CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The first world motorcycle lane was constructed along the Federal Highway Route 2 in the early seventies, under World Bank Project. In early 1992, an extension of the track was carried out by the Project Lebuhraya Utara Selatan PLUS, under the government’s privatization schemes. This extension was part of the improvement programmed to the existing two-lane expressway connecting the Subang International Airport to the town of Shah Alam and Klang.

In November 1993, major sections of the lane were completed ahead of schedule and opened for public use. Nowadays, the exclusive motorcycle lanes can be found in Shah Alam Expressway, Butterworth-Kulim Expressway, Federal Highway, Guthrie Corridor Expressway, Putrajaya-Cyberjaya Expressway, Port of Tanjung Pelepas Highway and all major highways in Putrajaya.

The Federal Highway is well-known as the first expressway in Malaysia to have motorcycle lanes. However, the motorcycle lanes in the Federal Highway are known for its dangers towards motorcyclists, such as it being dark, narrow and poorly-maintained lanes and ramps, dangerous sharp corners, and the nature of the motorcycle lanes themselves to be vulnerable spots for robberies. It is due to the fact that the motorcycle lanes are originally intended for bicycle riders, with the design speed limit as low as 60 km/h.
The Federal Highway Route 2 (FHR2) is a 16-km upgraded expressway connecting Batu Tiga, Shah Alam, Selangor and Sungai Rasau, Klang, Selangor. It consists of 2 toll plazas and is connected to the Federal Highway. The Projek Lebuhraya Utara-Selatan Berhad (PLUS) is a main concession for this road. The official opening date was 11 May 1993 with 6-lane upgraded toll highway. Figure 2.1 shows the location plan of Federal Highway Route 2 from Subang Airport to 7 Legged Roundabout [5].

Figure 2.1: The location plan of Federal Highway Route 2
(Source: PLUS Expressways Bhd., Malaysia)
2.2 Current Scenario

In Malaysia, the total number of registered motorcycle is increasing from year to year. From the statistics of Road Transport Department Malaysia, it was reported that 441,545 motorcycles were registered in Malaysia, which represented 43.4% of total registered vehicles in year 2009 [6]. Table 2.1 shows the list of new registered vehicles in Malaysia (by type and state) for year 2009.

Table 2.1 : New Registered Motor Vehicles By Type And State, in Malaysia, 2009

<table>
<thead>
<tr>
<th>Year</th>
<th>Motorcycle</th>
<th>Motorcar</th>
<th>Bus</th>
<th>Taxi</th>
<th>Hire &amp; Drive Car</th>
<th>Goods Vehicle</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERLIS</td>
<td>3,320</td>
<td>1,158</td>
<td>10</td>
<td>2</td>
<td></td>
<td>31</td>
<td>36</td>
<td>4,569</td>
</tr>
<tr>
<td>KEDAH</td>
<td>32,851</td>
<td>13,850</td>
<td>17</td>
<td>38</td>
<td>31</td>
<td>933</td>
<td>504</td>
<td>48,211</td>
</tr>
<tr>
<td>PULAU PINANG</td>
<td>41,445</td>
<td>47,307</td>
<td>240</td>
<td>167</td>
<td>50</td>
<td>2,531</td>
<td>576</td>
<td>52,120</td>
</tr>
<tr>
<td>PERAK</td>
<td>42,357</td>
<td>32,099</td>
<td>96</td>
<td>11</td>
<td>1</td>
<td>2,224</td>
<td>1,152</td>
<td>78,040</td>
</tr>
<tr>
<td>SELANGOR</td>
<td>43,316</td>
<td>33,544</td>
<td>342</td>
<td>1,007</td>
<td>30</td>
<td>5,432</td>
<td>3,792</td>
<td>87,495</td>
</tr>
<tr>
<td>W. PERSEKUTUAN</td>
<td>72,646</td>
<td>48,213</td>
<td>694</td>
<td>2,066</td>
<td>1,924</td>
<td>7,764</td>
<td>5,139</td>
<td>272,373</td>
</tr>
<tr>
<td>NEGERI SEMBILAN</td>
<td>15,422</td>
<td>14,182</td>
<td>41</td>
<td>96</td>
<td>1</td>
<td>1,037</td>
<td>154</td>
<td>30,931</td>
</tr>
<tr>
<td>MELAKA</td>
<td>15,917</td>
<td>18,989</td>
<td>14</td>
<td>42</td>
<td>1</td>
<td>695</td>
<td>190</td>
<td>36,919</td>
</tr>
<tr>
<td>JOHOR</td>
<td>60,944</td>
<td>62,793</td>
<td>179</td>
<td>372</td>
<td>1</td>
<td>4,390</td>
<td>1,890</td>
<td>138,485</td>
</tr>
<tr>
<td>PAHANG</td>
<td>22,486</td>
<td>17,493</td>
<td>22</td>
<td>44</td>
<td>3</td>
<td>1,299</td>
<td>374</td>
<td>41,543</td>
</tr>
<tr>
<td>TERENGGANU</td>
<td>18,052</td>
<td>11,395</td>
<td>21</td>
<td>19</td>
<td>2</td>
<td>543</td>
<td>218</td>
<td>36,170</td>
</tr>
<tr>
<td>KELANTAN</td>
<td>23,000</td>
<td>15,575</td>
<td>36</td>
<td>6</td>
<td>1</td>
<td>999</td>
<td>217</td>
<td>42,732</td>
</tr>
<tr>
<td>SABAH</td>
<td>26,910</td>
<td>31,394</td>
<td>179</td>
<td>147</td>
<td>52</td>
<td>3,671</td>
<td>2,451</td>
<td>58,934</td>
</tr>
<tr>
<td>SABAWAK</td>
<td>29,947</td>
<td>35,276</td>
<td>88</td>
<td>73</td>
<td>26</td>
<td>3,159</td>
<td>2,203</td>
<td>70,772</td>
</tr>
<tr>
<td>Total</td>
<td>441,545</td>
<td>513,954</td>
<td>1,984,4110</td>
<td>2,135</td>
<td>34,731</td>
<td>18,986,404</td>
<td>1,017,361</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Road Transport Department, Malaysia)

