Chapter 8

Traffic flow analysis at U-turn merging sections along Jalan Batu Pahat – Kluang (Federal Route FT050)

Basil David Daniel, Mohd Amiruddin Mad Nasir, Munzilah Md Rohani, Nursitihazlin Ahmad Termida, Mohamad Yusri Aman and Kamarudin Ambak

8.1 Introduction

A U-turning movement is a driving technique where the driver performs a 180 degree turn to reverse the direction of travel on a highway. Some highways in Malaysia such as multilane highways provide U-turn facilities. U-turn facilities is usually provided in areas with high population density such as residential and commercial areas. The ulterior goal of providing U-turn facilities is to allow change in direction of travel with minimal impact on traffic conflict points and congestion. U-turn facilities are preferred over conventional signalised intersections due to its more desirable traffic performance [1].

Presently in Malaysia, studies have been conducted to quantify the effect of U-turn facilities on traffic flow, and to assess U-turn facilities in terms of safety and level of service [2]. However, there has not been any research on developing traffic flow models and predicting the change in capacity, or “capacity drop” of traffic flow at U-turn merging sections, which is why this research was conducted.

Merging points are critical sections of roadways that need to be studied, seeing as the drops in capacity of traffic flow can cause bottlenecks, lower lane speed and worsen the level of service of roadways. Failure to predict the capacity drop will affect the level of service as the traffic volume grows in the future.
8.2 Traffic flow at Jalan Batu Pahat – Kluang

Traffic flow can be divided into two main types – the first being uninterrupted flow, which is defined as flow regulated by vehicle-vehicle interactions and interactions between vehicles and the roadway. The second is interrupted flow, where the flow is coordinated by external means, such as a traffic signal, a junction or a pedestrian crossing. Under interrupted flow conditions, vehicle-vehicle interactions and vehicle-roadway interactions play a secondary role in defining the traffic flow [3].

The three U-turn facilities along Jalan Batu Pahat – Kluang (refer to Figure 1) can therefore be categorised as uninterrupted flow facilities, seeing as the flow at the facilities is mainly governed by interactions between vehicles and the roadway configuration, as well as vehicle-vehicle interactions.

![Fig. 1 Location of U-turn facilities along Jalan Batu Pahat - Kluang](image-url)
From a 12-hour traffic count conducted on-site, the morning, afternoon and evening peak periods were determined to be 7:00 am – 9:00 am, 12:00 pm – 2:00 pm and 5:00 pm to 7:00 pm respectively. Hourly volumes ranged between 1,480 vehicles per hour to 2,681 vehicles per hour (refer to Figure 2).

8.3 Research methods

8.3.1 Experimental setup for the impact study

The installation of equipment was done after the site had been selected. The equipment used for collecting the data for this study was by video camera. Figure 3 shows the layout for setup of the impact study throughout the roadway section for every site location. The camera was installed at two places for each site, i.e. Camera A and Camera B. Camera A was placed on the approach driving direction of Kluang to Batu Pahat facing the merging section of the U-turn facility whereas Camera B was placed on the approach driving direction of Batu Pahat to Kluang facing
the merging section of the U-turn facility. The distance of the camera setup location to the U-turn and its merging section was 50 meters. For the traffic flow data collection, sets of data was taken during peak hours and off-peak hours.

The two cameras were placed before and after the merging section approximately 50 meters after the U-turn facilities. At this distance, the cameras were able to record the U-turning vehicles as well as the vehicles on the inner lane, before, at and after the merging sections. The cameras were placed on the road shoulder, hidden from the view of drivers in order to avoid driver distraction which would affect their normal driving behaviour.

![Fig. 3 Experimental setup for video observations](image)

**8.3.2 Traffic flow theory**

Macroscopic and microscopic parameters are commonly used to characterise traffic flow as a whole, as well as characterise the behaviour of individual vehicles in the traffic stream with respect to each other. The three principal macroscopic parameters that describe traffic flow in any roadway are volume (or rate of flow), density and speed [4]. These three parameters are described by the operational state or the actual condition of the traffic stream of a stream of a roadway and have been mentioned in previous studies [5].
Speed, flow, and density are all related to each other. Under the uninterrupted flow condition, flow, $q$ (vehicles per hour) is the product of speed, $v$ (kilometers per hour) and density, $k$ (vehicles per kilometer), i.e. $q = vk$. The flow is equal to zero when one or both of these terms (speed or density) is zero. It is also possible to deduce that the flow is maximised (i.e., the capacity of the roadway is reached) at some critical combination of speed and density.

