DELAY-FLOW RELATIONSHIP OF DISTURBED TRAFFIC; A SIMULATION APPROACH

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ABSTRACT

An investigation on the relationship between extra delay and flow was carried out based on the simulation study. The TRASMC model (Sumomo, 1992) was used in the investigation. For conditions of disturbed traffic such as the existence of a parked vehicle, continuous occurs and may cause excessive delay. Due to the disturbed traffic, delay discussed here is then referred to as extra delay.

It is believed that a parked vehicle near a signal could cause significantly extra delay. This is because saturation flow reduces due to a sudden change in the degree of saturation, i.e. in the ratio of flow to maximum possible flow.

Webster and Cobbe (1966) found out that variations in the queue and hence in the delay when a sudden change in the degree of saturation occurs can be depicted in Figure 1. It is clearly seen that an equilibrium can be achieved within a few cycles for the degree of saturation less than 0.9. However, for the degree of saturation (x), between 0.9 and 1.0, the queue needs a longer time to settle down. Moreover, it can be seen that for x>1, the queue increases rapidly at first and then continues to increase more slowly, for x>1.1 the queue approximately increases linearly with time.

In short, Webster and Cobbe (1966) pointed out that it is approximately correct, and fairly enough for practical purposes to conclude that equilibrium is achieved after following an increase in the degree of saturation which results in a limit degree of saturation of less than 0.9.

THE USE OF SIMULATION MODEL

In this experimental study TRASMC program (Sumomo, 1992) was used to simulate the real life conditions of monitoring extra delay due to the parked vehicle. Nevertheless, care was taken into account since initially the simulation program was developed for different purposes of this study. Therefore, the work of validation and calibration of the program was done in advance.

Validation

In this study, the work of validation stressed on the examination of the random variation. The use of random numbers in simulation study usually creates a source of variation in the results, particularly when a single random number is used, since by limiting to one sequence of random numbers, some degree of interdependency is implied for all stochastic processes in the simulation (Rathi, 1992). Accordingly, in TRASMC multiple random streams were employed, and therefore interdependency is implied for all stochastic processes in the simulation (Rathi, 1992).

To ensure TRASMC is valid, a sensitivity test on certain variables was carried out by running the simulation program using different seeds for the various streams of random numbers.

In this examination a number of run tests were performed to simulate one condition and to measure a variable that closely related to extra delay, i.e.; travel time. The simulation tests were completed in four runs with different seeds of random number streams to examine variation of the statistical output. Each run was conducted for one hour simulation, including warming up time, which is normally sufficient to reproduce measured variables. The measure of travel time was used in this test, and therefore the random number stream seeds which were varied were chosen on the basis of their likely ability to influence the measure.

The results of the run tests with different seeds of random streams are presented in Table 1.

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Table 1: Travel Times (sec) for Different Seeds of Random Streams

<table>
<thead>
<tr>
<th>Run</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>89.58</td>
<td>86.70</td>
<td>88.43</td>
<td>85.97</td>
</tr>
<tr>
<td>St</td>
<td>19.67</td>
<td>15.98</td>
<td>21.68</td>
<td>18.10</td>
</tr>
</tbody>
</table>

n = 391

Statistical tests were performed to examine the variation between runs. For this purpose the method of Comparison Among Means (CAM) was employed to test the agreement of values of variables tested from one run to the others. (Tallies 1981) Indications that this method may be used instead of the ordinary analysis of variance and F-test, since CAM indirectly includes analysis of variance. Based on the CAM analysis, it was found that the measured variable as reproduced by the simulation model is not significantly different among the runs.

Calibration

To calibrate the model, initially the values of some variables obtained by field measurement were used directly in the model. These variables include speeds, proportion of vehicle types, turning proportions, approach geometry and the signal timing plan. There were some other variables needed for the model, however, which were not available for the study site. These variables concerned car following parameters. Therefore in the calibration stage "fine tuning" of these variables was carried out. This is because these parameters are difficult to collect in the field, for example front gap, acceleration and deceleration for every type of vehicle used in the simulation. The model performance was found to be sensitive to these parameters.

To adjust the car following parameters, initially standard values of these parameters were taken from the literature (Young et al., 1989; Satomoto, 1992) and then to find a good agreement with the study site, "fine tuning" of the parameter was carried out. Fine tuning was carried out by comparing a model's response variable with the observed data. Calibration in this stage was deemed achieved when the difference between modelled and observed values was insignificant at 95% confidence.