The high percentage of registered motorcycles in Malaysia has shown that motorcycle is the most favourable transportation mode. There are many factors that contribute to this issue. Low cost of ownership and less fuel consumed per kilometre travelled of motorcycle compared to other modes is believed to be main reasons behind it. Besides that, poor quality and inadequate capacity of public transport facilities in Malaysia also contributes to why motorcycle has become the preferred mode choice for road users.

From the table 2.2, the number of nation’s population has increases steadily from 23,263,600 populations in 2000 to 27,900,000 population in 2009, a 19.9% increase. As one might expect, the total registered vehicles in Malaysia have also increased from 10,598,804 vehicles to 18,986,404 vehicles over the same period [7].
Table 2.2: General Road Accident Statistics in Malaysia

<table>
<thead>
<tr>
<th>Year</th>
<th>Registered Vehicles</th>
<th>Population</th>
<th>Length (KM)</th>
<th>Per 10,000 Vehicles</th>
<th>Per 100,000 Population</th>
<th>Per Billion VKT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>10,598,804</td>
<td>23,263,600</td>
<td>64,981</td>
<td>5.70</td>
<td>25.90</td>
<td>26.25</td>
</tr>
<tr>
<td>2001</td>
<td>11,302,545</td>
<td>23,795,300</td>
<td>64,981</td>
<td>5.17</td>
<td>24.60</td>
<td>23.93</td>
</tr>
<tr>
<td>2002</td>
<td>12,018,291</td>
<td>24,425,000</td>
<td>64,981</td>
<td>4.88</td>
<td>24.10</td>
<td>22.71</td>
</tr>
<tr>
<td>2003</td>
<td>12,819,248</td>
<td>25,050,000</td>
<td>71,814</td>
<td>4.88</td>
<td>25.10</td>
<td>22.77</td>
</tr>
<tr>
<td>2004</td>
<td>13,764,837</td>
<td>25,580,000</td>
<td>71,814</td>
<td>4.51</td>
<td>24.30</td>
<td>21.10</td>
</tr>
<tr>
<td>2005</td>
<td>14,816,407</td>
<td>26,130,000</td>
<td>72,400</td>
<td>4.18</td>
<td>23.70</td>
<td>19.58</td>
</tr>
<tr>
<td>2006</td>
<td>15,790,732</td>
<td>26,830,000</td>
<td>72,400</td>
<td>3.98</td>
<td>23.60</td>
<td>18.69</td>
</tr>
<tr>
<td>2007</td>
<td>16,812,440</td>
<td>27,190,000</td>
<td>74,603</td>
<td>3.73</td>
<td>23.10</td>
<td>17.60</td>
</tr>
<tr>
<td>2008</td>
<td>17,969,043</td>
<td>27,540,000</td>
<td>77,225</td>
<td>3.63</td>
<td>23.50</td>
<td>17.65</td>
</tr>
<tr>
<td>2009</td>
<td>18,986,404</td>
<td>27,900,000</td>
<td>0*</td>
<td>3.55</td>
<td>23.80</td>
<td>17.28</td>
</tr>
</tbody>
</table>

