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ENHANCED SCHEDULING TRAFFIC LIGHT MODEL USING DISCRETE EVENT SIMULATION FOR IMPROVED SIGNAL TIMING ANALYSIS

Zuraida Abal Abas, Lim Ee-Theng, Ahmad Fadzli Nizam Abdul Rahman, Zaheera Zainal Abidin and Abdul Samad Shibghatullah
Optimisation, Modelling, Analysis, Simulation and Scheduling (OptiMASS) Research Group,
Faculty of Information and Communication Technology (FTMK), Universiti Teknikal Malaysia Melaka (UTeM),
76100 Durian Tunggal, Melaka, Malaysia
E-Mail: zaheera@utem.edu.my, zuraidaa@utem.edu.my

ABSTRACT
Most traffic light today used pre-timed traffic light, traffic light using sensors and traffic light which displaying a countdown timer. However, the existing methods consume a long time of vehicle queuing and waiting the traffic light signals to change, which created congestion at intersection of roads. In this paper, the proposed model enhanced the scheduling traffic light, which simulates the vehicle behaviour based on discrete event simulation and queue theory. Therefore, the simulation becomes more realistic and contributes to accurate outcome. This work focuses on the analysis of the average waiting time for the vehicle in three cases: heavy, medium and low traffic volume. The most optimum traffic signal timing is the one with minimum waiting time for the vehicles. Moreover, the new model solves the critical traffic congestion problem not only in simulation but also in real environment, which drivers take the longest average waiting time is 86 seconds while the shortest average waiting time is 64 seconds at the junction although in heavy traffic congestion. An extensive simulations have been conducted in this work in which a green interval as a control parameter is selected.

Key words: Traffic Light Schedulling • Simulation and Modelling • Intelligent System • Discrete Event Simulation •

INTRODUCTION

Traffic signal lights have been widely used around the world for controlling traffic flows. In fact, studies have been done for decades in terms of managing traffic congestion (Wang et al. 2014)(Nagappan 2010)(Sumaryo et al. 2013)(Ganiyu et al. 2011), decreasing number of accidents (Rowe et al. 2015), improving the effectiveness in direction of traffic flow (Asthana et al. 2012)(Wang et al. 2014)(Kulkarni et al. 2014) and use green energy as the source of signal (Xiao & Konak 2015).

However, increasing in human population contributes to the growing number of automobile used on the road which causes traffic congestion (Mih et al. 2014). Due to this congestion problem, one of the possible solutions is to optimise the traffic light signal usage at road intersection. Traffic jams bring a lot of inconvenience to people, it causes traffic delays, increased accidents, wasting time and lead to economic losses (Yan & Gu 2013).

Therefore, an analysis of the traffic light signal at selected intersection is implemented by developing the traffic light signal model. The simulation of the traffic light model needs to be carried out in order to come out with an optimum traffic signal light. It must be noted that both simulation and optimization are significant domain of knowledge for better performances of wide range of real life application problem (Abas & Salleh 2014; Abal Abas et al. 2013; Basari et al. 2012; Shaffiei et al. 2014; Zaheera et al. 2014; Mansor et al. 2014).

There are researches worked on modeling and simulating the traffic light model (Ganiyu et al. 2011)(Leow 2013)(Huang & Chung 2008)(Wang 2014) on single intersection. In fact, various methods have been implemented to build the model and simulation such as PSO (Ng et al. 2013; Ramli et al. 2013), SAS (Leow 2013) and Monte Carlo (Yan & Gu 2013). Nonetheless, very few studies investigating on the real time congestion situation (Behzadan & Kamat 2009) using actual congestion data.

In this paper, a case study based on real environment at one of the traffic light single intersection in Malacca has been observed. The model is developed to analyse the effect of green phase timing towards the average waiting time at each lane in order to find the optimal phase duration.

Therefore, the objectives of this study are:

- To observe and analyse the real situation of traffic lights controls by collecting real life data at Lebuh Ayer Keroh, Melaka.
- To design and develop the computerized models based on the study using Discrete Event Simulation.
- To analyse the current performance and make recommendations.

