Model Calibration for Traffic Streams with Motorcycles

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This Study was concerned with successful calibration and validation traffic streams with large volumes of motorcycles. The assessment involved developing suitable passenger car equivalents (pce) for the motor cycles in order to successfully undertake calibration and validation of a micro-simulation model. The use of motor cycles for driver and passenger transport is becoming more prevalent in many developing economies as travel demands increase but are not satisfied with the regular modes of transportation. Application of modelling methods to analyze such streams necessitates a good understanding of those characteristics and developing approaches to quantify and take them into consideration.

The assessment was undertaken on an 8 km arterial road section in Kampala Uganda in East Africa as part of a feasibility and preliminary design study. Motorcycles are estimated to account for 10 to 15% of all travel in Kampala City and their proportion in the traffic stream within the Study area ranged from 30 to 40%. The motorcycles exhibit physical and operational characteristics that are not supported by the common micro-simulation models. They are small in size in comparison to private cars and trucks, and are able to manouvre through traffic queues, thereby experiencing less delays than the other vehicles. Because they also tend to congregate inform of stop lines, they depart faster and typically achieve higher saturation rates than the rest traffic. Modelling traffic streams containing large volumes of motorcycles therefore poses challenges and it becomes imperative to assess and quantify those characteristics in order to calibrate and validate the model successfully.

The study involved normal traffic modelling tasks including data collection, and model development. Data collection included volumes counts at intersections and roadway sections. Travel time and speed measurements were also undertaken using GPS equipment. A model of the arterial section was developed using the Paramics micro-simulation model. The assessment involved assigning different pce values to motorcycles and undertaking simulations runs for each scenario. As part of the calibration and validation process, the results for each run were summarized and compared to observed data The volume comparisons were undertaken using the GEH static which is a modified Chi squared test while the travel times /speeds were compared using the least squares approach. The optimal pce value for motorcycles in the Study Area was determined as the one that provided the best results on the basis of the comparisons.

The results show that for the traffic stream within the Study Area, a pce value of 0.35 to 0.40 was the most suitable for motorcycles. Application of this pce value resulted in successful model validation. This analysis shows that model calibration and validation needs to take into consideration unique characteristics of the Study Area which may often involve supplementary analysis.

1.   Introduction

Use of motorcycles and their derivatives is increasing rapidly in many parts of the world and especially in developing countries where they comprise a significant proportion of the traffic streams. Application of the common microsimulation models to traffic streams containing such vehicles has been largely unsuccessful as noted by many researchers and practitioners. The reason for that is primarily because the model assumptions do not reflect the actual operations and vehicular interactions in such streams. One reason for these shortcomings is thought to be the fact that these models are based mainly on homogenous lane-based flows of standard vehicles and are consequently deficient in handling various vehicle types with unconventional behavior. Secondly, it is thought that they barely consider stream dynamics in enough detail to take into account their impacts on the overall stream flow.

Although innovative models that consider non-lane based travel have been developed for analysing such streams, and those models have remained primarily academic and have not found wide spread application as do the ones commonly available. Spatial modelling targeting especially pedestrian and non-motorized traffic has also advanced and is now commercially available, but consideration of motorcycles and their derivatives in the main traffic stream has not found substantial consideration.

Application of modelling to traffic streams with motorcycles therefore requires careful consideration and calibration. A simple method is to use suitable passenger car equivalence of motorcycles. However the primary question is how to determine what pce value is appropriate for a particular traffic stream.

1.1   Study Objectives

The overall Study objective was to successfully calibrate and validate a micro-simulation model for traffic streams with high proportions of motorcycles. The specific objective as part of the calibration process was to determine the most suitable passenger car equivalence of motorcycles within the Study area.

The Study process therefore involved iteratively undertaking micro-simulation modelling with traffic demands assuming various passenger car equivalent factors for motorcycles. The actual study steps are described in the sections that follow.

2.   Study Area Characteristics

2.1   Study Area

The Study was undertaken along Kibuye, Busega to Masaka (KBM) arterial road in Kampala City in East Africa. **Figure 1** shows the location of the Study Area. The road runs east-west for approximately 7 km from Kibuye Roundabout to Busega Roundabout and includes eight intersections within the section.