*The data has not been required.

(Source: Jabatan Keselamatan Jalan Raya, Malaysia)

An increment in overall population does not necessarily mean there will be more increasing for vehicle ownership. However, for Malaysia case, vehicle ownership increased accordingly from 2.19 persons per vehicle in 2000 to 1.47 persons per vehicle in 2009.

On the other hand, the fatality index per 10,000 registered vehicles has dropped from 5.70 in 2000 to 3.55 in 2009. The same downward trend is also seen on road deaths per 100,000 populations. In year 2000, it was recorded that 25.90 road deaths for every 100,000 population and seeing a small decrease to 23.80 road deaths per 100,000 population in year 2009 [8, 9, 10].

From the Malaysian Road Safety Plan 2006-2010, three targets to be achieved by 2010 are two deaths per 10,000 registered vehicles, ten deaths per 100,000 population and ten deaths per 1 billion Vehicle-Kilometer Travelled (VKT) [11]. However, these three targets may not be achieved by 2010 if this trend continues. While the road deaths in Malaysia are decreasing slowly, it is not as good as developed countries.
2.3 Motorcycles are a Part of Traffic

The study related to motorcycle offers a multiplicity of theoretical perspectives in term of identity, class, and gender [12]. In a search for literature that related to the motorcycle facility, the guidelines for geometric design of roads and the guidelines for cycle track that were published by the Public Work Department, Ministry of Works Malaysia seems to be the closest available information [13, 14]. Therefore, motorcycles are an accepted part of traffic and their safety deserves the same attention in the design and management of roads in Malaysia as does that of other road users (Pedestrians, bicyclists, etc). Motorcycles range from low power machines (70cc) to high performance machines (more than 1000cc).

While accepted as part of traffic, motorcycles have particular needs and problems which may not be widely recognized by those responsible for road planning, road design and traffic engineering and management.

While the needs of some other “special” road user groups, especially pedestrians, bicyclists, trucks and buses are gradually being acknowledged and their needs reflected in mainstream traffic engineering and management guidelines has not yet been the case for motorcyclists [15].

Under the Laws of Malaysia, Act 333, Road Transport Act 1987, a motorcycle is defined as motor vehicles with less than four wheels, and the unladen weight of which does not exceed four hundred and fifty kilogram’s. Besides that, a motorcyclist is defined as anyone who rides, drags, pushes or propel a two or three-wheeled motor vehicle along a road [16]. Motorcycles are not ‘fast bicycles’ due to:

a) Motorcycle handling characteristics are different from those of bicycles, especially with regards to speed and positioning of vehicles on traveled way

b) Motorcycles have their own power source, resulting not only in greater speed, but also in greater opportunities to negotiate differing traffic conditions

c) Motorcycle riders are licensed and as such, are allowed on every class of roads (including expressways)

d) Motorcycles are motor vehicles, registered for on-road use.
Besides that, under the Laws of Malaysia, Act 333, Road Transport Act 1987 also, no person under sixteen years of age shall drive a motor vehicle on a road [16]. Riders range from those who are recently licensed to well experienced mature riders (normally riding the bigger capacity motorcycles in the urban areas) and inexperienced mature riders (normally riding smaller capacity motorcycles in the rural areas with little knowledge and or respect of traffic rules and road safety) [17, 18, 19]. Figure 2.2 presents the various type of motorcycle in Malaysia.

Figure 2.2 : Various Type of Motorcycle in Malaysia
2.4 Types of Motorcycle Lane Facilities

In a study related to design of a motorcycle lane [15], it was stated that there are three types of motorcycle lane facilities available in Malaysia such as an exclusive motorcycle lane, an inclusive motorcycle lane and a non-exclusive motorcycle lane.

