A Case Study of Public Bus Driver Behaviour at Batu Feringghi

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Abstract: This research aims to study driver behaviour of public transit bus at Batu Feringghi road in Penang island of Malaysia. The study investigates the relation of driver behaviour; speed and acceleration, with road geometry and passenger perception. The data were collected from 27 bus journeys with 22 different bus drivers in the period of June to July 2014. The findings include 1) the Batu Feringghi road design is inconsistent in terms of operational speed and posted speed limit, 2) the combination of horizontal and vertical alignments can influence the driver behaviour, 3) the tendency to speed is twice linearly significant for road-familiar drivers compared to driving-experience drivers, 4) the driver characteristics (age and experience) are negatively significant to the lateral and longitudinal accelerations, and 5) the occupant comfort is a function of acceleration but not the speed, and the standard deviation parameters as the most suitable identifiers for this function.

Keywords: Driver Behaviour, Bus Transit, Passenger Perception, Acceleration, Mountainous Terrain, Driver Characteristics

1 INTRODUCTION

Bus mode of transportation is vital component of Malaysia’s land transport. As of 2010, the annual registered buses grew at an average of 3.8%; this growth reflects the demand for bus transportation services. In comparison, the bus accidents stand at the average of 1.6% of total traffic accidents with 9,450 bus crashes per annum. Though the bus accidents present small portion of the road accidents in Malaysia, a sever bus accident does by far exceeds the resulted damages from any other type of automobile accident.

The Malaysian accident statistics do not categorise the bus accidents based on bus structure i.e. low and high floors and single and double decker buses, or bus functionality short transit, long distance, and tourist buses. Thereof, there is no specific statistics, to our knowledge, are found to measure the contribution of public transit bus to the overall bus accidents.

The coverage of public bus safety in Malaysian literature is rather limited in scope. The literature usually focuses on modelling customer expectation and bus services as in Borhan et al. (2014), Kamaruddin et al. (2012), Jayaraman et al. (2011), Mahmud (2010). These studies aim to understand the factors which contribute to the willingness of a customer to use the public transportation especially buses. Majority, if not all, agrees that the issue of on-board safety is at least among the main influencing factors to use a public bus. Therefore, the importance of this study is that it presents an approach to improve the safety of public bus at the mountainous roads. The mountainous terrain require special set of driving skills and is
expected to be the most challenging driving environment for a bus driver, thereof, the Batu Feringghi site is seen as a suitable case study for this research paper.

The issue of safety is no more related to high costs for alignment changes, and mountainous terrain constraints. In fact, it is believed that driving task can be much improved if we are capable of understanding driver behaviour. The driver-roadway interaction is important to identify the design deficiencies where a driver’s expectation and perception are not met. The delayed driving response and incorrect decisions can result in unsafe driving (Heger, 1998). The second objective of this study is to investigate how the driving behaviour is influenced by the driver characteristics including age and driving experience. The third objective is to understand how the occupant comforts is linked to the driver behaviour. This is important to point unsafe driving limits which a driver might not be aware of.

2 LITERATURE REVIEW

The study of driver behaviour in research is associated with the concept of traffic safety and geometric design studies, with the first type of study deals with the driver population as a whole, and the latter focuses on the differences among the driver population.

The traffic studies focus on the speed variable to stimulate the driver behaviour; due to the central prime role of the speed as design parameter. The speed identifiers include mean, variance, deviation and specific characteristic percentile. The mean speed is usually used in the context of the traffic-flow studies. On the other hand, the speed variance, variation and characteristic speed (normally the 85th percentile speed) are observed in the traffic accident occurrence and severity studies. The speed variance; difference between the faster (95th% speed) and slower (15th% speed) drivers, is found to be positively correlated with the accident rates. Similar positive correlation is for the speed deviation of the individual’s speed from the average traffic speed. The extreme variables normally associated with the accident occurrence and severity studies (Dimitropoulos and Kanellaidis, 1998).

The geometric design studies examine driver behaviour as a consequential variable arise from differences among the road users. These differences could be classified as human factors, driver-related factors and vehicle type. The human factors range from demographics characteristics including age, gender, education, and others, and a physical capability such as sight and hearing deficiencies, to psychological performance mainly includes workload and fatigue. Besides that, driver-related factors include the years of driving experience and more specific ‘road-related’ information including familiarity with the travelled road and purpose of trip. The type of vehicle includes motorcycles, passenger car, bus, and others depending on the purpose of the study.

