnieder in his research [10] explores the interactions between subsystems (driver, vehicle and infrastructure) that occur in traffic. The research resulting a model for traffic system that can be used as ADAS foundation. The simulation test results indicate that this system can be powerful to explain complex phenomena in traffic modeling. Yangs [8] in his research successfully build a decision-making system based on real-time data obtained. In some cities such as New Jersey, New York, London, Paris and Singapore have implemented the IT'S using congestion pricing. The model should be describes a congestion pricing system needed that supported by accurate model that can predict traffic. Yang also proposes a generalized traffic model of LWR models using stochastic partial differential equations. The simulation results compared was to the deterministic traffic models and found that the stochastic model is more accurate than the deterministic models.

One of the main problems of the traffic congestion is not only there are so much wasted time but also reduced productivity of millions of people. One possible solution is to provide the means information which can be distributed to driver on the road, or it could be by giving the driver information for route selection through the system to avoid congestion. Information about traffic jam can also be obtained from a static sensors placed at several locations (induction loops or camera sensor) or could be by placing a mobile vehicle that can provide such information. Leantiadis [11] tried to design a system that allows vehicles to obtain information about the traffic with crowd-based ad hoc manner and then implemented on a realistic network-mobility model simulator that can be evaluated. The results obtained that the navigation system can provide optimal traffic conditions and can help the driver to minimize travel time.

The subsequent issue of this development is how to attack the bottleneck. One of the solutions can be solved by Vehicular Data Network (VDNs), which is a vehicle transformation to intelligent mobile entities that can wirelessly communicate with each other and with stationary roadside units (RSUs). Several studies on the VDN can show a model which describe the phenomenon of traffic and also can show the VDN is accurate at the time of evaluation. Khabbaz [12] on his paper propose a universal model based on modeling the behavior of free-flow conditions approach the M / G / ∞ queuing system. This model is intended to be the foundation of the development of modeling VDN-vehicle until the vehicle can be supplied with a number of accessible information about road conditions, congestion, etc.

Along with the development of this VDN, the development of intelligent transportation technologies has led to Platooning. Platooning is the latest technology so that the vehicle can move autonomously and highly efficient in driving the freeways and conditions as well as driving safety support [13]. In addition, platooning may provide a driving experience in a different way which covers aspects of driver comfort and safety, reduce fuel consumption, and to provide space for the driver to simply relaxing such as reading e-mail, newspaper, calling when traffic conditions is in a state jammed. Platooning is an area of research that is quite challenging, because it requires some capabilities from many experts, such as control systems, transportation engineering, vehicle dynamics, and wireless networking. In his paper, Segata [13] tried to explain the concept of platooning system in terms of wireless networking, as well as explain the state-of-the-art regarding the development of the wireless communications platooning. This paper also explained that the wireless networking still there are some limitations, so it is still a very open problem to be able to do research.

MODELING BASED MICROSCOPIC CAR-FOLLOWING AND LANE CHANGING

Traffic modeling with microscopic scale is dominated by two theoretical approaches, namely car-following and lane-changing models. The second approach focuses on how a vehicle interacts and behaves in the various traffic conditions. Car-following theory is a theory that explains how a vehicle maintains a safe distance with the vehicle in front of him. Car-following model has been developed with different characteristics and different parameters. Das [14] trying to develop a car-following model for the narrow roads using automata cell approach. Lu [15] in his paper also developed a car-following model based on the theory of homeostasis. Homeostasis is studies about decision making in estimating the risk of a driver that will be generated based on the driver experience. Car-following model using risk homeostasis theory was developed using parameters desired safety margin (DSM). Safety margin is the value of risk limits that are informed to the driver while driving, which will be obtained by consideration of the stimulus parameters. The results from this simulation were compared with the Gazis-Herman-Rothery (GHR) model. The comparison result between the average and GHR DSM model is not so different, but in this study the model can change the parameters and make this model more flexible and effective to simulate the car-following theory. The model developed in this study also provides new knowledge about understanding and explaining the process of car-following based on risk homeostasis theory.

Efficiency of traffic simulation model depends on the model of car-following and lane-changing. In his paper Hamid [16] make tests on three car-following models that already exist (CARSIM, WAVSIM and PARAMICS). This test using real data obtained from three different regions and different environment conditions. The purpose of this study was to look for the best models that can be used as a basic assumption for developing car-following models. The results of this research show that CARSIM have a highest accuracy than the others.