2.4.1 Exclusive motorcycle lane

This type of motorcycle lane is a complete separate right-of-way established for the sole use of motorcyclists as shown in figure 2.3. This motorcycle lane is defined as a roadway meant exclusively separates motorcyclists from other motorist and normally has a wide right-of-way. It is not developed from an existing carriageway of a wide road. It is noted that all motorcyclists are compelled by law to use it and other vehicles are prohibited by law from use it. Such lane helps in reducing conflicts at crossing an intersection with the provision of underpasses and other related facilities. The width of an exclusive motorcycle lane is normally in the range of 2.0m to 3.5m.

Figure 2.3 : An Exclusive Motorcycle Lane.
2.4.2 Inclusive motorcycle lane

Inclusive motorcycle lane is popular in Malaysia road as shown in figure 2.4. It is developed within the carriageway of an existing road and usually sited on the left hand side of a road where motorcycles are encouraged / required to use while riding along a road. Some form of physical barrier or pavement marking define the corridor that is set aside for motorcyclists and route marking are necessary to define the route and reduce potential conflicts. However, at crossings and intersections, this kind of motorcycle lane ceases as an exclusive lane and conflicts may occur with other modes of transport.

Figure 2.4 : An Inclusive Motorcycle Lane.
2.4.3 Non-exclusive motorcycle lane

Another type of motorcycle lane is non exclusive motorcycle lane as shown in figure 2.5. It is defined as the extra lane or verge or marginal strip on the left hand side of a road where motorcycles are encouraged/required to use while riding along a road. A non exclusive motorcycle lane is a paved shoulder which does not have designated pavement marking and barrier. This lane provides space for motorcyclists but they have to share the space with other motor vehicles.

Figure 2.5 : A Non Exclusive Motorcycle Lane.
2.5 Design of Motorcycle

In a study related to design of motorcycle characteristics [15], it was stated that the design motorcycle – vehicle is represented by the low-to-medium sized motorcycles (less than 250 c.c.) which were found to be the types of motorcycle most commonly used in Malaysia. The side and front view of this design motorcycle vehicle are shown in figure 2.6 and figure 2.7 respectively. The length and width of the motorcycles and the height of the average motorcyclist are major factors that affect the practical capacity when designing facilities for motorcycles [20, 21].

Figure 2.6 : Design of Motorcycle (less than 150c.c.) – Side view

Figure 2.7 : Design of Motorcycle (less than 150 c.c.) – Front view
2.5.1 Static Space of Motorcycle-Rider Unit

Figure 2.8 and figure 2.9 showed the simplified outline and dimensions for a single motorcyclist. The physical breadth is 0.8 m while the length is 2.0 m. The total area of $1.60m^2$ (0.8 m x 2.0 m) is the physical space occupied by a static motorcyclist. Note that these figures represented a typical motorcycle with side-mirrors on both sides, and representing a maximum width.

Figure 2.8 : Front Outline of a Static Motorcyclist - Breadth of 0.8 m

Figure 2.9 : Side Outline of a Static Motorcyclist - Length of 2.0 m
2.5.2 Motorcyclists Side-by-Side Operating Space

The value of the separation distances of side-by-side motorcyclists is 0.50m. Besides that, the speed of motorcycle along the motorcycle lane is 70km/hr and the flow rate along the motorcycle lane is 1200 motorcycles/hr/lane. The side-by-side motorcyclists’ separation is illustrated as in figure 2.10.

Figure 2.10 : Side-by-Side Motorcyclists Separation Distance of 0.50 m
2.5.3 Operating Space of a Single Motorcyclist

The mean operating width required by a single motorcyclist is 1.3m and as illustrated in figure 2.11. Besides that, the eye level for motorcyclist is 1.43m and the total height of motorcyclist is 1.56m.

Figure 2.11 : Mean Operating Width of 1.3 m Required by a Motorcyclist
2.6 Macroscopic Models

Macroscopic stream models represent how the behavior of one parameter of traffic flow changes with respect to another. Most important among them is the relation between speed and density. The four commonly used macroscopic models are the Greenshield’s Model, Greensberg Model, Underwood Model and Drake et al. Model [22, 23, 24].