While the vehicle as a design parameter can be implemented properly in the design guidelines, it is more complex to integrate and copy with the human factor; as within the same category driver’s performance tend to behave differently. Thereof, avoiding generalisation is necessity, especially for findings which are in agreement with intuitive (Dimitropoulos and Kanellaidis, 1998).

2.1 Design Consistency Models

The researchers have developed different models to check for design consistency. Al-Masaeid et al. (1995) have used the alignment indices as guideline to evaluate the consistency of the horizontal alignment (Fitzpatrick and Wooldridge, 2001). The model provides guideline for the range of allowable degree of curvature based on vertical curve length, vertical gradient, pavement condition and continuous curve.
In comparison, Lamm et al. (1988) have developed a design consistency and safety model based on the operating speed, degree of curvature, and side friction measurements. The model considers ‘Good’ design if (1) speed consistency criteria; the difference between the 85th operational speed ($V_{85}$) and design speed ($V_d$), is 10km/hr or less, (2) operating speed criteria; the difference between subsequent 85th section speeds, is 10km/hr or less, and (3) driving dynamics; the difference of coefficient of demanded side friction ($f_{RD}$) and assumed side friction ($f_{RA}$), is $\geq +0.01$. Moreover, these criteria are equally weighted for the overall evaluation of a road section. The following table 1 summarises the safety criteria.

<table>
<thead>
<tr>
<th>Lamm et al. (1988) Model</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>Consistency Check</td>
</tr>
<tr>
<td>I</td>
<td>Speed Consistency Criteria</td>
</tr>
<tr>
<td>II</td>
<td>Operating Speed</td>
</tr>
<tr>
<td>III</td>
<td>Driving Dynamics</td>
</tr>
</tbody>
</table>

In order to determine the applicability of the module as an accident predictive, accident rates on observed roadway sections of a three year period were compared with the module criteria. The findings had concluded that the accident rates agree well with the results of the developed safety criteria or at least the results are on the safe side. Only in some rare cases the actual accident rate is higher than the predicted one (Lamm et al., 1988).

The ASSHTO recommends the usage of Lamm model to check for design consistency of the alignment as the speed reduction on horizontal curve relative to the preceding curve has the strongest and most sensitive relationship to accident frequency (Fitzpatrick and Wooldridge, 2001).

### 2.2 Motion Profile and Driving Task

The driving task consists of information-processing and decision making. The driver’s mental condition, physical capability and demographics primarily influence the driving task which is then translated as behavioural output centred on the ability to control vehicle’s cruise speed, and lateral positioning.

Tseng (2013) had studied the relationship between driver characteristics and at-fault accident for 2023 tour bus drivers in Taiwan. The study has revealed that the driving experience was the most crucial factor contributing to at-fault accident rate; drivers with less than 3 years of experience have the highest at-fault accidents rate (12.4%). This group lacked driving experience and familiarity with road geometric, mainly mountainous terrain. The drivers with more than 20 years of experience were not only the 2nd in rank of at-fault accident but their rating has doubled the overall average at-fault accidents of 2.8%. Drivers with driving experience between 6 to 8 years possessed the lowest at-fault accident rate (0.9%). The driver demographics including age and educational level were not significantly correlated with at-fault accident.

Borhan et al. (2014) conducted a case study concerning the public transportation at Putrajaya, Malaysia. The study aimed to identify the factors which could affect the willingness of a traveller to use public transportation. The study has found that the service quality and attitude have positive impact on the intention of taking public transportation, while environmental impacts has no direct significance on the behavioural intention of the traveller.
Jayaraman et al. (2011) investigated the public transportation at Penang, Malaysia. The authors aimed to develop a conceptual model to improve the utilization of bus transportation to meet the needs of Malaysian citizens. Among the findings, the reliability of schedule, safety and comfort, and information system are among the most influencing factors to improve the public bus services.

Dell’Olio et al. (2010) modelled the user perception of bus transit quality at Santander, Spain. The study involved 768 participants who have prior experience in the public bus service. Based on the statistics presented, the comfort during journey and the comfort during starting and stopping have combined weight of 22.9% of overall initial evaluation placing it 3rd after the waiting time (23.8%) and service reliability (27.6%). The evaluation of comfort increases with age group. The gender category has little significant impact on the comfort evaluation.