Moreover, the new model is proposed by using enhancement method which involves discrete event simulation and queuing theory. The new model investigates real situations as well as real time data collection at the first phase. It brings an accurate and efficient result for this simulation. After the observation, the data is translated into a computerized model by using discrete event simulation. Furthermore, process of analyse the collected data and the computerised model is executed. Thus, the computerized model aided the decision making processes in order to improve the overall performance of the traffic light control.

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ENHANCED SCHEDULLING MODEL

Introduction to a new model of enhanced schedulling

A standard traffic light is displayed in three types of colour lights (Red, Yellow, and Green) which represent different meaning to road users. In addition, there are another three types of traffic lights used especially in Malysia that is a) pre-timed traffic light b) traffic light with a sensor and c) traffic light with a countdown timer beside the traffic light. The evolution of traffic light has not only proven in its hardware architecture but also in the software model. To develop the propose model, discrete event simulation technique is used.

Discrete event simulation is most widely simulation technique used in Operational Research. It is a process that simulates any desired system as a discrete sequential event. The entity enters the system and meets some of the state before it satisfies the ending condition of the system. Each of the event forms specific change in the system's state at a particulars time. In between subsequence events, no change in the system is considered occur.

Nonetheless, although there is no change in the system, in reality, the non occurance event exist an event which discrete event simulation skips over large time steps due to its limitation. Therefore, another element, which in this study, queuing theory, need to be combined with discrete event simulation in order to perform better.

In general, the primary queuing process includes customers arrived at a queuing system to wait for service. This process usually happens when the server reached a limit to serve customer. If the server is busy, customers join the queue in a waiting room. They are then served based on a predefined queuing discipline, after which they leave the system. Figure 1 is an illustrated concepts of queuing theory.

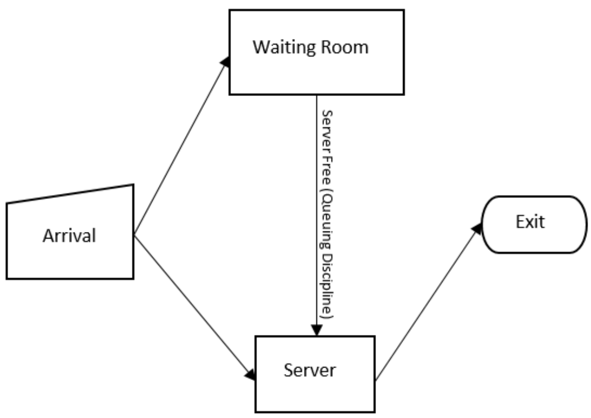

Figure 1 Single Server Queuing System

The waterfall model has been chosen as methodology for this model. It is a sequential design process in which progress is seen as flowing steadily downstream like a waterfall. The waterfall model is implemented into five phase which is preliminary studies, data preparation, algorithm design, computerised model, and result analysis.

The preliminary studies phase is to understand the overview of the project and then determine the goals of the project. Through literature review process, it provides important information that how does other researcher carry out experiment in this domain. Observation of the real case study also conducted in this phase.

Data preparation is a phase to collect the real world data. The method of collecting real life data is through video recording. Each of the data will be recorded as displayed in the video. After collected a set of data, it was proceed to the next phase for further implementation.

The analysis and algorithm design is the phase that analyse current situation and design an algorithm to simulate real scenario. Raw data is processed through mathematic algorithm. The computerise model is the phase of translating all the algorithm design into computerise model by using JaamSim. Meanwhile, Eclipse has been used to implement a program for calculation. The data that collected from real traffic situation is converted into digital data and used to simulate the traffic flow. Last phase of this methodology approach is result analysis. The performance of current traffic light system has been compared with the proposed model. At the end of this phase, recommendation is suggested.

