Derivation Of A Reliable And Consistent Volume Delay Functions For Town Road Network Based On Users Feedback

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**ABSTRACT**

Volume delay function (VDF) of a road network is one of the key elements when running trip assignment in traffic modeling exercises. Often the modeler opts to adjust the tedious road network and trip matrices models while keeping the VDF constant although the later was merely adopted from prevailing database without making effort to review its validity. Adjusting the VDF is time consuming and a modeler really has to be familiar with the study area road network and experience driving on every road during peak and off peak hours. Furthermore the results are still subjected to variations due to time and day difference even for a team of well-trained numerators. As such there seem to be an opportunity to get simultaneous responds say during AM peak hours from a comprehensive users’ feedback survey. This paper presents the methodology on deriving VDF for a town road network based on users’ feedback and compare the validity of the study approach with various VDF models such as Spiess’s conical volume function, Singapore model, the Indonesian Highway Capacity Manual (MKJI) volume delay function and the well-known US Bureau of Public Road (BPR) function.

**1. Introduction**

There are various types of Volume Delay Function (VDF) models such as US Bureau of Public Road (BPR) function, Indonesian Highway Capacity Manual (MKJI) VDF, Spiess’s Conical VDF and other VDF models can be used in running the trip assignment but the compatibility with the study area is important in getting the result that close to the actual condition.

Different towns have a different type of road network and traffic pattern, that's why modeler must choose the right VDF model to be used. Indonesian case for example Irawan, Sumi&Munawar (2020) had shown that the Indonesian Highway Capacity Manual (MKJI) VDF is more suitable with Yogyakarta’s traffic condition instead of the BPR VDF. Meanwhile a study by Davis &Xiong (2007) on comparative analysis of the BPR function, Singapore Model, Conical VDF, Skabardonis-Dowling model and Highway Capacity Manual (HCM) formula found that the Skabardonis-Dowling model is most compatible for the Minneapolis’s road network.

Due to the compatibility issue that mentions above, this paper will suggest the methodology that can be used in deriving the most suitable VDF for Malaysia road network (in this case study, Kuantan Town). Note that, Kuantanas shown below is the State Capital of Pahang and the 9th largest town in Malaysia with population in 2010 of 461,906 (Wikipedia2012).

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The following section will describe and compare where applicable the four leading VDF models namely the Indonesian Highway Capacity Manual (MKJI) volume delay function, Singapore model, Spiess’s Conical VDF and BPR function.

2.1. Indonesia Highway Capacity Manual (MKJI) VDF

Irawan, Sumi and Munawar (2010) in their study concluded that MKJI VDF is closer to actual condition as compared to BPR function since MKJI VDF considers the local road network time of delay, road characteristic and its free flow speed while BPR function ignore the time of delay and assume uniform road type. Procedure used in the study to determine the most suitable VDF function for Yogyakarta is illustrated in Figure 2.

![Figure 2: Procedure used to determine the most suitable VDF for Yogyakarta, Indonesia (Irawan, Sumi, & Munawar, 2010)](image)

The practical capacity formula, \( c \) is derived in equation 2 below.

\[ c = C_0 \left( F_{W} F_{SP} F_{SF} F_{CS} \right) \]

Where,
- \( C_0 \): free flow capacity in pcuh,
- \( F_{W} \): link width capacity factor,
- \( F_{SP} \): link separated capacity factor,
- \( F_{SF} \): side friction capacity factor, and
- \( F_{CS} \): city size factor.

The free flow speed formula, \( s \) is derived in equation 3 below.

\[ s = (S_0 + F_{SF}) \cdot F_{W} \]

Where,
- \( S_0 \): basic free flow speed in kmh,
- \( F_{W} \): effective width factor,
- \( F_{SF} \): side friction factor, and
- \( F_{CS} \): city size factor.

2.2. Singapore Model

Xie, Cheu & Lee (2001) separated the link travel time into two categories: the cruise time and the signal delay. Loop detectors are used to calculate the cruise time while the Webster formula is used to calculate the signal delay. They run the Singapore model with INTEGRATION Version 2.0 in order to get the average moving speed of vehicles on a link. Equations 4, 5 and 6 illustrates the Singapore model.

\[ TT = \text{Cruise time} + \text{Signal delay} \]

\[ \text{Cruise time} = \frac{1}{FFS} \]

\[ \text{Signal delay} = \frac{q}{x} \left[ \frac{2(1-x)^2}{S \cdot \lambda} + \frac{x^2}{S \cdot \lambda} \right] \]

Where,
- \( TT \) = Predicted mean travel time,
- \( FFS \) = Free Flow Speed,
- \( S \) = Cycle length in seconds
- \( \lambda \) = Effective green proportion (g/C),
- \( x \) = Volume/capacity ratio (0 ≤ x < 1), and
- \( q \) = arrival rate (veh/second).