The KBM Road is a two lane road classified as an urban arterial serving the east-west demands within the southern part of the City. There are extensive road side road activities which lead to encroachment and congestion. The intersections are controlled by either traffic police or through unsigned priority rules.

Figure 2 shows photos of the roadway environment at two locations.

Figure 1: Study Area

Figure 2: The Masaka Road Corridor Environment

2.2   Traffic Data Collection and Characteristics

Actual traffic volume surveys were undertaken in 2012 and involved mid-block and turning movement volume counts. Travel time surveys were also undertaken using GPS equipment mounted on floating cars. Since the overall Study involved both demand forecasting and micro-simulation modelling, additional data such as cordon counts. All counts were conducted for 12 hours between 07:00 hrs and 19:00 hrs on each day. Additional counts were undertaken in November to complement the previously obtained data. **Table 1** provides details of the traffic surveys while **Figure 3** shows the count locations.
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Table 1: Traffic Survey Details

Count Type	Details
Classified Mid-block counts	Undertaken on a total of 40 roadways sections located on 9 screen line locations
Turning Movement Counts	Undertaken at 8 intersections on Masaka Road between Kibuye and Busega
Plate Trace Surveys	Undertaken at the Kibuye Roundabout and Busega Roundabout
Travel Time Surveys	Undertaken using GPS on KBM corridor as well along the Entebbe Highway

Figure 3: Typical AM Peak Hour Traffic Volumes
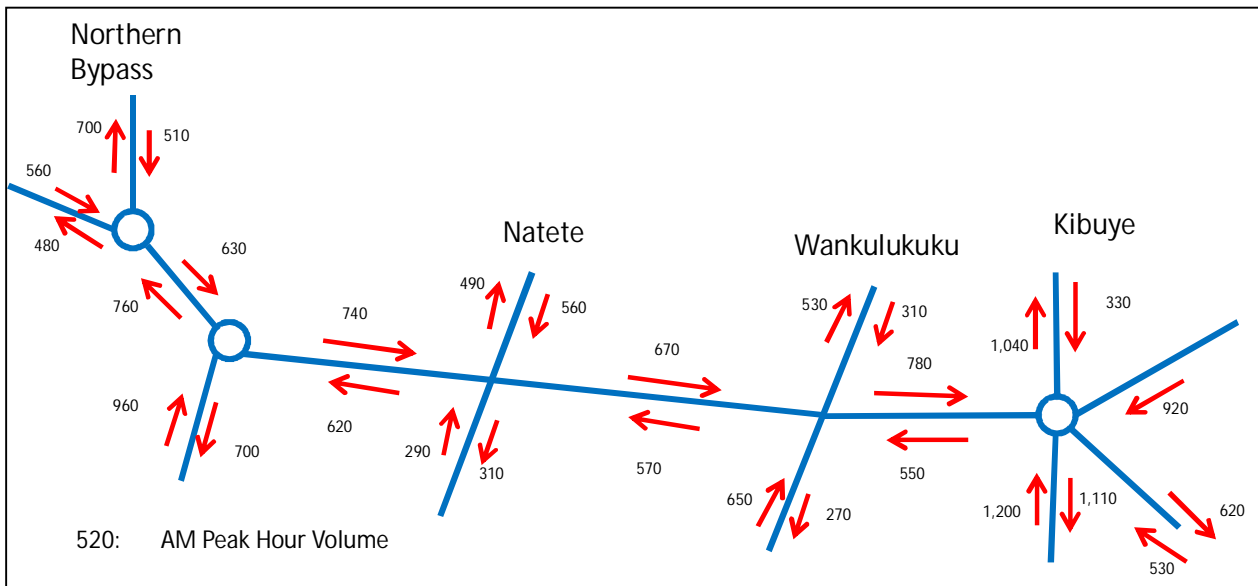
Traffic composition in the Study area was comprised of a high proportion of motorcycles as shown in **Figure 4**. Typically, motorcycles form the largest single type of vehicles in the traffic with 38% within the core KBM corridor and 43% in the entire Study Area. Cars pick ups and vans come second closely followed by para-transit vehicles (*matatus*). Heavy goods vehicles (HGV) comprised the smallest part with only 1% within KBM and 2% in the entire area. The figure indicates that there is a higher proportion of cars and matatus using the KBM corridor than the City average.