The Real Life Environment of Traffic Flow

The real case study has been conducted in Lebuh Ayer Keroh. It is one of the busiest streets in Melaka. In this model, there are four links (east, west, north and south) with total 15 lanes. Lanes is referring to the vehicles that enter the links only. At east link, it contains four lanes which are one left turn lane, two straight lanes, and one right turn lane. At south link, it contains three lanes which are left turn lane, straight lane, and right turn lane. At the same time, the straight lane also allow vehicle to turn right. Next, west link contains four lanes which are one left turn lane, two straight lanes, and one right turn lane. Lastly, north link contains four lanes which are one left turn lane, two straight lanes, and one right turn lane. At the same time, one of the straight lane also allow vehicle to turn right. This environment is illustrated in Figure 2.

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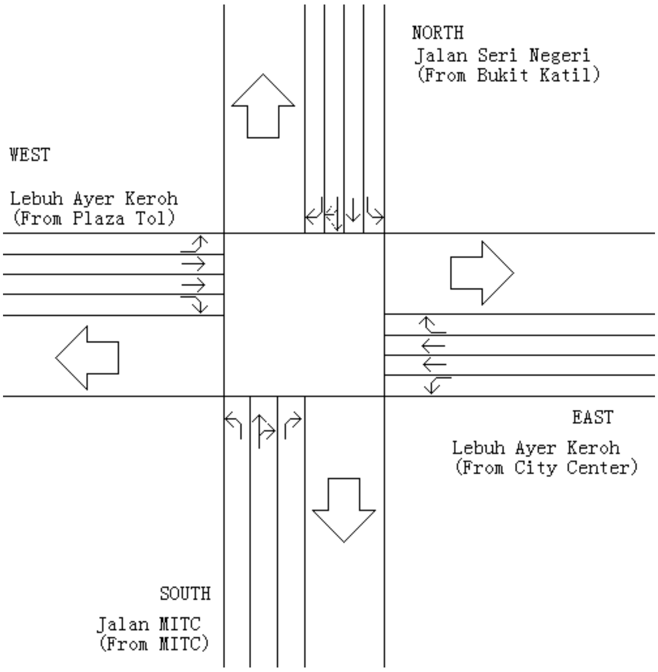

Figure 2: The Real Life Environment

Proposed Model

The proposed model is modelling with discrete event simulation. There are few types of vehicle considered in this model which are car, bus and truck. There is only one event in this model which is the process of vehicle pass through the traffic light intersection. The event is illustrated in Figure 3.

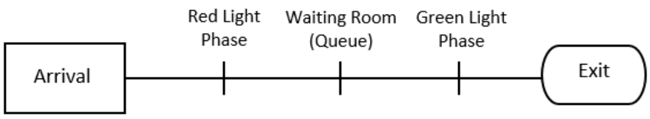

Figure 3: The Event Process

To model the traffic light, some rules are needed to define. In this project, the rule that is applied for traffic light is, if either one of the links is executed in green phase, then other three links is automatically in red phase. Jaamsim ables to simulate this rule by using entity gates. Each entity gates is controlled by signal threshold. Figure 4 illustrated the pseudo code which is applied into the new model.

Pseudo code:

```
For each link
if Entity Signal is TRUE
 then Entity Gate is opened
else Entity Gate is closed
 if Entity Gate is opened
   then release vehicle in Waiting Room
 else vehicle queue in Waiting Room
```

Figure 4: Pseudo Code

The pseudocode as in Figure 4 is formulated from the mathematical estimation as provided as in (1) and (2).

Average arrival rate of each vehicle:

$$\lambda(x) = \frac{\sum ST}{\sum v(x) - Q_i(x) + Q_l(x)} \tag{1}$$

In the above equation, x is refer to links, ST is the service time, v is the number of vehicle pass by, Q_i is the initial number of vehicle in waiting lane, Q_l is the last cycle number of vehicle in waiting lane. Probability of each turn:

$$P(x) = \frac{total\ each\ turn\ in\ x}{total\ vehicle\ pass\ by\ x} \tag{2}$$

In the above equation, x refers to links and each turn refer to the direction of vehicle pass through.