A Linear Density relationship is given by :-

\[
\begin{align*}
  u &= u_f - \frac{u_f}{k_j} k \\
  \text{(2.1)}
\end{align*}
\]

where :-

\[
\begin{align*}
  u &= \text{Speed} \\
  u_f &= \text{Free flow Speed} \\
  k &= \text{Density} \\
  k_j &= \text{Jam Density}
\end{align*}
\]

From the above relationship, free-flow speed is defined as the theoretical speed of traffic when density is almost to zero. The optimum speed, or so-called critical speed, refers to speed when the maximum flow rate is achieved. The corresponding density at this condition refers to optimum or critical density. The jam density represents the density at which all movements in a traffic stream stop.

Substituting U from the general equation of a traffic stream,

\[
\begin{align*}
  \frac{q}{k} &= u_f - \frac{u_f}{k_j} k \\
  \text{(2.2)}
\end{align*}
\]

where :-

\[
\begin{align*}
  u &= \frac{q}{k} \\
  q &= \text{Density value} \\
  k &= \text{Density at that instant}
\end{align*}
\]
Interchanging the relationships between the variables velocity, flow and density by successive elimination of one of these variables, we find that as the flow increases, density increases and the speed decreases. At optimum density, flow becomes maximum value. In other words, as the speed increases from zero, flow increases from zero until it becomes $q_m$ (maximum density) at $u = u_f / 2$ and $k = k_j / 2$.

Hence;

\[
q_{\text{mix}} = \frac{\sigma f}{k}
\]  \hspace{1cm} (2.3)

where :-

- $q_m =$ Maximum Density
- $u_f =$ Freeflow Speed
- $k_j =$ Jam Density

Highway capacity manual and all traditional codes use this sets of equations. However practical field data does not follow this relationship accurately. Hence a number of theoretical models have cropped up over the past six decades. Earlier models assumed a single regime that would include a gamut of flow conditions.
2.6.1 Greenshield’s Model

Greenshield’s Model was able to develop a model of interrupted traffic flow that predicts and explains the trends that are observed in real traffic flows. While this model is not perfect, it is fairly accurate and relatively simple.

Greenshield’s made the assumption that, under uninterrupted flow conditions, speed and density are linearly related. In the other term, speed is a linear function of density. Free-flow speed and jam density are required to estimate speed. This relationship is expressed mathematically and graphically below.

\[ u = u_f - \frac{u_f}{k_j} k \]  

(2.4)

where :-

\[ u = \text{Velocity at any time (kilometres/hour)} \]
\[ u_f = \text{Freeflow Speed (kilometres/hour)} \]
\[ k = \text{Density at that instant (vehicles/kilometre)} \]
\[ k_j = \text{Jam Density (vehicles/kilometre)} \]

This is normally done by collecting velocity and density data in the field, plotting the data and then using linear regression to fit a line through the data points. Greenshield’s assumed a linear speed-density relationship as illustrated in figure 2.12 to derive the model. It indicates that when density becomes zero, speed approaches free flow speed.
Over the relation between speed and flow established, the relation between flows can be derived. This relation between flow and density is parabolic shape and is shown in figure 2.13. Also, as known that,

$$q = k \cdot v$$  \hspace{2cm} (2.5)

Now, substituting equation 2.4 in equation 2.5,

$$q = u_f \cdot k - \frac{u_f}{k_f} \cdot v^2$$  \hspace{2cm} (2.6)

Similarly, we can find the relation between speed and flow. For this, put $$k = \frac{q}{v}$$ in equation 2.4 and solving,

$$q = k_f \cdot v - \frac{k_f}{v_f} \cdot v^2$$  \hspace{2cm} (2.7)

This relationship is again parabolic and is shown in figure 2.14. Once the relationship between the fundamental variables of traffic flow is established, the boundary condition can be derived. The boundary conditions that are of interest are jam density, free flow speed and maximum flow.
To find density at maximum flow, differentiate equation 2.6 with respect to k and equate it to zero, ie.,

\[ k = \frac{k_f}{2} \]  

(2.8)

Denoting the density corresponding to maximum flow as \( k_{d} \),

\[ k_{d} = \frac{k_f}{2} \]  

(2.9)

