Vissim-based Simulation of Variable Slip Road Length Design of the Federal Highway in Malaysia

K. D. Kamaruzzaman, S. M. Abdul Rahman

Abstract: Traffic congestion on highways is mainly the result of overcrowding. This phenomenon happens when a great number of vehicles storm the road, disrupting the smooth flow of traffic. In this study, traffic simulation, using PTV Vissim software as a scenario planning tool, was conducted to analyze slip road length as a traffic congestion source at a selected intersection point. The intersection point was designed based on Federal Highway between KM14.8 and KM14.5 in Shah Alam. The VISSIM model was calibrated using traffic flow, delay time, average number of vehicles and maximum queue length data obtained from one-hour instances of video recordings of the respective intersection during evening peak periods. Based on the field data, the average throughput is 1003 vehicles with an average speed of 40 m/s. The traffic condition in the area can be regarded as congested. One of the reasons for congestion in this area is the proximity between in and out feed to the Federal Highway. Three different distances between in and out feed to the Federal Highway were simulated, which were 140m, 280m (baseline) and 420m. Based on the results obtained from the simulation, it could be gathered that the longer the slip road, the higher the length of delay. However, the distance of the in/out feed had little to no effect in terms of vehicle throughput. While running the simulation, it could be observed that the delay mainly occurred due to merging and lane-changing activities at the input. Nonetheless, further analysis is needed for different slip road settings to conclude congestion pattern based on road design.

Keywords: Intersection Point, Slip Road, Traffic Congestion, VISSIM

I. INTRODUCTION

The Federal Highway is the highway connecting the capital city of Kuala Lumpur, and Klang, Selangor. It is the busiest highway in the Klang Valley during rush hour to/from Kuala Lumpur. Massive daily traffic jams along Federal Highway are common especially early in the morning and late afternoon [1]. As a result, new expressways were developed to reduce the congestion of the Federal Highway. However, up until today, traffic congestion still occurs. This may be due to high population density in Kuala Lumpur and Selangor which amounts to 15% of Malaysia’s population [2] and the increase in number of registered vehicles by approximately 3.5% from 2017 to 2018 [3]. The traffic at the intersections and the area in those vicinities are getting serious and hampering daily activities of those citizens [4]. Generally, traffic congestion occurs when traffic demand is greater than the capacity of the road. Traffic congestion can be characterized based on three factors, which are slower speed of vehicles, longer travel times and increased queuing [5].

The Federal Highway is occupied with a tremendous number of vehicles especially in the morning and late afternoon since the road itself connects the capital city of Kuala Lumpur and Klang, Selangor [6]. Reducing the number of vehicles on the road might be impossible for several cases but the percentage of traffic congestion can still be reduced with proper analysis and research in traffic flow behaviour. It is hypothesized that the design of the road is an important subject to reduce traffic congestion.

However, the design of the road could be a debatable matter in this study. Despite human behaviour, the design of the road seemingly contributes a big impact towards traffic congestion [7]. The road intersection, which is a slip road, causes vehicles to change the lanes. Technically, vehicles tend to slow down during lane changing and will cause a delay on the road [8]. This research hypothesized that the problem is not only caused by the lane-changing activity but also due to the length of the slip road.

In response to this problem, this study proposes to investigate several slip road length designs. The length of the slip road was to be observed and then analysed using a traffic model simulation such as PTV Vissim to obtain an ideal length in reducing the traffic congestion at the area. PTV Vissim is a stochastic process where the outcome result will be random depending on its random seed and is suitable for the traffic analysis [9]. The initial stage of planning was to collect the data which included the total number of vehicles at the input from the direct field survey at the desired location, which was at the Federal Highway.

Slip roads are roads which join to carriageways, or most commonly called, motorways [10]. One must need to be of similar or higher speed of vehicles when joining the motorway to avoid becoming a hazard to traffic already on the carriageway [11]. In other words, it could also lead to traffic congestion. In Malaysia, it can be seen that people tend to use the length of the slip road as an additional road, causing lane-changing and leading to traffic congestion. This study does not emphasis on the driving behaviour, but focuses on the delay of the vehicles due to the distance between in and out feeds instead.
II. METHODOLOGY

A. Site Selection

Several slip roads in Shah Alam were visited to collect actual data. The purpose of visiting several places was to identify a suitable site for the data collection. A few criteria had first been considered before selecting the intersection which was to be the study area: the data-collection site must have good access and must be safe for the survey personnel and equipment to be set up during the data collection process. Other than that, the traffic volume should be relatively high on both the slip road and main road.