In this work, a java language system is created by using Eclipse to process the raw data. The raw data is loaded from text file. Calculation is done according to the formulas. After process the raw data, the result is linked to Jaamsim by overwrite the model file as in Figure 5. This system also allow user to insert the duration of green phase signal for each links. After inserting the green phase duration, the system modifies the model file. Lastly, user needs to execute the simulation of real traffic scenario using Jaamsim.

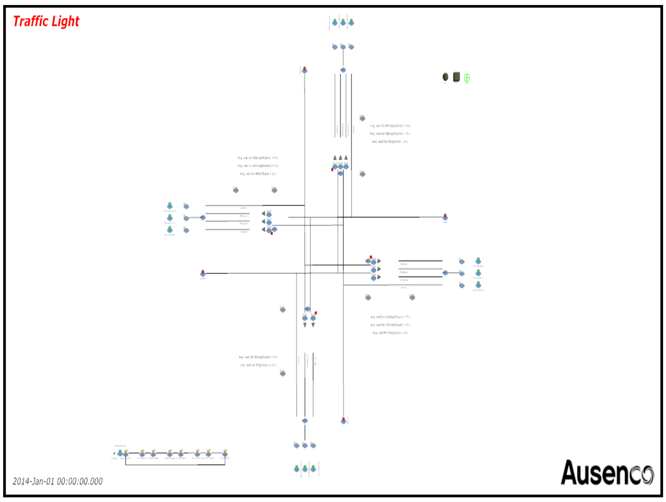

Figure 5: The Proposed Model in Jaamsim

RESULT ANALYSIS

The analysis has been conducted according to high, medium and low traffic volume. The duration of the green phase signal for each link is supplied to the model. It is displayed through the numbering system as illustrated in Figure 6. For example $60-37-40-30$ indicates 60 seconds, 37 seconds, 40 seconds and 30 seconds for the

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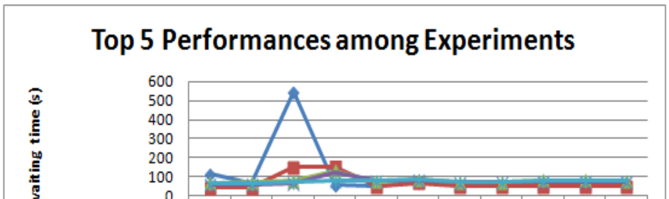
duration of green phase signal at east, south, west and north link respectively.

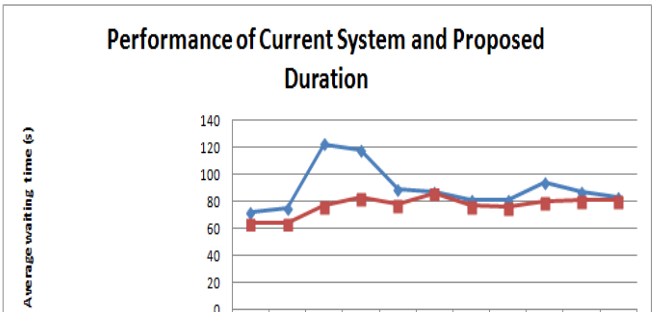
Comparison during High Traffic Volume



	EStraightLane1	EStraightLane2	ERightLane	SStraightLane	SRightLane	WStraightLane1	WStraightLane2	WRightLane	NStraightLane1	NStraightLane2	NRightLane
(1st)30-30-30-30	119	64	544	60	54	71	57	53	56	54	53
(2nd)35-20-25-20	45	42	152	155	51	70	53	49	49	52	51
(3rd)65-35-45-35	70	72	81	133	77	86	75	75	84	84	78
(4th)60-32-40-30	62	59	69	123	82	80	71	73	74	77	74
(5th)60-37-40-30	64	64	77	83	78	86	77	76	80	81	81