Figure 4: Traffic Compositions with Motorcycles.
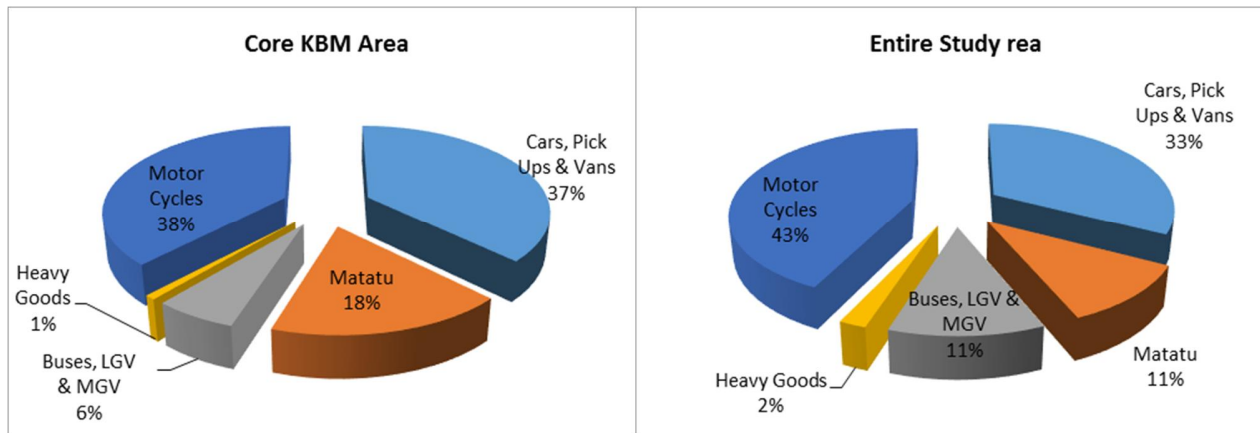
Travel time studies were also undertaken using Global Positioning System (GPS) units mounted on floating vehicles. Several floating car runs were undertaken along the KBM Road recording travel time and instantaneous speeds during the peak and non- peak periods. The average travel speeds in individual sections ranged from 15 to 30 km/h with overall speeds of 15.6 km/h in the EB direction, and 21.7 km/h in the westbound direction corresponding to travel times of respectively 27.2 minutes and 19.7 minutes respectively.

3.   Modelling Approach

3.1   Model Development

Traffic operations analysis was undertaken using the Paramics Micro-Simulation Model. The model covered KBM sections from Kibuye Roundabout to Busega Roundabout including all the crossing roads over a total length of 7 km. The model development involved coding the road network including intersection layout, lane configurations and intersections including roundabouts as illustrated in **Figure 5**.

The model was developed to include the observed network features as well as the traffic characteristics that were obtained from the surveys. The AM peak hour was adopted in the analysis because it had higher volumes than the PM peak hour. A speed limit of 50 km/h was assumed on KBM and intersecting roads.

The Paramics model is based on origin destination (OD) matrices to control traffic movements in the modelled network. As such, an OD matrix was developed from the traffic surveys and used in the model to generate traffic volumes which were then compared with the observed field data.