Thieffault and Bergeon (2003) have found that those experienced and road-familiar drivers are likely fall to experience fatigue as their driving task shift towards automatic process in under-demanding environment. Thereof, the driver alertness weakens to act on small errors such as steering bias and changing speeds of surrounding vehicles resulting in accident.

On the other hand, excessive workload can have negative impact on driving task. Heger (1998) had studied the driver’s mental workload as a criterion for horizontal alignment design. The study combined the operating-speed-based measurements and workload-based measurements from real field federal and state highways in Germany where each of the 12 participants (age 20 to 35) was required to navigate 12 test courses vary from 35m to 1500m radii. The results have revealed that the most psychophysiological parameters (e.g eye blink, variance of heart rate, galvanic skin reaction) reach their maximum after the inconsistent design feature. The author has linked this finding with the high portion if accidents occur on tangents after inconsistent design feature. Thereof, the index of mental workload can be used as a detection parameter for inconsistencies in alignment design and accident-related trends. In short, optimal geometric design should insure moderate workload on drivers.

2.3 Limitation to Current Studies

The bus accidents stand at the average of 1.6% of annual transportation accidents with 9,450 bus crashes per annum. Nonetheless, the Malaysian’s transportation literature lacks the presentation of driver behaviour for the bus transportation in general and the transit bus in particular (as for this study). Thereof, it is important to explore the driver behaviour for the buses in order to establish policies and/or to modify design standard deficiencies if exist, in order to contribute and to enhance the transit bus safety and occupancy as mode of public transportation.

3 METHODOLOGY

3.1 Data Collection Sites

The data used in this study are first-hand data which had been collected during bus journeys in the period of June to July 2014. The mountainous terrain require special set of driving skills and is expected to be the most challenging driving environment for a bus driver, thereof, the Batu Feringghi site is seen as a suitable case study for this research paper.

The Batu Feringghi is located at the Northern coast of the Penang Island. The site location is well-known as a tourist destination. The road at Batu Feringghi is a single
carriageway which varies normally between a 2way-1lanes at climbing spots to 2way-2lanes at other spots. Moreover, as the road runs parallel to the coast, the road becomes unsignalised T-junctions at certain locations. Also, 2 main signalised intersections are located at the main hub of the Batu Feringghi area. The following Figure 1 shows the investigated site.

Figure 1: Batu Feringghi, George town, Penang (Google maps, 2015)

The operator of the low floor public bus is RapidPenang. The bus allows for standing passengers with approximated full combined capacity not exceeding 50 passengers. Also, the transit bus has bus stops between departure and arrival terminals.

The trip data is considered a one way direction; back or forth, which is about 20 minutes. Total of 27 trips were accomplished with 22 different drivers as in the following Table 2.

<table>
<thead>
<tr>
<th>Data Collection Period</th>
<th>Location</th>
<th>REAM (2002) Design Guidelines</th>
<th>Speed Limit (km/hr)</th>
<th>Data Collection (Start/End)</th>
<th>Length (km)</th>
<th>Bus Structure</th>
<th>Total No. of Trips</th>
<th>Total No. of Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>20/06/2014 to 13/07/2014</td>
<td>Batu Feringghi</td>
<td>R4</td>
<td>70</td>
<td>Jalan Tanjung Bungah/Teluk Bahang</td>
<td>10</td>
<td>Low Floor Single Deck</td>
<td>27</td>
<td>22</td>
</tr>
</tbody>
</table>

3.2 Data Collection and Extraction

Both quantitative and qualitative data used in this research were collected throughout the bus journeys. The quantitative data are the measurements for the bus acceleration profile motion and speed and positioning using the USB accelerometer of type X8M-3 Marine and Global Positioning system (GPS) receiver; GM1-86 USB model, respectively. The qualitative data are presented in the passenger’s survey feedback and the driver’s survey.