Therefore, density corresponding to maximum flow is half the jam density. Once get \( k_d \), it can derive for maximum flow, \( q_{\text{max}} \). Substituting equation 2.9 in equation 2.6,

\[ q_{\text{max}} = \frac{v_f \cdot k_f}{4} \]  

(2.10)

Thus, the maximum flow is one fourth the product of free flow and jam density. Finally, to get the speed at maximum flow, \( v_0 \), substitute equation 2.8 in equation 2.4 and get,

\[ v_0 = \frac{v_f}{2} \]  

(2.11)

Therefore, speed at maximum flow is half of the free speed.
2.6.2 Greensberg’s Model

Several researchers have used the analogy of fluid flow to develop macroscopic relationships for traffic flow [25, 26, 27]. Greensberg Model is a non-linear model where a hydrodynamic analogy is combined with equations of motion in mechanics.

Greenberg assumed a logarithmic relation between speed and density. The main of drawbacks of this model is that as density tends to zero, speed tends to infinity. This shows the inability of the model to predict the speeds at lower density. Figure 2.15 presents average speed versus density.

The velocity is governed by :-

\[ u = u_o \ln \frac{k_j}{k} \] \hspace{2cm} (2.12)

where :-

\( u \) = Speed at any time (kilometer/hour)
\( u_o \) = Optimum speed (kilometer/hour)
\( k_j \) = Jam Density (vehicles/kilometer)
\( k \) = Density at that instant (vehicles/kilometer)

Figure 2.15 : Speed vs. Density by Greenberg Model
2.6.3 Underwood Model

*Underwood Model* was a new single regime model proposed to account for the problem of free-flow reaching infinity value during free flow condition in the Greensberg Model. The main drawback of this model is that speed becomes zero only when density reaches infinity. Hence, this model cannot be used for predicting speeds at high densities. Figure 2.16 presents average speed versus density for Underwood Model.

According to this theory,

$$u = u_f e^{-(k/k_o)}$$

(2.13)

where :-

- \(u\) = Speed at any time (kilometer/hour)
- \(u_f\) = Free flow speed (kilometer/hour)
- \(k_o\) = Optimum density (vehicles/kilometer)
- \(k\) = Density at any time (vehicles/kilometer)

![Figure 2.16: Speed vs. Density by Underwood Model](image)
In the car-following model, by formulating the acceleration of each following vehicle with the leading vehicle, interrelationships between levels of speed–density states are derived. The acceleration of following vehicles is represented by a nonlinear differential equation in which the variables are the speeds of the following vehicles and their headway, as measured by, for example, distances between vehicles.

The model generates the various speed–density functions referred to Underwood Model in the form of the combinations of values taken by the exponents on the variables.

Underwood Model and Drake et al. Model were developed to solve the disadvantage of the Greenberg Model by introducing an exponential speed – density form. The disadvantage of the Greenberg model is that when density approaches zero, free-flow speed increases toward infinity. Both Underwood Model and Drake et al. Model require the knowledge of free-flow speed and optimum density.

Although these models are appropriate for low densities, the disadvantage lies at high densities, where speed asymptotically approaches zero but never actually reaches it. Hence, a maximum flow rate or capacity is needed to be independently assumed or observed.

In term of measurement, jam density is difficult to observe and the estimation of optimum speed is not easy, making the Greenshield’s and Greenberg Models unfavorable. The optimum density is also difficult to obtain in the Underwood and Drake et al. Model. However, the free flow speed can be readily measured.
2.6.4 Drake et al. Model

Drake et al. Model proposed a similar model in the form of the half bell-shaped curve model. This model was investigated in an important empirical test then forms a speed-density curve as below. The measure data consists of volume, time mean speed and occupancy. The density was calculated from volume and the time mean speed.

The time mean speed is governed by :-

\[ u = u_f e^{-u_f k_o/k} \]  

(2.14)

where :-

\( u \) = Speed at any time (kilometer/hour)
\( u_f \) = Time mean speed (kilometer/hour)
\( k_o \) = Optimum density (vehicles/kilometer)
\( k \) = Density at that instant (vehicles/kilometer)
2.7 LOS Designation for Motorcycle Lane

Similar to the vehicular traffic streams, the relationship between motorcycle speed and motorcycle density indicated that as motorcycle density increases, motorcycle speed decreases. In a study related to the capacity for uninterrupted motorcycle path, it was found that the motorcycle speed-flow-density relationships for the headway concept and space concept are analogous to vehicular traffic streams [28, 29].