Figure 5: Model of KBM Roadways.
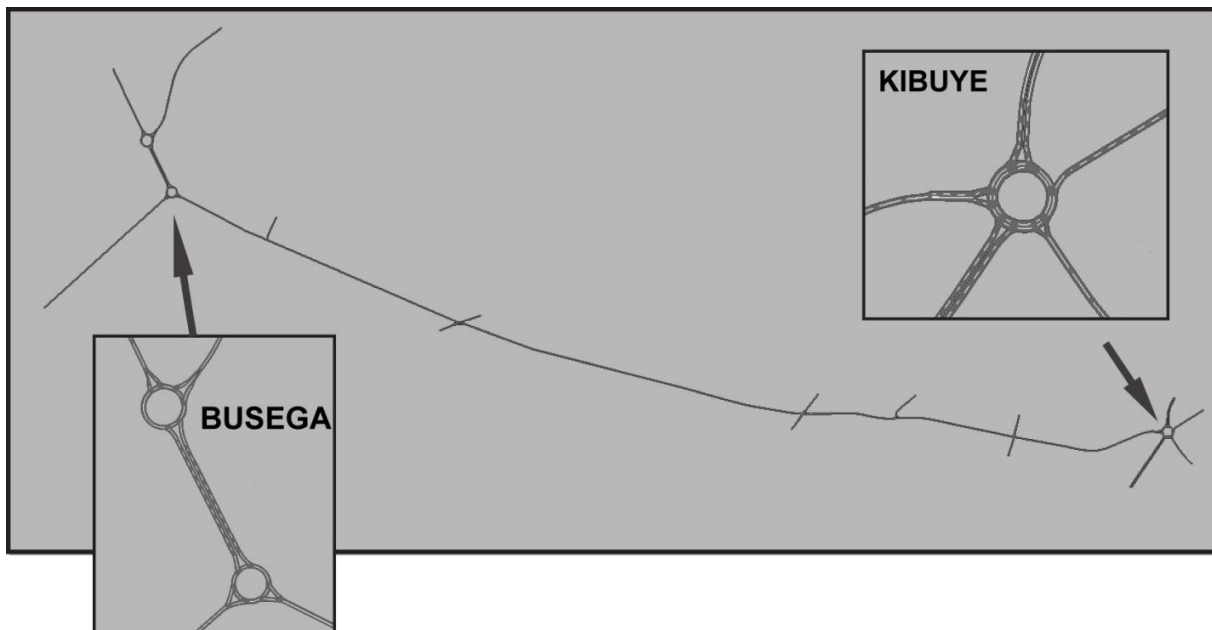
3.2   Analysis Approach

The analysis in this Study was undertaken as part of the general calibration process that involved selection of suitable model parameters based on the vehicle and roadway characteristics. The initial calibration was undertaken with demands representing traffic without motorcycles at the first instance in order to select suitable model parameters such as reaction time and target headways. The model parameters were adjusted until an acceptable match between the model results and the observed traffic volume data was achieved. This initial comparison only considered modelled and observed link flows and turning movement volumes. Thereafter, the process was completed by considering motorcycles and undertaking model validation with the travel times.

Motor cycles comprised 38% of the traffic on KBM Road and the primary objective of the Study was to determine the most suitable passenger car equivalency. To that end the analysis approach involved undertaking simulation modelling of various traffic demands assuming various passenger car equivalencies for motor cycles. Passenger car equivalency was varied from 5% to 100% with that latter implying that the motorcycle is essentially the same as a passenger car. With 5% equivalency, it was assumed that each motor cycles represented only 0.05 of a car. The resultant traffic demand for each scenario comprised passenger cars and other vehicles as well as the assumed number of motorcycles converted using the *pce* ratio. The modelled volumes and measures of effectiveness were then compared to observed values.

Flow comparisons relied on the GEH statistic, which is a modified Chi-squared statistic that incorporates both relative and absolute differences. The GEH statistic is represented by the equation

$$GEH = \sqrt{\frac{(M-O)^2}{0\cdot5*(M+O)}}$$

Where
M: simulated flows
O: observed flows

Various GEH values give an indication of a goodness of fit as outlined below:

GEH < 5   Flows can be considered a good fit
5 < GEH < 10   Flows may require further investigation
**10< GEH**   Flows cannot be considered to be a good fit

A comparison of modelled and observed volumes was conducted along roadway sections and for turning movement at main junctions. Since micro-simulation is a stochastic process in which every computer run represents a single observation, a complete experiment consisted of 6 to 8 computer runs and the results were averaged for each parameter. The mean values were then compared to the observed data.

4.   Study Results and Discussions

4.1   GEH for Volume Comparisons

Modelled and observed volumes were compared and an overall GEH value obtained for all the comparisons. The results are presented in **Figure 6**.