Figure 6: Top 5 Performances among Experiments during High Traffic Volume

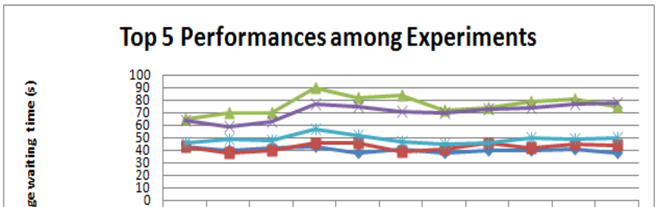
According to Figure 6, the fifth experiment shows the best result for simulation during high traffic volume. The longest average waiting time is 86 seconds while the shortest average waiting time is 64 seconds for fifth experiment. With this result, the comparison in terms of the average waiting time is made between the fifth experiment (as proposed green phase duration) and the current system as illustrated in Figure 7. It can be seen that the proposed green phase duration is better than the current system because the average waiting time is shorter. Therefore, during high traffic volume, the recommended duration for green phase is $60-37-40-30$ for east, south, west and north link respectively.



	EStraightLane1	EStraightLane2	ERightLane	SStraightLane	SRightLane	WStraightLane1	WStraightLane2	WRightLane	NStraightLane1	NStraightLane2	NRightLane
Current System (65-37-52-40)	72	75	122	118	89	87	81	81	94	87	83
Proposed Duration (60-37-40-30)	64	64	77	83	78	86	77	76	80	81	81

Figure 7: The Performance of Current System and Proposed Duration during High Traffic Volume

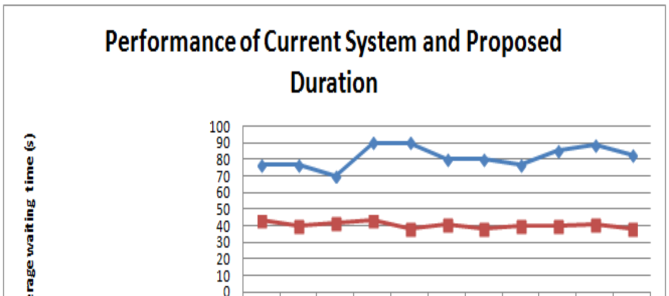
Comparison during Medium Traffic Volume



	EStraightLane1	EStraightLane2	ERightLane	SStraightLane	SRightLane	WStraightLane1	WStraightLane2	WRightLane	NStraightLane1	NStraightLane2	NRightLane
(1st)20-20-20-20	43	40	42	43	38	41	38	40	40	41	38
(2nd)25-20-20-20	43	38	40	46	46	39	41	46	42	45	44
(3rd)65-35-45-35	65	70	70	90	82	84	72	74	79	81	75
(4th)60-32-40-30	64	59	63	77	75	71	70	73	74	77	78
(5th)30-20-25-25	46	49	48	57	52	47	45	46	50	49	50

Figure 8: Top 5 Performances among Experiments during Medium Traffic Volume

According to Figure 8, first experiment shows the best result for simulation during medium traffic volume. The longest average waiting time is 43 seconds while the shortest average waiting time is 38 seconds. Again with this result, the comparison in terms of average waiting time is made between the first experiment (as proposed green phase duration) and the current system as illustrated in Figure 9. It can be seen that the proposed green phase duration is better than the current system because the average waiting time is shorter. Therefore, during medium traffic volume, the recommended duration for green phase is $20-20-20-20$ for east, south, west and north link respectively.



	EStraightLane1	EStraightLane2	ERightLane	SStraightLane	SRightLane	WStraightLane1	WStraightLane2	WRightLane	NStraightLane1	NStraightLane2	NRightLane
Current System (65-37-52-40)	77	77	70	90	90	80	80	77	85	89	83
Proposed Duration (20-20-20-20)	43	40	42	43	38	41	38	40	40	41	38

Figure 9: The Performance of Current System and Proposed Duration during Medium Traffic Volume