Based on the criteria, a Federal Highway intersection was selected as the study site as shown in Fig. 1. The study intersection was between the slip road and main road from east to west. The input of the slip road is from 3214 road and the output is to Persiaran Selangor. The main road is a three-lane single carriageway with a single-lane width of 3.5 m each, while both in and out feed of slip roads were two lanes with a single-lane width of 3.0 m each.

**Fig. 1. The study area as shown on Google Maps at the intersection point between KM14.8 and KM14.5**

B. Field Data Collection

In order to build a VISSIM simulation model for the selected intersection and to calibrate it for local traffic conditions, (1) geometric data, (2) demand data, (3) delay data and (4) throughput data were collected at the field.

C. Geometric Data

The widths of the lanes were measured on site by using odometers on car and also from the Federal Highway website.

D. Demand and Delay Data

Traffic volumes on in/out feed of the slip road and the main road were collected using a video camera. The traffic volume was recorded for a period of one hour, and in this case, during the evening peak period from 6.00 p.m to 7.00 p.m. A video camera was set up on a tripod to obtain a clear view of input/output of the roads. The video recording was played back on a computer whereby traffic throughput and composition data were extracted at 10-minute intervals. The traffic composition included cars and HGVs.

A ‘travel time’ section was created on both main and slip roads to measure the delay data of each vehicle which passed between the start and end sections of travel time. The delay data on the field survey was taken by using 3 runs of vehicles on the road.

III. VISSIM MODEL

The existing slip road was modelled in PTV VISSIM by using an aerial image of the site from Google Earth, as shown in Fig. 2. The image was then imported, scaled and the links and connectors indicated the highway were established in the VISSIM, as illustrated in Fig. 3. The vehicle composition such as the speed of the vehicles were set as constant in this study (100 km/h for cars and 80km/h for HGVs). The marker was set to the model to collect data such as delay, throughput and average speed.

**Fig. 2. Existing main road and intersection modelled in VISSIM**

**Fig. 3. Model intersection in wireframe display mode showing links (red) and connectors (blue).**

PTV VISSIM is a stochastic process which means the simulation would give different results randomly after the model had been run. The stochastic process in PTV VISSIM also is indicative of the nature of traffic in the real world, which is random. Three simulation runs were performed with different random seeds to ensure that the outcome values were a true statistical representation of the average. As a result, measured data such as delay, entry flow and throughput were recorded and averaged over three simulation runs.

IV. VISSIM CALIBRATION

A. Entry Flow Measurement

For the entry flow measurement, the data was obtained by using the “data collection point” tool in VISSIM. The function of the data collection points is similar to counting boards which are attached to roadway tracks for recording of traffic volume in some countries [12]. Data collection points were used to count the simulated throughput of
vehicles when placed at the intersection of in/out feed of the main road and slip road. The comparison between field and simulation data was done by using the GEH formula as shown in (1). The GEH Statistic is a formula used in traffic engineering, forecasting, and modelling to compare two sets of traffic volumes. To model traffic in the “baseline” scenario, a GEH less than 5.0 is considered a good match between the modelled and observed hourly volumes [13].

\[ GEH = \sqrt{\frac{2(m - c)^2}{m + c}} \] (1)

\( m \) = traffic volume from the traffic model (or new count) 
\( c \) = real-world traffic count (or the old count)

Results of the simulated and field data during the peak evening hour have been presented in Table-I. A GEH test value of 5 or lower was obtained for each of the three observations. This indicated that the simulated and field flows could be considered an acceptable fit.

**Table-I: Table of GEH statistic comparing field data and simulation data**

<table>
<thead>
<tr>
<th>No. of observation</th>
<th>Field data count</th>
<th>Simulation data</th>
<th>GEH</th>
<th>GEH &lt; 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>980</td>
<td>1031</td>
<td>1.61</td>
<td>YES</td>
</tr>
<tr>
<td>2</td>
<td>990</td>
<td>1050</td>
<td>1.88</td>
<td>YES</td>
</tr>
<tr>
<td>3</td>
<td>1033</td>
<td>1054</td>
<td>0.65</td>
<td>YES</td>
</tr>
</tbody>
</table>

**V. RESULT AND DISCUSSION**

Three simulation runs were conducted to determine the relationship between delay and time. Table-II shows the comparison data of simulation and field delays at 280m (baseline). The values between each simulation and field data were compared by using single factor analysis of variance (ANOVA) test to determine whether the difference was statistically significant. The result of the ANOVA test as presented in Table-II showed that \( F (0.01204) < F_{critical} (5.9874) \) and the P-value (0.916) > \( \alpha (0.05) \); as such, the null hypothesis was accepted. This indicated that there was no significant difference between simulation and field data.