Lane-changing theory is an important element in how a vehicle changes the lane for several reasons, for example to avoid obstacle, following a slower vehicle, and others. Abdi [17] on his paper analyzed some lane-changing algorithms that exist, in order to know the effective factors that can be used on lane-changing scenario. Lane-changing algorithm analysis in this study uses fuzzy clustering method. Rahman [18] also make comparisons of the lane-changing models existing in an attempt to find the most optimal model. Rahman stated modeling lane-changing will even more complex modeling with distruction driver factors (eg: do sms or phone when driving), the environment, road conditions and much more that has yet to fully implemented to the lane-changing models.

Modeling driver behavior during car-following and lane-changing is done by observing from field data obtained. Ma [19] on his paper develops a data collection method that used to build microscopic traffic simulation. In this study he built an instrument to collect data on driver behavior was focus on the car-following and lane-changing. To reduce the noise in the measurements on car-following pattern, the author used Kalman smoothing to the part state-physical state (acceleration, velocity and position).

MODELING DRIVER BEHAVIOR

Microscopic modeling of traffic will always be associated with how to model the behavior of each vehicle and driver. Study literature on driver behavior modeling has been done with many approaches and different methods with the aim to obtain a simulation that is completely realistic. Song [20] in his research tries to model driving behavior using a cognitive model of the existing simulation tools (SmartAHS). The contribution in this study is to build a database of knowledge formation of the driver and the development of cognitive processes

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modeling when the driver was doing driving activities. The information in the database is able to simulate the behavior of the driver to select from a collection of possible behavior do exist, such as the following or overtaking.

Booth [21] constructs a neural network to improve the driver agent realistic simulation of the vehicle. The neural network is used for modeling lane-changing behavior. The results of agent-based modeling driver behavior are compared with the simulation of human driver. Based on the tests performed the author concluded that neural agent driver better than a human driver in estimating or determining when the right time to change lanes and determine the exact speed of the vehicle to change lanes.

Modeling driver behavior will be influenced by many factors, including age, emotional maturity, gender, condition of one's personal and environmental conditions. Some research on driver behavior modeling performed using several approaches, such as fuzzy logic, fuzzy rules for low-level control action models, hidden markov models, and dynamic bayesian networks. Most of these approaches use a random distribution of the data obtained on the behavior of the driver while driving. Tavellaei [22] developed a driver behavior model using two fuzzy methods. The first method will be used to model fuzzy low-level control (to model the steering angle and speed variation), second the use of fuzzy multi-criteria decision making is implemented on a high-control action (modeling the decision-making process by the driver). Validation of this model shows that the simulation is quite natural and can be used as a basis for modeling the behavior of individual drivers that can be used as the foundation of automatically guided vehicles.

Several studies [23] [24] began to develop driver behavior modeling to use platform that can be generated by virtual world on the outcome or traffic case more realistic. Microscopic simulation models and the current network is usually implemented on different platforms, and simulation of driver behavior should be made as accurate as possible and have comparable results with reality. Boubaker [25] also construct a microscopic model using linear models and the intelligent driver models. The purpose of this simulation is presented car-following models that have characteristics of longitudinal vehicle motion. This model simulates the response of each vehicle based on the behavior of the vehicle in front of him and do the calibration using Levenberg Maquardt principles, and then can be determined and the selection of important parameters suitable for the calibration process.

In order to simulating the model on normal road conditions, some studies [26][27] tried to simulate traffic at the time of the meeting on the highway (expressway). This condition called merging section, where a vehicle will often make changes during the merge lane (see when going into or out of the main line), the interaction of conflict between vehicles on the acceleration lane and the adjacent lane need to get different attention than usual on the road. Jia [26] was study about merging vehicles and trying to modeling behavior that result more accurate model to overcome the weaknesses of previous models. The platform used to develop the model is MTSS system, using data from Guangzhou to calibrate and validate the model merging probability. Results of simulations compared with field data and the results are quite satisfactory.

Modeling the behavior of the driver can be made easier if the framework to simulate already available. Schakel [28] on his paper discusses an open source framework for microscopic simulation. The focus of research Schakel try to make a solution that can generate a simulation of open source and can provide full access and can be used as a framework for the development of new ITS applications and enable to make changes at the microscopic simulation.

Table-1. Sumarry of Microscopic Model Literature Review.

