Concept and Design of an Intelligent Strategy to Mitigate Traffic Congestion at Intersection

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Abstract: Traffic congestion on public roads is one of the leading causes of lost productivity and decrease in the standard of living in urban setting. The continuous increase in the congestion level, especially at rush hour, is a critical problem and is becoming a major concern to transportation specialists and decision makers. Traffic congestion causes excessive delays, reduced safety and increase in environmental pollution. An intersection is the area where one street or road crosses another. Almost all modes of travel i.e. pedestrian, bicycle, motor vehicle, and transit involve dealing with the intersection area for a given time period, which in turn makes it as a focus of activity, conflicting movements area and a traffic control centre, and as a consequence reducing its capacity. Traffic control at the intersection is an old and ever growing problem in cities all over the world. In many cities, intersections represent bottlenecks in the traffic flow. Evaluating and managing intersections are complex, difficult, costly, and time consuming. The existing methods for traffic management, surveillance and control, are not adequately efficient in terms of performance, cost, maintenance, and support. In this paper, we propose a framework of an intelligent approach for the Dynamic Intersection Traffic Control (DITC) system. We also present some intersection designs that would benefit from the proposed DITC. The proposed strategy reduces conflicts through geometric design and an intelligent traffic control systems. The proposed DITC system has no waiting time and has a specific configuration.

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1 INTRODUCTION

The goal of Intelligent Transport System (ITS) is applying information technology, communications, sensor technology and the internet to transportation systems to improve travel safety, reliability, passenger convenience, mobility, and mitigate traffic congestion as well as reduce fuel consumption. The Intelligent Traffic Control System is an important part of the ITS (Shandiz, Khosravi, & Doace, 2009).

Traffic congestion appears when a large number of vehicles attempt to use common transportation infrastructure which has limited capacity. It leads to queuing phenomena and corresponding delay (in the best case), and a degraded use of the available space and thus, reduce throughput (in the worst case). Traffic congestion is a severe problem in many cities around the world (Liu, 2008). Wen (2008), Yang and Wen (2008), and Liu (2008) found that traffic congestion results in excessive delays, reduced safety, and increased environmental pollution. To a commuter or traveller, it means lost time, missed opportunities, and frustration while to an employer congestion means lost worker productivity and trade opportunities, delivery delays, and increase costs.

In this paper, we describe a framework for an intelligent approach for the Dynamic Intersection Traffic Control (DITC) system. We also present some intersection designs that would benefit from the proposed DITC.

2 RELATE WORK

We need some programming languages or software to build a model/simulation model such as Java and Matlab/Simulink, and software such as, Excel, VISSIM, Arena, StellaTM, and Quadstone Paramics and Azalient Commuter.
Groenewoud and Rinkel (2012) depicted the classification of different kinds of simulation models as illustrated in Figure 1.

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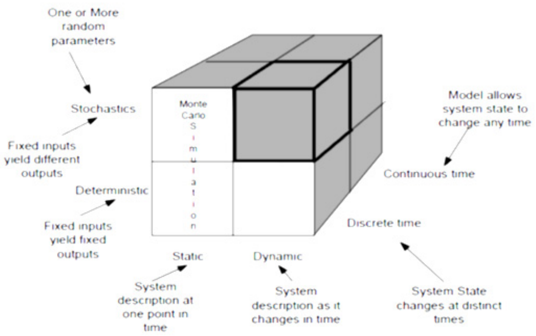

Figure 1: Classification of different types of simulation models

There are three model of approaches in simulation models, i.e. 1) continuous simulation; 2) static, stochastic simulation (Monte-carlo simulation); and 3) discrete, dynamic, stochastic simulation also called Discrete Event Simulation (Groenewoud & Rinkel, 2012). In a continuous model, state variables change continuously as a function of time. In general analytical method such as inductive mathematical reasoning is used to define and solve a system. According to Groenewoud and Rinkel (2012), the Monte Carlo methods varies, but tends to follow a particular pattern:

1. Define a domain of possible inputs.
2. Generate inputs randomly from a probability distribution over the domain.
3. Perform a deterministic computation on the inputs.
4. Aggregate the results.

Discrete event models represents only those time steps at which change occurs, and consequently it is called *event base* or *event driven*, where the system jumps from one event to another, leaving out the irrelevant behaviour for the model, in between the events.