Figure 6: Traffic Compositions with Motorcycles.
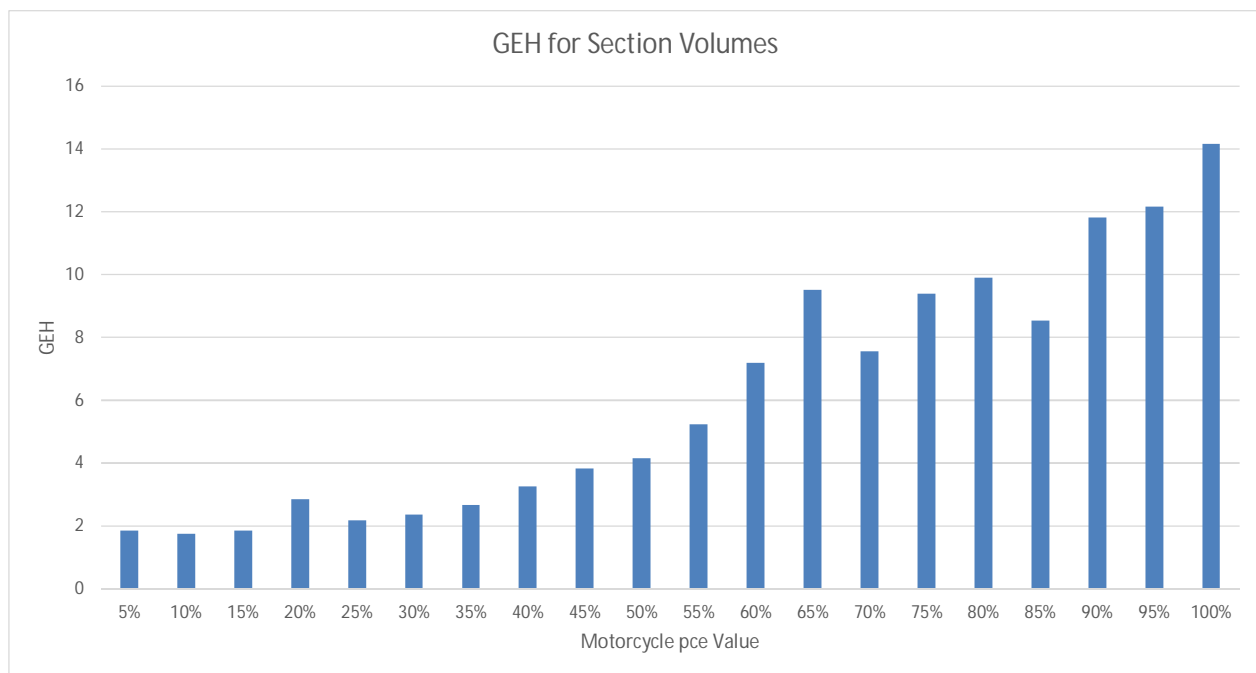
GEH values less than 5 that indicate a good fit between modelled and observed volumes. From Figure 6 it was found that pce ratios of 55% or less provided GEH values of less than 5 and indicated a good fit on the basis of GEH. The trend showed that the GEH values increased with the proportion of motorcycles. That was largely expected since the lower the pce value, the less the total demands, and the network operations remained uncongested. These results indicate that on the GEH comparisons alone would not provide sufficient information to determine the most suitable pce ratio for the traffic stream.