	Research	**Author**
SIMULATION BASED ON INTELLIGENT TRASNPORTATION SYSTEM	Develops an existing IDM using the new constant-acceleration heuristic. To know the effect of influenced vehicle using ACC.	Kesting [9]
	Modeling traffic to explores the interaction between subsystem (driver, vehicle and infrastructure). To find an appropriate model for use as a foundation for ADAS.	Schnieder [10]
	Build a decision-making based on real-time data obtained. To make a system which can implemented in ITS for congestion pricing. This system use LWR model with stochastic partial differential equations.	Yang [8]
	To design a system that allows a vehicle to obtain information about the traffic of crowd-based ad hoc manner and then implemented on a realistic network-mobility model simulator that can be evaluated.	Leantiadis [11]
	This model is intended to be the foundation of the development of modeling VDN-vehicle until the vehicle can be supplied with a number of accessible information about road conditions, congestion, etc. This model using the M / G / ∞ queuing system.	Khabbaz [12]
MODELING BASED MICROSCOPIC CAR-FOLLOWING AND LANE CHANGING	The research trying to develop a car-following model for the narrow roads using automata cell approach.	Das [14]
	This research try to modeled the decision making of drivers using parameters desired safety margin (DSM) theory of homeostasis.	Lu [15]

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	Safety margin is the value of risk limits that are informed to the driver while driving, which will be obtained by consideration of the stimulus parameters.	
	Make a tests on three car-following models that already exist (CARSIM, WAVSIM and PARAMICS). The test using real data obtained from three different regions and different environment conditions. The purpose of this study was to look for the best models that can be used as a basic assumption for developing car-following models. The results of this research show that CARSIM have a highest accuracy than the others.	Hamid [16]
	This research try to analyzed some lane-changing algorithms that exist, in order to know the effective factors that can be used on lane-changing scenario. The analysis using fuzzy clustering methods.	Abdi [17]
	The paper try to make comparisons of the lane-changing models existing in an attempt to find the most optimal model.	Rahman [18]
	Modeling driver behavior during car-following and lane-changing is done by observing the data obtained in the field. Ma [19] on the paper develops a data collection method that is used to build microscopic traffic simulation. In this study he built an instrument to collect data on driver behavior was focus on the car-following and lane-changing. To reduce the noise in the measurements on car-following pattern, the author used Kalman smoothing to the part state-physical state (acceleration, velocity and position).	
MODELING DRIVER BEHAVIOR	This research tries to model driving behavior using a cognitive model of the existing simulation tools (SmartAHS). The contribution is to build a database of knowledge formation's driver and the development of cognitive processes modeling when the driver was doing driving activities.	Song [20]
	Construct a neural network to improve the driver agent realistic simulation of the vehicle.	Booth [21]
	This study developed a driver behavior model using two fuzzy methods. The first method will be used to model fuzzy low-level control (to model the steering angle and speed variation), second the use of fuzzy multi-criteria decision making is implemented on a high-control action (modeling the decision-making process by the driver).	Tavellaei [22]
	This research constructs a microscopic model using linear models and the intelligent driver models. The purpose of this simulation is presented car-following models that have characteristics of longitudinal vehicle motion.	Boubaker [25]
	The study was about merging vehicles and trying to modeling behavior that result more accurate model to overcome the weaknesses of the previous models. The platform used to develop the model is MTSS system, using data from Guangzhou to calibrate and validate the model merging probability. Results of simulations compared with field data and the results are quite satisfactory.	Jia [26]
	This research discussed about open source framework for microscopic simulation. The focus of research Schakel try to make a solution that can generate a simulation of open source and can provide full access and can be used as a framework for the development of new ITS applications and can enable to make changes at the microscopic simulation.	Schakel [28]

CONCLUTION AND FUTURE WORKS

Based on the literature that has been discussed previously, we can conclude that there is no generic model that can be used to represent all traffic conditions. This is because the traffic condition characterized respectively (environmental conditions, infrastructure, traffic management, etc). Although researchers of the western developed countries have made considerable progress in the field of traffic simulation models and software. However, the Western traffic simulation software is difficult to be applied directly in Indonesia for the reason that the traffic systems in most cities of Indonesia have a distinct characteristic of mixed traffic which is obviously different from the Western developed countries. The unique of Indonesian traffic flow was emerging not only from the mixed traffic conditions which there are many varians of vehicle on the road but also the behavior of driver from different kind vehicle will show different actions.

Based upon the review, it has been conclude a several things: 1) There is no generic model for microscopic traffic flow model; 2) Crowd modeling in traffic is still rarely, perhaps due to the fact that motivations have only recently been recognized; 3) Each region or nation usually has different characteristic traffic and different behavior of driver. Through this reason, development issues of traffic flow modeling for Indonesian traffic has many opportunity, because Indonesian traffic was a complex system that many factors will influenced the flow (such as: driver behavior, environment, geometry road, type of vehicle, etc).

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