The accelerometer; X8M-3, is built in 2GB memory and is capable of recording data at rate of 6Hz. Acceleration is recorded in the 3 dimensions namely X, Y, and Z axes which correspond to lateral, longitudinal and vertical accelerations respectively as in the following Figure 2.
The lateral acceleration is the movement of the vehicle at right angle to the direction of travel. The longitudinal acceleration is the movement of the vehicle parallel to the direction of the travel. The vertical acceleration is perpendicular to vehicular path. The accelerometer orientation records positive and negative depending on the acceleration direction.

The GPS receiver needs to be connected to a laptop in order to start recording and save the data to NMEA file; standard Satellite files, these records are converted to spreadsheet format files through available open source software such as GPSBabel used in this study. The limitation of using a GPS is its recording accuracy. At certain obstructed environments such as forested areas and urban canyons, the GPS receiver might not have a clear view of the sky, therefore, the dilution of precision (DOP) can be large and position accuracy will suffer (Langley, 1999).

The occupant survey aims to understand a passenger perception. The participants were asked to key-in their perception of comfort/discomfort in special designed local network application which has a scale of five units; 5 most comfort to 1 most discomfort, throughout the journey. Due to the limited scope; time and resources which are allocated for the project, the passenger surveyors are university students aged between 22 to 24 years, thus, the occupant surveys might not represent the whole passenger population. It is estimated that these young aged groups are usually high risk takers, meaning that their perception for risk is usually higher than older age group. The evaluation of comfort increases with age group (Dell’Olio et al., 2010). Therefore, the average rating results are considered for the analyses.

At the end of a bus trip, the bus driver was asked to answer set of manual survey questions related to their age, total number of years of bus driving experience, number of driving years at the Batu Feringghi road, and the driver’s personal perception about the factors which endanger driving at the investigated route.

3.3 Data Analyses

The driver characteristics and road geometric elements were substitute to scale of 5 numbers. This scale is important in order to ease the cross analyses and comparison. Moreover, the Pearson correlation is used as a linear regression factor to investigate the relation of driver behaviour and geometric alignment and driver characteristics.

3.3.1 Data Scale

The driver characteristics and road geometric elements were substitute to scale of 5 numbers. This is important in order to ease the descriptive and cross analyses and comparison. Nonetheless, the grouping of the geometric variables is based on the literature.

The angle of inclination was divided into scale of 3 numbers. The bases of grade is taken as 0% to 1.6%, 1.6% to 6.5% and above 6.5%. These values correspond to the critical
grade of a loaded truck of 180kg/kW and the maximum speed reduction of 15km/hr based on REAM (2012). As the terrain is mountainous negative scale numbers is used as indication for descending.

The radii of horizontal curves are divided into scale of 5 with number 1 indicates very sharp curves of below 100m, and number 5 indicates large curves of 800m and above. The tangent length is divided to scale of 4 with number 1 for short tangents; below 100m and number 4 for 300m and longer tangents due to winding nature of the terrain. The following Table 3 summarise the driver and geometric elements conversion.

Table 3: Driver characteristics and geometric elements and their equivalent scale

<table>
<thead>
<tr>
<th>Scale Number</th>
<th>Driving Experience (Years)</th>
<th>Driving at the Investigated Road (Years)</th>
<th>Age (Years)</th>
<th>Tangent (m)</th>
<th>Radius (m)</th>
<th>Grade (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 to 5</td>
<td>1 to 5</td>
<td>21 to 30</td>
<td>=&lt;100</td>
<td>=&lt;100</td>
<td>=&lt;1.6</td>
</tr>
<tr>
<td>2</td>
<td>6 to 10</td>
<td>6 to 10</td>
<td>31 to 40</td>
<td>&gt;=100</td>
<td>&gt;=100</td>
<td>1.6-6.5</td>
</tr>
<tr>
<td>3</td>
<td>11 to 15</td>
<td>11 to 15</td>
<td>41 to 50</td>
<td>&gt;=200</td>
<td>&gt;=200</td>
<td>&gt;=6.5</td>
</tr>
<tr>
<td>4</td>
<td>16 to 20</td>
<td>16 to 20</td>
<td>51 to 60</td>
<td>&gt;=300</td>
<td>&gt;=450</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>21 and above</td>
<td>21 and above</td>
<td>61 and above</td>
<td>NA</td>
<td>&gt;=800</td>
<td>NA</td>
</tr>
</tbody>
</table>

3.3.2 Pearson Correlations

The reliability of driver behaviour (both speed and acceleration) was calculated as Pearson correlations for the whole population, split-half based on bus category and then each half is further categorised based on climbing and descending trips. The Minitab software was utilised to perform the Pearson correlations.