After "fine tuning" of parameters, the next stage was to compare the data reproduced by the model with that observed. In this final stage of calibration, a variable of travel time was tested. The TRASMIC simulation was run for two conditions. The condition without any parked vehicle, and the condition with parked vehicles at 45 m from the stop line. Results of simulation tests and the observed data are presented in Table 2. Statistical tests were performed to examine whether there was significant difference between observed and simulated data. A formal F-test and t-test were conducted to examine the variance and mean of the two sample data. Evidently, simulated data showed insignificant difference from that observed at 95% confidence interval, for data of travel time, on both conditions. This concludes that the TRASMIC can reproduce results as they are taken from a real field experiment.

RESULTS AND DISCUSSION

After the TRASMIC model has passed the validation and calibration stages, the main interest is then to examine its performance. Therefore, the intention of this section is to explore the capability of TRASMIC model by running it for analyses of the effects of a parked vehicle. The analysis was derived from data reproduced by the simulation combined with the observed one. The analyses was mainly focused on the effects of a parked vehicle on extra delay.

The main intention was to examine the extra delay due to the parked vehicle. TRASMIC model was run for two different conditions, one without a parked vehicle, the other with a parked vehicle with a Blockage distance 45 m. The simulation tests for both conditions were employed with different flow levels. Thus, the extra delay can be derived as the difference of travel time between the two conditions at each flow level.

Two relationships can be performed, the first is the relationship between extra delay and flow level and the second is the relationship between extra delay and degree of saturation, Figure 2 and 3 show these relationships.

Figure 2 shows that extra delay gradually increases with flow in the conditions of free flowing. Once the flow increases beyond free flow conditions, the extra delay showed a steeper increase. In fact, this suggests that different flow levels have different sensitivities to disturbance of the parked vehicle which is true as in reality. Furthermore, extra delay may increase to infinity in the conditions of congested flow.

Comparing with the flow - delay curve at traffic signals (Webster and Cobbe, 1966), the pattern of the flow - extra delay curve was slightly different. The extra delay curve found in this study seems to have three parts. In the first part, extra delay has a gradual increase with the increase of flow, in fact this is in free flow conditions where flows are less sensitive to the presence of the parked vehicle. In the second part, extra delay has a steep increase until certain level of flow, and this suggests that the presence of the parked vehicle has influenced the increase of extra delay. It was believed that the heavier the flow the more difficult drivers found it to execute lane changing (merging and diverging) around the parked vehicle, and therefore the heavier the flow the greater the increase of extra delay.

In the final part of the curve which is for congested flow, extra delay shows a very steep increase approaching to infinity. This suggests that in congested conditions drivers found it very difficult to execute lane changing to the extent...
that sometimes they became stuck behind the parked vehicle resulting in excessive extra delay to infinity. A detailed examination for this case showed that the last part of the curve started when the flow reached 80% of the capacity with the parked vehicle. Moreover, compared with the normal flow delay curve, the existence of the parked vehicle causes delay to increase earlier at a smaller flow level than normal (without a parked vehicle). Therefore, in contrast with Webster's delay curve, here the period of gradual increase of delay only lasts for some flow levels, and then a steeper increase happens.

![Figure 2: The Relationship between Extra Delay and Flow](image)

![Figure 3: The Relationship between Extra Delay and Degree of Saturation](image)

The relationship between extra delay and degree of saturation seems to have a similar curve as found by Webster and Cobbe (1966) for traffic signals. However, it can be seen that extra delay increases steeply approaching to infinity earlier than delay at traffic signals, i.e., at the degree of saturation around 0.8 rather than 0.9 as normal delay at traffic signals.

Figure 3 shows that the degree of saturation of 0.8 results in extra delay of 35 seconds/vehicle. This means that when the flow greater than 80% of the capacity extra delay might increase steeply from 35 seconds/vehicle to infinity. This is because of the instability of driver's change lane (merging and diverging) due to the parked vehicle.

CONCLUSIONS
From this simulation study some conclusions can be drawn as follows:
1. the TRASMIC model can perform well for the purpose of this study after validation and calibration process was carried out.
2. the pattern of the delay-flow relationship of disturbed traffic showed that the delay-flow curve consists of three parts which showed a different characteristic.
3. the relationship between delay and degree of saturation of disturbed traffic has a similar curve as found by Webster and Cobbe (1966). At the degree of saturation around 0.8 delay increases steeply approaching to infinity.

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