Ross (2005) defined the simulation approach based on a framework which generates the stochastic mechanisms of the model and then observes the resultant flow of the model over time as the discrete event simulation approach. Depending on the reasons for the simulation, there will be certain quantities of interest that someone wants to determine. Furthermore, the key elements in a discrete event simulation are variables and events. In general, there are three types of variables that are often utilized, i.e. the time variable t, refers to the amount of (simulated) time that has elapsed; counter variables, which keep a count of the number of times that certain events have occurred by time t; and the system state variable, that describes the "state of the system" at the time t. Whenever an "event" occurs, the values of the above variables are changed or updated, and any relevant data of interest are collected as output.

There are a lot of ways to classify simulation models. Kelton, Sadowski, and Swets (2010), and also Groenewoud and Rinkel (2012) claimed that one of the useful ways is along these three dimensions:

1. Static or Dynamic
2. Continuous or Discrete
3. Deterministic or Stochastic

In the static model, time does not play a natural role but does in dynamics model. The Buffon needle problem is an example of static model. Most operational models are dynamic. In a continuous model, the state of the system can change continuously over time while in a discrete model, change can occur only at certain times. An example of continuous model would be the level of reservoir as water flows in and is let out, and as precipitation and evaporation occur. A manufacturing system with parts arriving and leaving at specific times, machines going down and coming back up at specific times is an example of a discrete model. Models that have no random input are deterministic, a strict appointment with a booked operation with fixed service time is an example. On the other hand, stochastic models operate with at least some inputs being random. An example is a bank with randomly arriving customers requiring varying service times.

From traffic simulation models point of view, there are two common approaches for traffic modelling i.e., macroscopic and microscopic models. Macroscopic traffic models are based on gas-kinetic models and use equations relating to traffic density and velocity while microscopic traffic models offer a way of simulating various driver behaviours and it consists of an infrastructure that is occupied by a set of vehicles. Each vehicle interacts with its environment according to its own rules, so different kinds of behaviour emerge when groups of vehicles interact (Wiering et al., 2004). Meanwhile TransModeler (2013) and Salimifard and Ansari (2013) divided traffic simulation models into three kinds of models i.e., microscopic, macroscopic and mesoscopic models. Microscopic models predict the mood of single and individual vehicles both continuous and discrete types such as individual vehicle speed and locations, macroscopic models make ready an extensive depiction of the traffic flow simulation, end mesoscopic include the mixed aspects of both microscopic and macroscopic models.

3 THE PROPOSED DITC ALGORITHM

By applying lane closure strategy, continuous flow treatment in intersection zone provides an amazing idea to create a reliable intersection traffic control. A signalized intersection is treated as if it is an unsignalized intersection for certain condition. Figure 2 shows how this combined technique performs its function. The intersection normally functions as a signalized intersection, but in certain situation when the traffic control system is out of order (control system failure or due to electrical power supply failure) or traffic jam occurs at the intersection then it will function as an unsignalized intersection with special treatments. If the situation returns to normal again, i.e. the traffic control systems is working as usual or the jam or congestion has reduced, the intersection reverts to a signalized intersection.

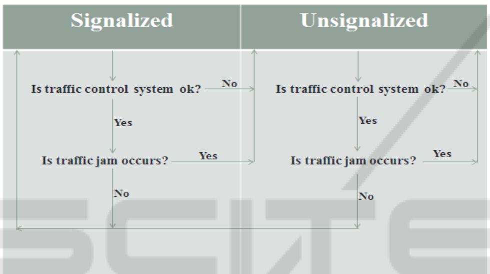

Figure 2: Main algorithm of proposed DITC Model

4 THE 4-WAY INTERSECTION TIME-BASED SYSTEM

Medan is the largest city outside of Java, and the 3rd largest city in Indonesia, after Jakarta and Surabaya. This study concentrate on one of the main 4-way intersections and one of the main 3-way intersections of the urban traffic system in Medan, the capital city of the province of North Sumatera, Indonesia. The observed intersections are an isolated (single) 4-way signalized intersection located at Juanda street and Katamso street as depicted in Figure 3.