2.3. BPR Function

This function was developed by US Bureau of Public Road (BPR) and it is commonly used in traffic assignment. The BPR function equation can be defined as:

\[ T = T_0 \left[ 1 + \alpha \left( \frac{v}{c} \right)^\beta \right] \]

where,
- \( T \) : travel time in minutes,
- \( T_0 \): free flow travel time in minutes,
- \( \alpha \) and \( \beta \) are the parameters
- \( \alpha \), \( \alpha_2 \) and \( \beta \) are the parameters
- \( T_0 \) : free flow travel time in minutes,
- \( v \) : traffic volume in pcuh,
c : practical capacity in pcuh, and
α and β are the parameters

2.4. Spiess’s Conical Volume Function

Meanwhile, Spiess’s conical volume function improved the BPR function and the equation can be expressed as shown below (Spiess, 1990).

\[
TT - FTT = \left[2 + \sqrt{\alpha^2 \left(1 - \frac{V}{c}\right)^2 + \beta^2 - \alpha \left(1 - \frac{V}{c}\right) - \beta}\right] (8)
\]

Where,
TT : predicted mean travel time in minutes,
FFT : free-flow travel time in minutes,
v : volume in pcuh,
c : capacity (possibly adjusted by green time/cycle length ratio),
α = positive number greater than 1, and
β = \frac{2\alpha - 1}{2\alpha - 2}

2.5 Malaysia VDF Models

To date, the best Malaysia VDF models is perhaps the one developed for the Highway Development Plan Study (HNDP, 2010) by Perunding Atur Sdn. Bhd. However, the model is consistent for rural and interurban road and highway only. For urban urban road and highway a study entitled Malaysia Urban Transport Plan (MUTP, 1995) is probably the best developed for Johor Bahru, Ipoh and Sungai Petani that represent all three sizes of city and town in Malaysia. Since then, model for traffic study had been adopting and adjusted according to local traffic condition such as the traffic model developed for Putra LRT, 1997. The adjustment to local conditions for VDF has been the practice by traffic consultants in the country based on HNDP and MUTP models until now. In some cases however, the model required adjustment beyond the acceptable limits and this trigger necessity for development new VDF base model particularly with the application of the Malaysia Highway Capacity Manual (MHCM, 2006).

3. Research methodology

The method use in this study as shown in Figure 3 is basically developed from MHCM and relevant functions from HNDP and MUTP models. Based on MHCM, the ideal saturation flow rate for Malaysia road condition is 1930 pcu/h-ln and this value is relatively higher than the value used in previous models (1800pcu/h-ln in HNDP and MUTP) in Table 1 and slight higher (at 2196 pcu/hr-ln) than that of MKJI.

![Image 1](image1.png)

![Image 2](image2.png)

![Image 3](image3.png)

![Image 4](image4.png)

**Figure 3:** The proposed flowchart for derivation of Kuantan Town VDF

<table>
<thead>
<tr>
<th>VDF Function</th>
<th>Road Category</th>
<th>Link Type No</th>
<th>Speed (kmh)</th>
<th>Capacity (pcuh/ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>fd1</td>
<td>Arterial</td>
<td>1</td>
<td>100</td>
<td>1800</td>
</tr>
<tr>
<td>fd2</td>
<td>Distributor</td>
<td>2</td>
<td>80</td>
<td>1500</td>
</tr>
<tr>
<td>fd3</td>
<td>Collector</td>
<td>3</td>
<td>60</td>
<td>1020</td>
</tr>
<tr>
<td>fd4</td>
<td>Local Road</td>
<td>4</td>
<td>40</td>
<td>750</td>
</tr>
<tr>
<td>fd5</td>
<td>Centroid</td>
<td>99</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

We are going to use EMME3 traffic modeling software to create the road network and run the trip assignment as per Figure 4.

![Image 5](image5.png)

**Figure 4:** The EMME3 core modeling framework (Inro, 2012)

All four VDF models described in Section 2 are going to be tested using local values for speed and capacity as per Table 1. The novelty of the study is that it employs user feedbacks to provide travel time information for critical links instead of the usually presumed travel time derived from the travel time calculation; t in hour = length in km per travel speed in kmh. The best model that suit the acceptance criteria will be recommended to be adopted as Kuantan Town VDF.

Zoning for the study area has been established at two levels: larger Kuantan Town and Town Centre levels as below. Both levels comprises of 21 internal and 9 external zones with a total of 558 links.
Validation for the trip assignment is based on the trial and error basis that compare the modeled and the counted traffic volume at strategic links as shown in Table 2.

Table 2: Trip assignment validation

<table>
<thead>
<tr>
<th>Node From</th>
<th>Link Name</th>
<th>Node To</th>
<th>Volume (vph)</th>
<th>% Diff</th>
</tr>
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<tbody>
<tr>
<td>100</td>
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The whole model is assumed to be validated once the difference between the modeled and the counted traffic volume at all stations converges to be less than or equal 5%. The whole modeling process might take a few more steps before we can comfortably say that the based year traffic model for Kuantan Town has been successfully established with a reliable and consistent VDF.

4. Initial Findings

A number of studies had been conducted using questionnaire surveys as to get feedbacks on the perceived level and the main cause of congestion for Kuantan Town. In the first phase of the study, 55 respondents consisting of Kuantan Municipal Council (MPK) Senior Staff, Public Work Department (JKR) Director, Deputy Director and Engineers, Kuantan Senior Traffic Police Officers, Hospital TengkuAmpuanAfzan (HTAA) Staff and traders in Kuantan town. The second phase of the study comprise 276 respondents from all strata of the public including the bus passengers and the taxi drivers. The study found that the major cause of traffic congestion in Kuantan town is due to delay at signalized junctions and limited parking space available at the town centre.

Zoning for the study area was also established at two levels: Kuantan Town and Town Centre levels as below. Both levels comprises of 21 internal and 9 external zones with a total of 558 links.

5. Conclusions

The current paper explains the proposed study to derive a reliable and consistent volume delay function (VDF) for town road network based on users feedback with Kuantan Town as the study case. Since every town has a unique traffic model, this study will help engineers and planners to produce better traffic data for a medium size town in Malaysia.
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References