The Pearson correlation is strong, moderate or weak as r>=0.75, >=0.5 or >= 0.25 respectively. Thereof, those correlations which are less than 0.25 are considered to be unrelated based on Pearson’s scale of correlation. It is of vital importance to understand that, those variables of less than 0.25 cannot be exclusively proven not to have correlation with the driver behaviour. This is because Pearson’s method can only identifies linear regressions, hence, other correlations or interactions could exist as well. The Pearson correlation is given in the following formula.

\[
r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2 \sum_{i=1}^{n}(Y_i - \bar{Y})^2}}
\]

Where,

- \( r \): Pearson correlation coefficient
- \( \bar{X} \): mean of variable X
- \( \bar{Y} \): mean of variable Y

4 RESULTS AND DISCUSSIONS

The study at Batu Feringghi includes about 10km length of road which is divided based on horizontal alignment configuration; curves and tangents to 72 sections. The sample population of 22 drivers were analysed based on driver surveys. The road geometry at Batu Feringghi
was analysed based on Lamm model (1988) to identify any existence of a design deficiency. The motion profile; as a driver behaviour identifier, was linearly investigated based on Pearson correlation factor against geometric elements and driver characteristics. The passenger perceptions were used to determine which driver behavioural factor influences the occupant comfort.

4.1 Sample Population

Based on the data collected, the gender parameter cannot be investigated as all the driver population were male. The driver age groups between 41 and 60 years have dominated the sample population. Nonetheless, the drivers in terms of experience, one could say, they are fairly juniors with 1 to 5 years bus driving experience at Batu Feringghi road as in the following Figure 3.

![Figure 3: Sample population demographics in terms of years of experience](image)

The domination of road geometry at 81% as a risk factor is expected in such mountainous terrain which requires high skilled and excellent drivers, though the lack of experience is not seen as a risk factor for driver at 0% rating. The proportion of junior drivers in terms of total years (50%) and road related experience (67%) can explain why road geometry is seen as draw back factor though drivers do not seem to realise that the lack of driving experience is risky as well (driver survey bias). The weather, car mechanical, age, and weather are not seen as risk factors for the sample population as in the following Figure 4.

![Figure 4: Risk factors at Batu Feringghi based on driver perception](image)

The study at Batu Feringghi includes about 10km length of road which is divided to 72 sections based on horizontal alignments to curves (68%) and tangents (32%). The measurements for these sections are based on the AutoCAD which is acceptable procedure as mentioned in the guide book for traffic and road safety audit (MIROS, 2012). Figure 5 indicates the percentages for both vertical and horizontal alignments at Batu Feringghi road.
4.2 Lamm \textit{et al.} (1988) Model for the Geometric Design Consistency

The operational speeds are much lower than the 70km/hr speed limit. This variation between the posted speed and actual operating (85th speed in this case) is due the road winding and challenging terrain which does not allow drivers to speed up. Figure 6 presents the uphill and downhill driver speed at different road sections.

\begin{equation}
    f_R = \frac{V^2}{127 (R)} - e
\end{equation}

Where,

\begin{itemize}
    \item $f_R$: Coefficient of friction (either assumed or demanded)
\end{itemize}
V : Design speed (m/s) for the assumed friction, Or

85th operational speed for the demanded

R : Radius of curvature (m)

e : Superelevation (m/m)

Overall, the frictions for both direction of travel are below the assumed friction coefficient as in the Figures 7 and 8. These findings are expected as the friction is a function of speed.