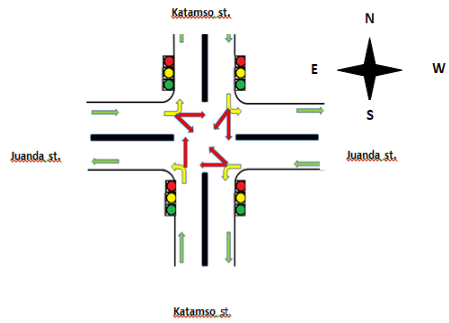

Figure 3: Traffic Flow of 4-way Intersection

There are some patterns in traffic light control system, and they depend on traffic condition, government policies and others. At Juanda street and Katamso street, the intersection has the patterns and stages as given in Figure 4 and Figure 5. In the 4-way intersection there are four stage sequences, i.e. stage A, stage B, stage C and stage D, with special patterns, and they are all controlled by three signals: red, yellow, and green lights of the signals. Stage B has a sligtly different pattern from stage A, stage C and stage D where in the former vehicles may not turn to the right permanently and in the latter, they may turn to the right. These patterns are designed to reduce the complexity of system.

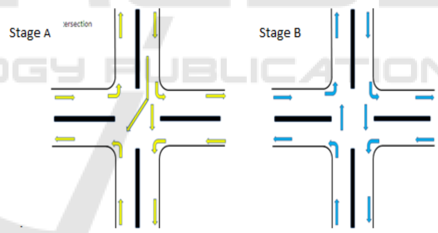

Figure 4: 4-way Intersection: Stage A and Stage B

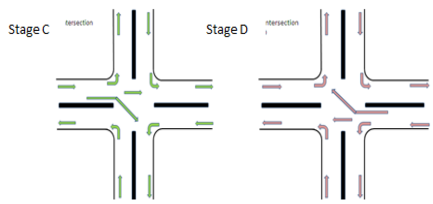

Figure 5: 4-way Intersection Stage C and Stage D

Almost all traffic light control system in Medan are fixed-time control where all signal timing parameters are pre-computed and kept constant i.e. fixed-time which is also called time-based system. In this study, the simulation will be based on this system.

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5 OVERVIEW OF THE PROPOSED FRAMEWORK OF THE DITC SYSTEM

The proposed DITC System framework consists of three blocks i.e. block A (Signalised intersection), block B (Unsignalised Intersection), and the control module block as shown in Figure 6.

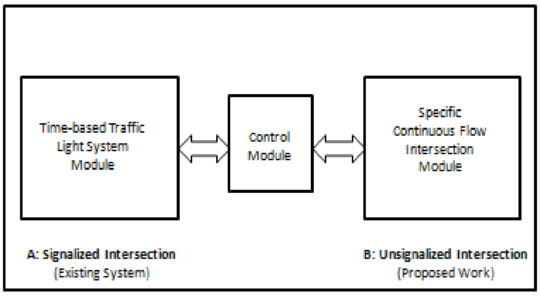

Figure 6: Proposed Framework of the DITC system

This DITC System divided into several modules in its implementation. All modules in this study will be implemented, tested and the result will be obtained using Arena version 14.50.00002 (Student version).

6 THE PROPOSED DITC MODELING FOR 4-WAY INTERSECTION

In reducing or mitigating traffic jam or to overcome power failure at intersection zone, this study will use the optimal configuration of lane closure strategy by completely closing four lanes in the middle of an intersection zone of one road or street (with four lanes, divided road or street), diverting all vehicles to the left side of that direction and then detouring some of them by means of U-turn rotation, following the rest of the road and then at the intersection zone, turning to the left to continue their movement in the previous direction. This proposed strategy is shown in Figure 7 and an illustration of Intersection's lane closure is given in Figure 8.

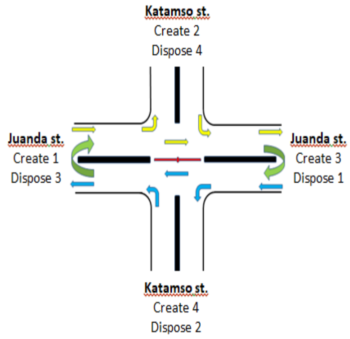

Figure 8: Illustration of intersection's lane closure

7 CONCLUSION

The strategy used in this study is by reducing conflicts through geometric design improvement, operating speeds on approaches, choosing appropriate traffic control, and improving management access by using lane closure (in the middle of the intersection), U-turn, and continuos flow intersection treatment. The proposed DITC system has no waiting time, no phase movement to follow and has specific configuration when acting as unsignalized intersection. In this study only two lanes are considered, it could be expanded into multi-lane in a future work.

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