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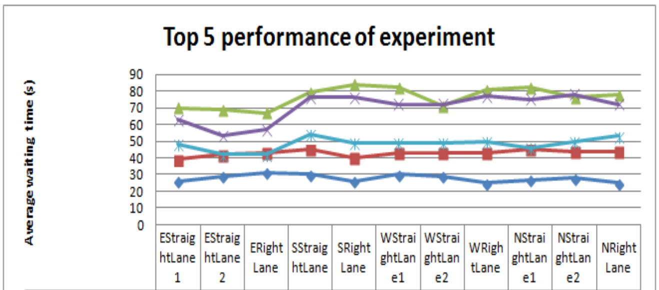
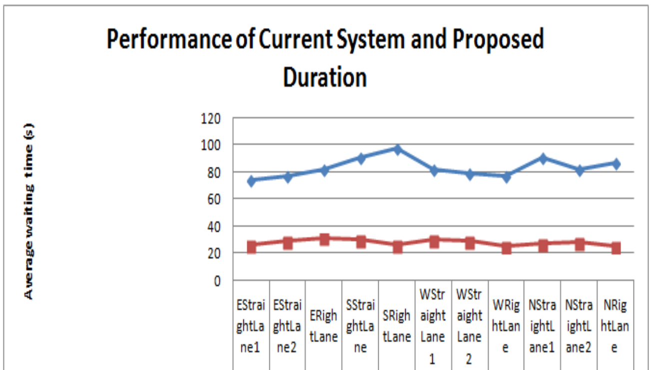
Comparison during Low Traffic Volume



	EStraightLane1	EStraightLane2	ERightLane	SStraightLane	SRightLane	WStraightLane1	WStraightLane2	WRightLane	NStraightLane1	NStraightLane2	NRightLane
(1st)10-10-10-10	26	29	31	30	26	30	29	25	27	28	25
(2nd)25-20-20-20	39	42	43	45	40	43	43	43	45	44	44
(3rd)65-35-45-35	70	69	67	79	84	82	71	81	82	76	78
(4th)65-27-40-30	63	53	57	76	76	72	72	77	75	78	72
(5th)30-20-25-25	48	42	42	54	49	49	49	50	46	50	53

Figure 10: Top 5 Performance Experiments during Low Traffic Volume

According to Figure 10, the first experiment shows the best result. The longest average waiting time is 31 seconds while the shortest average waiting time is 25. Again with this result, the comparison in terms of average waiting time is made between the first experiment (as proposed green phase duration) and the current system as illustrated in Figure 11. It can be seen that the proposed green phase duration is better than the current system because the average waiting time is shorter. Therefore, during low traffic volume, the recommended duration for green phase is 10 – 10 – 10 – 10 for east, south, west and north link respectively.



	EStraightLane1	EStraightLane2	ERightLane	SStraightLane	SRightLane	WStraightLane1	WStraightLane2	WRightLane	NStraightLane1	NStraightLane2	NRightLane
Current System (65-37-52-40)	74	77	82	91	97	82	79	77	91	82	87
Proposed Duration (10-10-10-10)	26	29	31	30	26	30	29	25	27	28	25

Figure 11: The Performance of Current System and Proposed Duration during Low Traffic Volume

FINDINGS

The proposed simulation model determine the duration to sustain traffic signal light especially in green phase which gets the highest performance according to the 3 cases (High, medium and Low Traffic). Simulation of traffic control is very important since it helps to avoid critical traffic congestion problem and also bring convenience to people. In fact, the performance of the proposed duration has been improved, which solves the critical traffic congestion problem in real life. Furthermore, the satisfaction of road user is also improved. Road user may not waste time to queue up at the junction. The result of this project is able to make recommendation to user. Through the proposed model simulation, it provides an option for user to make decision.

On the other hand, there is a method to overcome the limitation of this model through implementing agent based modelling technique which it is able to simulate the vehicle behaviour. Hence, the simulation becomes more realistic and it gives a better result.

CONCLUSION

In this paper, the enhancement of discrete event simulation for traffic flow and congestion is presented. Based on the proposed model, it is successfully simulate the real traffic flow of congestion according to scenarios of high, medium and low traffic volumes. Finally, the experimental results show that the event can be reconstructed by assimilating the real time data traffic into the simulation model. Future work will be focused on the vehicle behaviour using agent based simulator for more accuracte results. Results from the simulation produces better simulated outcomes which provide an option for user to make decision and to optimize the performance of traffic light system.

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