**Table-II: Comparison between simulation data and field data for delay at baseline**

<table>
<thead>
<tr>
<th>Delay (baseline)</th>
<th>No. of observation</th>
<th>Maximum (s/veh)</th>
<th>Minimum (s/veh)</th>
<th>Average (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation</td>
<td>3</td>
<td>29.4</td>
<td>9.8</td>
<td>15.54</td>
</tr>
<tr>
<td>Field</td>
<td>3</td>
<td>26</td>
<td>13</td>
<td>19</td>
</tr>
</tbody>
</table>

Fig. 4 to 6 show the example of 10 minutes traffic volume pattern at input from slip road to output to main road and slip road exit during evening peak period from 6.00 p.m to 7.00 p.m at three different days. Based on the field data collection result, it can be seen that the pattern of inflow and outflow traffic is comparable, thus validating the field data.
Fig. 8 indicates a graph of delay versus time which had been obtained from running the simulation at 140 m. The simulation was also tested with 3 runs. The result from the simulation showed that minimum length of distance of feed in/out has shorter in delay (0 to 13 seconds) compared with the baseline which is about 10 to 30 seconds. The range of delay was also smaller for the simulation at 140 m as compared to the simulation at 230 m.

**Fig. 8. Delay vs. Time at 140 m**

Fig. 9 showed data obtained from the simulation run at 420 m slip road length. All three simulation runs showed comparable delay data. The result shows that the maximum length of the distance can be reached above baseline (280m) delays, which is slightly above 30 seconds. The dispersion or range of delays was observed to be wider than the baseline condition.

**Fig. 9. Delay vs. Time at 420 m**

Overall, it can be observed that the slip road length of 140 m had the smallest delay of around 5 to 10 seconds while delay for the slip road length of 420 m was between 10 to 35 seconds, which is similar to the baseline slip road length delay. This shows that the range of delay can be minimized with shorter slip road length as it would minimize driving behaviour variations.

**B. Travel Time**

Three observations were tested at 140 m, 280 m and 420 m. Travel time is the time taken for a vehicle travelling from the starting point to the selected end point. The travel times for the baseline in the simulation was between 20 to 40 seconds (Fig. 10) while the average travel time of field data was 27 s. The simulated data can be accepted as the simulated data is in the range of the average field data. Vehicle speed was approximately between 25km/h to 50km/h.

**Fig. 10. Travel Time vs. Time at 280 m**

The travel time at 140 m in Fig. 11 was below 20 seconds, which was faster than the travel time of the baseline. This occurred because the length of the feed in and out of the slip was shorter than the baseline which was 280 m. The travel time range was also observed to be smaller than the baseline value. It was also observed that the vehicle was travelling at a slightly faster speed than in the baseline condition (25km/h to 60km/h).

**Fig. 11. Travel Time vs. Time at 140 m**

From Fig. 12, the travel time was mostly above 30 seconds and was slower than both lengths of 140 m and 280 m. This occurred because the length itself was most stretched, as compared to the slip road designs at 140 m and 280 m. It was also observed that the vehicle was travelling at a slightly slower speed than in the baseline condition (30km/h to 50km/h). This also confirmed that the longer the slip road, the larger the variation in driving behaviour, thus resulting in larger travel time and delay.

**Fig. 12. Travel Time vs. Time at 420 m**

VI. CONCLUSION AND RECOMMENDATIONS

In conclusion, the study was able to observe the effect of the slip road towards the traffic congestion. The traffic congestion could be seen by observing the obtained delay and time travel results of the vehicles. Based on the results obtained from the simulation, it could be gathered that the longer the slip road, the higher the amount of delay and the slightly lower the vehicle speed. Even though the distance of the in/out feed had...
little to no effect in terms of vehicle throughput, it could be observed that the delay occurred mainly due to merging and lane-changing activities at the input. Thus, larger distances will result in a larger variation in driving behaviour. However, further analysis is needed to conclude congestion patterns based on road design and driving behaviour.

REFERENCES


AUTHORS’ PROFILE

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