For the headway concept, the motorcycle density is measured in mc/km/lane and table 2.3 and figure 2.17 shows the Level of Service for One-Way Exclusive Motorcycle Lane in Headway Concept.

Table 2.3 : LOS Criteria for One-Way Exclusive Motorcycle Lane (Headway Concept)*

<table>
<thead>
<tr>
<th>Level of Service</th>
<th>Density (mc/km/ln)</th>
<th>Expected Flows and Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average Speed (km/hr)</td>
</tr>
<tr>
<td>A</td>
<td>6</td>
<td>53</td>
</tr>
<tr>
<td>B</td>
<td>21</td>
<td>45</td>
</tr>
<tr>
<td>C</td>
<td>44</td>
<td>35</td>
</tr>
<tr>
<td>D</td>
<td>68</td>
<td>29</td>
</tr>
<tr>
<td>E</td>
<td>235</td>
<td>13</td>
</tr>
<tr>
<td>F</td>
<td>&gt; 235</td>
<td>&lt; 13</td>
</tr>
</tbody>
</table>

*Average conditions for 1 minute.

Figure 2.17 : LOS for One-Way Exclusive Motorcycle Lane (Headway Concept)*

*Average conditions for 1 minute.
For the space concept, the motorcycle density is measured in m²/mc and table 2.4 and figure 2.18 shows the Level of Service for One-Way Exclusive Motorcycle Lane in Space Concept.

Table 2.4: LOS Criteria for One-Way Exclusive Motorcycle Lane (Space Concept)*

<table>
<thead>
<tr>
<th>Level of Service</th>
<th>Space (m²/mc)</th>
<th>Expected Flows and Speed</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average Speed (km/hr)</td>
<td>Flow Rate (mc/hr/m)</td>
</tr>
<tr>
<td>A</td>
<td>295</td>
<td>65</td>
<td>221</td>
</tr>
<tr>
<td>B</td>
<td>69</td>
<td>46</td>
<td>662</td>
</tr>
<tr>
<td>C</td>
<td>33</td>
<td>36</td>
<td>1104</td>
</tr>
<tr>
<td>D</td>
<td>21</td>
<td>30</td>
<td>1435</td>
</tr>
<tr>
<td>E</td>
<td>6</td>
<td>13</td>
<td>2207</td>
</tr>
<tr>
<td>F</td>
<td>&lt; 6</td>
<td>&lt; 13</td>
<td>Variable</td>
</tr>
</tbody>
</table>

*Average conditions for 1 minute.

Figure 2.18: LOS for One-Way Exclusive Motorcycle Lane (Space Concept)*

*Average conditions for 1 minute.
2.8 Level of Service

A term closely related to capacity and often confused with it is service volume. When capacity gives a quantitative measure of traffic, level of service or LOS tries to give a qualitative measure. A service volume is the maximum number of vehicles, passengers, or the like, which can be accommodated by a given facility or system under given conditions at a given level of service [22, 23, 24].

Level of service (LOS) is graded on a letter scale from A to F. A being the highest level of service and F being the lowest. At LOS A, traffic flows freely, selecting desired travel speeds with ample passing opportunities. At LOS F, traffic flow is forced, the traffic volume has exceeded the capacity of the roadway to handle it and there are no passing opportunities. LOS D is generally considered to be the lowest tolerable level of service for roadways. Roadway designs attempt to operate at LOS D in only the worst case situations and preferably at higher levels of service.

2.8.1 Level of Service (LOS) A

LOS A is represents free flow. Individual users are virtually unaffected by the presence of others in the traffic stream. Freedom to select desired speeds and to maneuver within the traffic stream is extremely high. The level of comfort and convenience provided to the motorist, passenger or pedestrian is excellent. The driver only needs minimal attention.