### 8.3.3 Regression analysis

After obtaining the traffic flow parameters, the data sets were further analysed using SPSS software. The Curve Estimation method under the Regression Analysis function was applied in this study. Regression analysis is basically a statistical process for developing association among variables, in the case of this study, the variables were speed, flow and density.

Regression analysis is usually conducted for one of two purposes; to predict the value of the dependent variable based on information concerning the explanatory variables is available, or to estimate the effect of some explanatory variables on the dependent variable [6].

The Curve Estimation method was employed in order to obtain the best fit curve for the flow models. This is based on the assumption that the relationship between the variables may not necessarily linear, but could also be explained by either exponential, logarithmic or power models.

The coefficient of determination, $R^2$ is a measure of the amount of variability in the data accounted for by the regression model. It is the ratio of the regression sum of squares to the total sum of squares. The value of $R^2$ is typically between 0 and 1. If the value of $R^2$ is 0, this means there is no relationship between the two variables tested. A value of 1 means that the developed model is a perfect fit. Thus, this study aims to achieve $R^2$ values closer to 1.

The F-test and t-test were used to determine whether the regression model and its independent variables were significant. The testing of the
significant F-value (Sig. F) and the t-statistic values (t-stat) were conducted. Statistical significance is indicated when the calculated Sig. F and t-statistic is larger than the critical F-value and t-value, or the p-value is equal to or smaller than the significant value, $\alpha$ of 0.05 at a level of confidence of 95%.

8.4 Results and discussion

8.4.1 Speed-density and speed-flow models

The speed and density relationships were found to be best explained by exponential models. The speed-density ($v-k$) models were developed for both peak and off-peak hours at U-turn facilities along Jalan Batu Pahat - Kluang, as shown in Table 1.

<table>
<thead>
<tr>
<th>Period</th>
<th>Equation</th>
<th>$R^2$</th>
<th>Sig. F</th>
<th>t-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off-Peak</td>
<td>$v_{off\text{-peak}} = \frac{98.03}{\exp(0.0184k)}$</td>
<td>0.864</td>
<td>0.000</td>
<td>39.19</td>
</tr>
<tr>
<td>Peak</td>
<td>$v_{peak} = \frac{109.53}{\exp(0.0258k)}$</td>
<td>0.859</td>
<td>0.000</td>
<td>38.91</td>
</tr>
</tbody>
</table>

Note: The models were significant (Sig. F < 0.05)
The coefficients were also significant (t-stat > t critical = 1.990)

Based on the speed-density models, speed-flow models can therefore be developed as shown in Table 2. It can thus be concluded that the capacity (maximum flow) of the U-turn merging section during off-peak period is 2,527 vehicles per hour with an optimal speed of 40.1 km per hour. As expected, there was a 46.3% drop in capacity during the peak period. The capacity constricts to 1,358 vehicles per hour with an optimal speed of 30.1 km per hour.
When analysed separately, each individual U-turn facility that was studied in this research demonstrated different results. This comes to show that transport facilities do not necessarily replicate traffic flow characteristics of another, unless traffic conditions and geometric layouts are similar.

Capacity drops were higher at Site B (near the BHP petrol station), compared to Site A (near Kolej Kemahiran Teknologi MARA) and Site C (near SMK Seri Gading), as can be seen in Table 3. This was due to the higher trip attraction to the area surrounding Site B, which includes a residential area, commercial centers, a college and a petrol station.

<table>
<thead>
<tr>
<th>Site</th>
<th>Capacity drops, in vehicles per hour (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kluang – Batu Pahat</td>
</tr>
<tr>
<td>A</td>
<td>1,890 (8.4 %)</td>
</tr>
<tr>
<td>B</td>
<td>1,643 (20.3 %)</td>
</tr>
<tr>
<td>C</td>
<td>1,743 (7.1 %)</td>
</tr>
</tbody>
</table>
8.5 Conclusion

The findings from this study show a distinct relationship of between speed and density, and flow and speed at U-turn merging sections, as yielded from the regression models developed. The relationships were best explained using exponential functions as opposed to the conventional linear models. These models enabled the researchers to make estimations of capacity drops that were expected to occur when transitioning from off-peak periods to peak periods. A drop in capacity as high as 46.3% was predicted, while site specific capacity drops ranged between 6.2% to 21.2%. It can therefore be concluded that U-turn facilities provided on multilane highways may seriously affect the capacity of the traffic flow involving the main stream through traffic, thus causing delays and congestions during peak hours.

References