According to Lamm et al. (1988) all the three criteria are weighted equally as stated earlier in the literature review. Thereof, the overall evaluation of the geometric design based on the module indicates that the alignment design is safe, yet major draw-back in the speed design consistency with ‘poor’ design scale due to the difference between the operational and speed limits. The 85th operational speed is found to be 48km/hr compared to the 70km/hr speed limit. The operating speed consistency shows smooth transition from one section to another. Table 4 summarise the safety module classification.
Table 4: Module Safety Classification

<table>
<thead>
<tr>
<th>Data Site</th>
<th>Destination</th>
<th>Criteria I: Design Speed Consistency</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batu Feringghi</td>
<td>Going Uphill</td>
<td>0%</td>
<td>6%</td>
<td>94%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Going Downhill</td>
<td>0%</td>
<td>10%</td>
<td>90%</td>
<td></td>
</tr>
</tbody>
</table>

Criteria II: Operating Speed Consistency

<table>
<thead>
<tr>
<th>Data Site</th>
<th>Destination</th>
<th>Criteria II: Operating Speed Consistency</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batu Feringghi</td>
<td>Going Uphill</td>
<td>79%</td>
<td>19%</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Going Downhill</td>
<td>79%</td>
<td>19%</td>
<td>1%</td>
<td></td>
</tr>
</tbody>
</table>

Criteria III: Driving Dynamic Safety

<table>
<thead>
<tr>
<th>Data Site</th>
<th>Destination</th>
<th>Criteria III: Driving Dynamic Safety</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batu Feringghi</td>
<td>Going Uphill</td>
<td>96%</td>
<td>4%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Going Downhill</td>
<td>96%</td>
<td>4%</td>
<td>0%</td>
<td></td>
</tr>
</tbody>
</table>

4.3 Motion Profile and Geometric Alignments

The reliability of driver behaviour (both speed and acceleration) was calculated as Pearson correlations for the whole population. It is of vital importance to understand that, those variables of less than 0.25 cannot be exclusively proven not to have correlation with the driver behaviour. This is because Pearson’s method can only identifies linear regressions, hence, other correlations or interactions could exist as well.

The horizontal alignment is linearly correlated with the speed. The speed Pearson’s values for radius of curvature and road tangent are 0.54, and 0.31 respectively. Figure 8 shows that the drivers maintain their mean speed at climb and descend for gradient angle of 1.6% to 6.5%. Besides that, the mean speed drops significantly below the population mean speed as the gradient exceeds 6.5% especially at descending trip as in Figure 9.

Figure 9: Main effects plot for the 85th speed

The geometric road elements cannot be conclusively proven to be linearly correlated to driver lateral acceleration. The Pearson’s correlations for geometric road elements are less than 2% and p-values greater than 40% as in Figure 10.
Figure 10: Main effects plot for the mean 85th lateral acceleration

The gradient is most significant factor for the longitudinal acceleration at 0.12. Figure 11 shows that the longitudinal acceleration is higher at declination than inclination. The longitudinal acceleration tends to increase linearly with the tangent length till it reaches 300m and then the acceleration behaves inversely. The latter relationship is found to be related to grades of less than 6.5% and is not combined with horizontal curves.

Figure 11: Main effects plot for the mean 85th longitudinal acceleration

The road curvature and tangent length have almost similar significance correlation with the vertical acceleration at -0.21 and -0.19 as in Figure 12.
The findings related to the horizontal and vertical alignments indicate that the geometric design can influence the driver behaviour. Therefore, changing one geometric element could enhance driver behaviour and safety at road.

4.4 Motion Profile and Driver Characteristics

Regards the speed profile, the years of driving experience at the Batu Feringghi is most significant character at 0.11 compared to total years of driving experience at 0.05 significance value. This interesting finding indicates that the tendency to speed is twice more linearly significant for road-familiar drivers compared to driving-experience drivers. Though, hypothetically a combination of both driving experiences should produce the higher speed. The driver group between 11 to 15 years possesses the least mean speed compared to all other groups especially the 16 to 20 years group who records the maximum mean speed. The driver age and mean operational speed tend to stabilise for the older driver groups. The following Figure 13 presents these relationships.
Based on Figure 14, overall the Pearson linear correlation values indicate that the driver characteristics are negatively significant to the acceleration behaviour. The driver age and total years of driving experience to be the most significant factors at -0.22 and -0.2 respectively. For instance, the senior experienced drivers tend to cruise at lower mean speeds compared to the junior less experienced drivers.

Figure 14: Main Effects Plot for Lateral Acceleration

The driver character is found to be negatively correlated with the longitudinal acceleration. The driver age’s Pearson correlation of -0.27 is the prominent significance compared to other characters. The total years of driving experience significance is -0.16. From Figure it is noticeable that recorded longitudinal acceleration for the younger and junior experienced driver’s are above the mean longitudinal acceleration of the whole sample population. Therefore, these driver groups accelerate and decelerate much harshly than other groups such behaviour can have negative impact especially on standing passengers. The following Figure 15 presents those findings.