2.8.2 Level of Service (LOS) B

LOS B is in the range of stable flow, but the presence of other users in the traffic stream begins to be noticeable. Freedom to select desire speeds is relatively unaffected, but there is a slight decline in the freedom to maneuver within the traffic stream from LOS A. The level of comfort and convenience provided is somewhat less than at LOS A, because the presence of others in the traffic stream begins to affect individual behavior. The comfort is excellent, as the driver simply needs to keep an eye on nearby vehicles.
2.8.3 Level of Service (LOS) C

LOS C is in the range of stable flow, but marks the beginning of the range of flow in which the operation of individual users becomes significantly affected by interactions with others in the traffic stream. The selection of speed is now affected by the presence of others, and maneuvering within the traffic stream requires substantial vigilance on the part of the user. The general level of comfort and convenience declines noticeably at this level. This is because the driver has a growing impression of being caught between other vehicles.

2.8.4 Level of Service (LOS) D

LOS D represents high-density, but stable flow. The speed and the maneuverability are severely restricted, and the driver or pedestrian experiences a generally poor level of comfort and convenience. Therefore, the road users must constantly avoid collisions with other vehicles. A slight increase of the traffic risks causing some operational problems and saturating the network.

2.7.5 Level of Service (LOS) E

LOS E represents operating conditions at or near the capacity level. All speeds are reduced to a low, but relatively uniform value. Freedom to maneuver within the traffic stream is extremely difficult, and it is generally accomplished by forcing a vehicle or pedestrian to “give way” to accommodate such maneuvers. Comfort and convenience levels are extremely poor, and driver or pedestrian frustration is generally high. Operations at this level are usually unstable, because even small increases in flow or minor perturbations within the traffic stream will cause breakdowns.
2.8.6 Level of Service (LOS) F

LOS F is used to define forced or breakdown flow in terms of unstable speed with the formation of waiting lines at several points. This condition exists wherever the amount of traffic approaching a point exceeds the amount which can traverse it and queues begin to form. Operations within the queue are characterized by stopping and starting. Over and over, vehicles may progress at reasonable speeds for several hundred feet or more, and then be required to stop. It should be noted, however, that in many cases once free of the queue, traffic may resume to normal conditions quite rapidly.

The rate of traffic service is the maximal hourly rate that can cross a point or a road section according to road, traffic and control conditions. Therefore, each road infrastructure has five traffic rates of service (the F level is not used because unstable). Traffic reports also use color codes to illustrate traffic conditions such as green (levels A and B), yellow (levels C and D) and red (levels E and F).
2.9 Semi-Automatic Video Analyser (SAVA) Software

Many researchers in the research works had used video recordings technique of traffic data collection. This technique had made data collection safer and efficient, and the researchers had developed models out from their studies.

Based on Jeffery Archer (2003), the Semi-Automatic Video Analyser (SAVA) program provides a basis for analyzing traffic film data. The program has been designed to interpret the information from digital films recorded in (*.avi) format and (*.mpeg) format. The basic functionality of the program includes being able to step forwards or backwards through the film one frame at a time using the media player controls, arrow keys or the mouse wheel [30].

The program has a timer or clock that keeps track of the relative position of the current frame in the film sequence in terms of time, thus each time the user moves one step forward the clock advances 40 milliseconds. The program also provides the possibility to change the timer in order that it can be synchronized with other sources of logged data. Figure 2.19 shows the illustration of Semi-Automatic Video Analyser (SAVA) Program.
The main function of the program involves the use of virtual lines that can be placed on the screen by the user to log event times for road users. Each time a road user reaches a virtual line, the event can be registered by either clicking on the line representing the virtual line, or clicking on the box in the application. This will result in an event time entry into a log file that consists of the current film time, the virtual line number, the road user type and the road user identification number.

The resulting information from SAVA program analysis can cover 100% of all road users and possible to establish the origin and destinations of all road users. The program generates a text-file (ASCII-file) that includes one row for each event for all vehicles in a chronological order. In order to establish more useful statistical data further processing is required using a statistical package such as Microsoft Office Excel or SPSS.

Basically, figure 2.20 shows the process and sequence of video-captured technique employed in one of the study undertaken related to flow measurement at the Federal Highway, Route 2, where the exclusive motorcycle lane is located. Suitable site was identified that suite the criteria specified in the study was selected. The equipments that were used in the study were video camera with its accessories, computer for data recording and retrieval, and data reduction software.
An exclusive motorcycle lane

Fieldwork Video-Captured

Video-capture in AVI format

Using SAVA Software

Result and Analysis

Figure 2.20: Method of Data Collection using Video-Capture Technique