4.2   Travel Time Plots

Further analysis involved plotting travel time plots obtained from analysis with the various pce ratios. **Figure 7** and **Figure 8** show the obtained results for the EB and WB direction respectively.
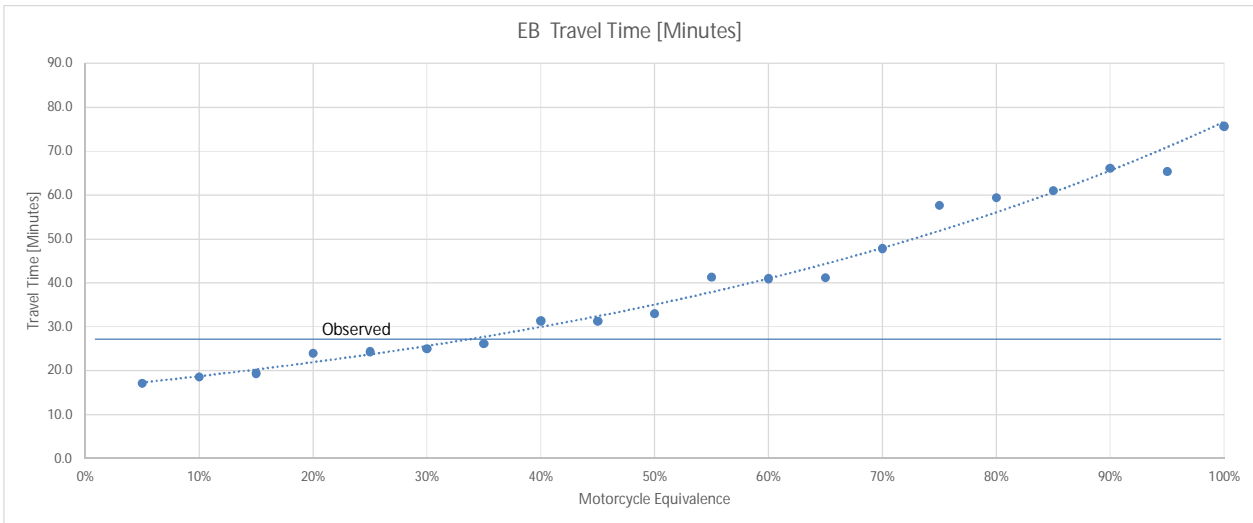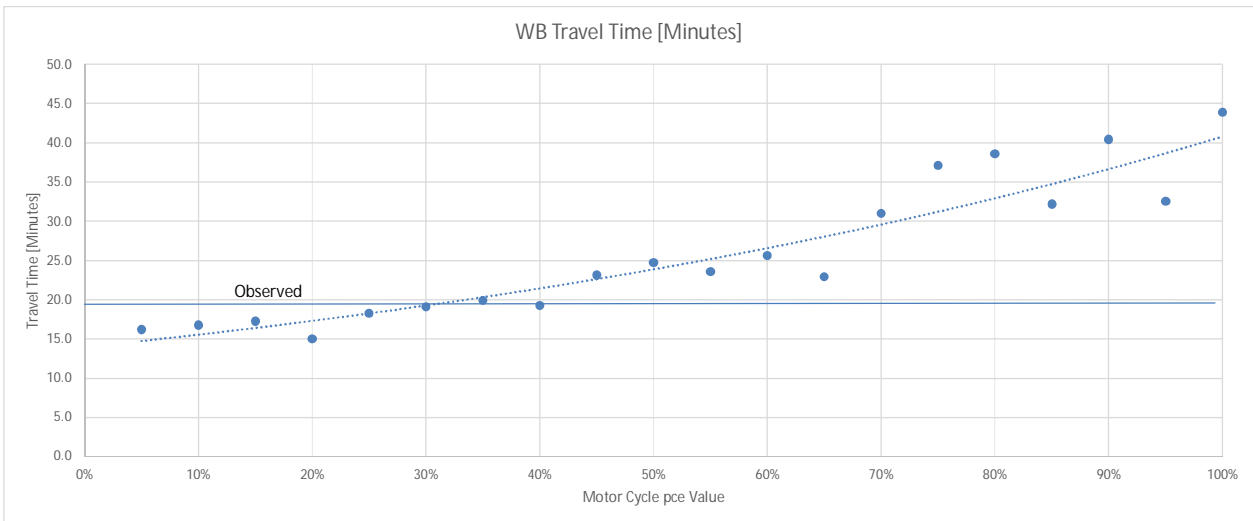
Figure 7: Travel Time Plot-EB Direction

Figure 8: Travel Time Plot-EB Direction

As expected the plots indicate a non-linear relationship between the travel time and the pce ratio with the travel time increasing exponentially with motorcycle pce values. With higher pce value, higher traffic demands are obtained thereby resulting in higher delays and longer travel times and lower speeds. The EB direction leading towards the Kampla CBD shows higher delays during the AM peak hour as a result of the higher volumes.

The plots show that with motorcycle pce ratios of 30% to 40% the modelled travelled time approximated the observed field values of 27.2 minutes and 19.7 minutes in the EB and WB directions respectively.

4.3   Discussions

The results indicate that for the KBM network a pce ratio in the range 30% to 40% provides best overall results with GEH ratios between 2.4 to 3.3 indicating a good fit between the modelled and observed traffic volumes, and travel times matching the observed field data.

That implies that the marginal contribution of one motorcycle in terms of traffic operations is equivalent to 30-40% of the passenger car. This intrinsically implies that on average the motorcycle behavior results in better operational performance than a passenger car.