Figure 15: Main Effects Plot for Longitudinal Acceleration
Despite of Figure 16 shows correlation between the driver characteristics and the vertical acceleration, the vertical acceleration is independent of driver characteristics as the vertical acceleration is a component of bus weight and not the speed.

![Main Effects Plot for Vertical Acceleration](image)

Figure 16: Main Effects Plot for Vertical Acceleration

### 4.5 Passenger perception

The cross analyses were used to examine how the occupant comforts is linked to the driver behaviour. The speed and acceleration parameters including the mean, standard deviation, variance, 85th percentile were cross-analysed with the passenger rating as in the following Table 5.

<table>
<thead>
<tr>
<th>Passenger Rating</th>
<th>Speed (km/hr)</th>
<th>Lateral Acceleration (g)</th>
<th>Longitudinal Acceleration (g)</th>
<th>Vertical Acceleration (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>StDev</td>
<td>85th %</td>
<td>Mean</td>
</tr>
<tr>
<td>1</td>
<td>42</td>
<td>9</td>
<td>52</td>
<td>0.031</td>
</tr>
<tr>
<td>2</td>
<td>38</td>
<td>10</td>
<td>49</td>
<td>0.019</td>
</tr>
<tr>
<td>3</td>
<td>35</td>
<td>9</td>
<td>45</td>
<td>0.053</td>
</tr>
<tr>
<td>4</td>
<td>34</td>
<td>10</td>
<td>45</td>
<td>0.069</td>
</tr>
<tr>
<td>5</td>
<td>36</td>
<td>11</td>
<td>47</td>
<td>0.059</td>
</tr>
</tbody>
</table>

The passenger comfort is found to be independent of the speed as there is no clear pattern between the speed parameters and the passenger rating.

The tabulated lateral arithmetic measurements are found to be intuitive as the discomfort tends to spread away from the 0g lateral acceleration which human body experiences when no lateral forces are experienced.

The longitudinal acceleration has shown fluctuation in measurements. This finding is related to the acceleration noise which is due to the influent driving environment of the transit bus. In support to this argument is the large range of the longitudinal acceleration at moderate and comfort scales compared to the discomfort level.

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The vertical acceleration is a result of the normal force on bus. Theoretically, the passengers should feel unrest as the g-force deviates from 1g (normal g acceleration a human body experiences). Nonetheless, the tabulated measurements indicate that the passengers feel more comfortable as the road gradient increases. However, the perception of passengers cannot be exclusively related to the bus weight. Rather passengers rating are a result of other motion factors.

The standard deviation is favoured over the mean, and the 85th percentile measurements as it can better reflect the tolerance limits towards specific driver behaviour e.g lateral acceleration. Meaning that, the greater the standard deviation value indicates that passengers have different perceived level of tolerance to the driver behaviour and vice versa. Therefore, the standard deviation is the most suitable identifier for the passenger comfort compared to other arithmetic parameters.

5 CONCLUSIONS

The design evaluation of geometric alignment at Batu Feringghi, is found to be safe for the transit bus traffic, yet the bus 85th cruise speed is only 48km/hr compared to the 70km/hr as speed limit; thus, ‘Poor’ design in terms of speed design consistency.

The findings related to the horizontal and vertical alignments indicate that the geometric design can influence the driver behaviour. Therefore, changing one geometric element could enhance drive behaviour and safety at road.

The Pearson correlation method was used to investigate the relationship of driver character and motion profile. Though normally literatures only focus on the total years of experience as a variable, in this study the driver familiarisation with road is found to be twice linearly significant to the speed. Moreover, the driver characteristics are negatively significant to the lateral and longitudinal behavioural acceleration, while the vertical acceleration is independent function from driver characteristics.

The limitation regards the occupant comfort is that the passenger surveyors are university students aged between 22 to 24 years, thus, the survey results might not represent the whole passenger population. The occupant comfort is found to be a function of acceleration but not the speed. Besides that, the standard deviation of the acceleration is the most suitable identifier for the passenger comfort compared to the mean, and the 85th percentile measurements.

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