The motorcycle behavior that makes it perform better than a passenger car relate primarily to their queueing behavior at intersections. They do not normally remain at the position at which they arrive at the queue but, instead creep at reduced speeds towards the front as illustrated by the time distance diagram in Figure 9 (A). In the figure, vehicles 1 and 5 creep towards the front upon meeting the queue, line AC, whereas the rest wait until the departure wave, line BC.

At stand still, motorcycles queue side by side to the normal vehicles or to one another. The most commonly observed discipline follows the first pattern in Figure 9B but as their composition increases some spill over to the area immediately in front of the stop line. When traffic is released to proceed either at the beginning of the green period or by police action, they quickly depart ahead of all other vehicles.

Figure 9: Motorcycle Behaviour

A: Time distance diagram: trajectories 2 to 4 represent cars   B: Queuing patterns
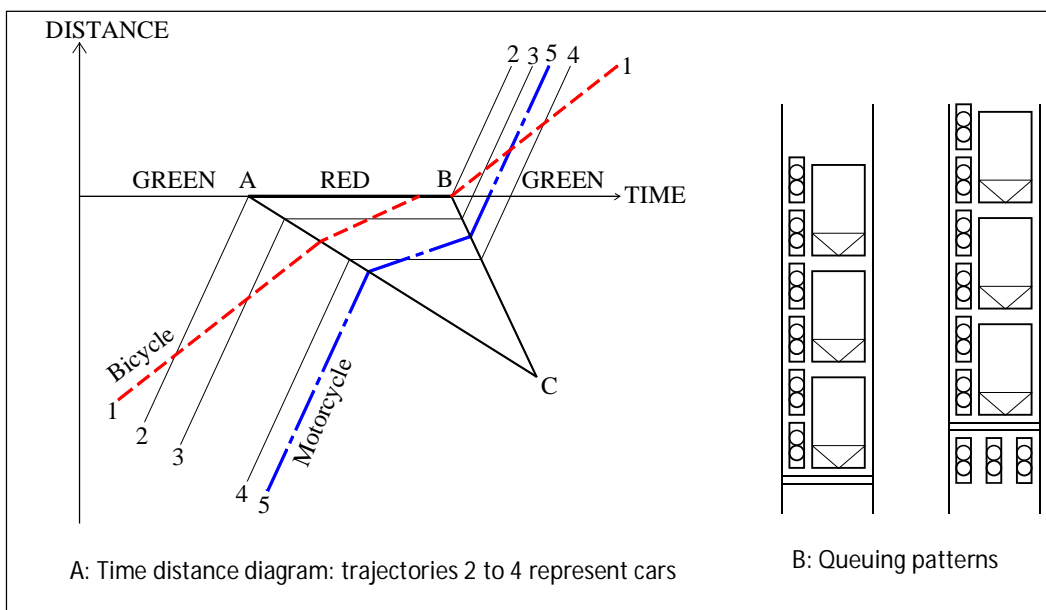
These findings do not in any way advocate for increased usage of motorcycles in the Study Area, or in any other location for that matter. In contrast to the traffic operational benefits demonstrated, there are serious health and environmental concerns that should be considered in drawing any policies governing their usage in a given jurisdiction. Motorcycles are associated with higher and more severe collisions experience than the passenger car. Moreover it is also known that they have higher pollutant emissions because of the nature of their two or four stroke motor operations.

5.   Conclusions and Recommendations

This Study was concerned with successful calibration and validation of traffic streams with large volumes of motorcycles. The assessment involved developing suitable passenger car equivalents (pce) for motorcycles in order to successfully undertake calibration and validation of a micro-simulation model. The analysis involved undertaking simulation modelling of various traffic demands assuming various passenger car equivalencies for motorcycles ranging from 5% to 100%. The modelled volumes and measures of effectiveness were then compared to observed values.

The results show that for the traffic stream within the Study Area, a pce value of 0.35 to 0.40 was the most suitable for motorcycles. Application of this pce value resulted in successful model validation. This analysis shows that model calibration and validation needs to take into consideration unique characteristics of the Study Area which may often involve supplementary analysis.

It is recommended that further research be undertaken to confirm the transferability of these results.