

# Long Bus Vehicle Rear Swing Out Impact Assessment Using On-Board Video Camera

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**Abstract-** The current maximum allowable overall length of bus for Malaysia is only 12.2 m. However, the government had gazetted the United Nations Regulation (UNR) 107 and due to be implemented in July 2017. The implementation of UNR107 among others will allow the use of bus for overall length more than 12.2 m. This study investigates the manoeuvrability of single rigid, 15-metre bus based on its rear swing out impact. The rear swing out impact assessment of longer bus (15-metre) was made by recording a video from a video camera mounted on the rear, pointing rearward of a single rigid, 12-metre bus during manoeuvre. The video camera view angle was set to represent the excessive 3 m of longer bus and any infrastructures that appeared in the view were identified as the possible impact. From the video recording, it was found that longer bus will have a minimal manoeuvrability issues on the road. However, modification may be needed specifically at tight intersection or small roundabout to allow a smooth manoeuvrability of longer bus.

**Keywords-** Long bus, Rear swing out, Video recording, Infrastructure impact

## 1. Introduction

There are different type of buses operated in Malaysia such as double decker, single decker bus and mini bus. Due to overall length of bus restriction, bus of overall length more than 12.2 m is never being used (*Road Transport Rules*, 2014). Such prescriptively defined regulation (overall length) does not provide a clear outcome of the

regulation and limit the use of more productive bus such as articulated (18 m) or long single decker bus (15 m).

Maneuverability is the performance outcome of the prescriptively defined overall length regulation. Maneuverability was defined as the safety performance outcome and could be divided into specific performance measure. Overall length of a vehicle influenced the rear swing out value and Figure 1 shows the simulation of different rear swing out value (red mark) by different overall length of buses under the same maneuver control.

The United Nations Regulation (UNR) which currently being implemented in Malaysia for different type of vehicles including bus, maneuverability (rear swing out) was stated under the UNR 36. The UNR 36 required any bus to not exceeding 0.8 m of rear swing out for single-rigid vehicle (R36, 2008).

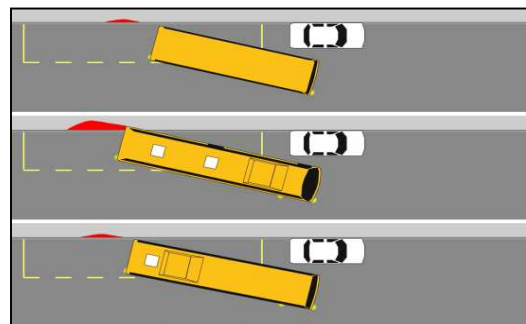


Figure 1: Video simulation on the different degree of rear swing out (see red mark) for different length of bus under the same maneuver control.

Source: [3]

The existing on-road assessment of long bus rear swing out was conducted and exemplified by

(Sleath et al. 2006). They attempted to verify the maneuverability of different type and length of buses produced from a computer simulation and off-site, full scale assessment. The method used is simple where a video recorded from outside, recording a bus attached with a mock body frame to represent the excessive length (Figure 2) and assess the rear swing out while exiting a bus stop, negotiating a roundabout and 90 degree turn along 4 km urban road in South Auckland.

The on-road rear swing out assessment demonstrated by Sleath et al. (2006) however may be impractical for assessment of long distance route. Besides, the observation made at the road side may not be thorough as it does not provide the rearward point of view of the bus. Therefore, this research attempted to develop a new rear swing out impact assessment that practical enough to be applied for a long distance route assessment. It was found that the video recording made from the bus was able to record any possible infrastructures that could cause damages to the infrastructure and the bus.

## 2. Problem Statement

The existing on-road rear swing out assessment method of long bus is impractical for a long distance route. The existing method known to require a video recording made from outside the bus to record the bus movement towards its rear swing out. This would require a frequent stops being made at every each intersection, roundabout and bus stop. Considering the fact that the existing roads were mainly designed for road vehicles with overall length not more than 12 m [5], conducting the rear swing out assessment from a video recording made from the bus may provide the solution.

## 3. The Aim of Research

This paper conducted research to develop on-road rear swing out assessment of long bus using a video camera mounted on the bus at the rear. The results also may suggest the capability of single rigid, long bus (15-metre) to maneuver safely on the existing roads.

## 4. Methodology

This study was conducted on the road within the Universiti Teknologi MARA, Shah Alam campus compound area. The bus was driven approximately 5 km of roads consist of intersections, roundabouts and bus stops. The road also consists of gradual uphill and downhill which may affects the driving dynamics. The bus used in this study was a 12-metre bus and made available by the university. The physical dimensions of the bus are in Table 1.

Table 1: Physical dimensions of the bus used in this study

Dimensions	Unit (m)
Overall length	12.1
Wheelbase	5.8
Front overhang	2.6
Rear overhang	3.7
Width	2.2
height	3.45

The video camera used in this study was the action camera type which provides a high definition quality video recording with advance features of remote control. The remote control feature allows the start/stop recording made from inside the bus and this does not require the bus to make a stop before recording the video. This method allows the driver to drive the bus naturally thus, providing the undisturbed real on-road driving condition.

The action camera was mounted on a standard mounting accessory pointing rearward at the rear and the mounting was attached to the bus body using a 3M double sided tapes. The view angle was 120 degrees and set to represent the excessive 3 m of long bus (overall length of 15 m) from the rear bumper (see Figure 2). Any infrastructure viewed in the video recording will be identified as the possible impact.



Figure 2: The view angle of the action camera.

As the bus driven along the roads, the video recording was controlled from inside the bus (controlled by authors) and the recording starts when the bus driven passing through intersections, roundabouts and bus stops.

## 5. Results, Analysis and Discussion

A total of 22 minutes of video recording were made during the data collection. The video was transferred into a computer and the video was edited and played using the AVS Video Editor software. An imaginary line then drawn as the bus body line on video recorded using the video effects editing tool available in the software. The video recording was observed to identify any infrastructures that could cause a damage to the

infrastructure and the bus based on the imaginary line drawn.

From the observations made through the video recording, it was found the video recording was able to represent the excessive 3 m of long bus. It was evidenced that the potential infrastructures that could cause damages to the infrastructure and bus whenever the bus maneuver at intersections, roundabouts or bus stops were recorded. Road furniture such as sign post and road curb were viewed in the video recording (see Figure 3). Besides, encroachment of the bus rear into the adjacent lane was observed during maneuver and it may hit other vehicles (see Figure 4).



Figure 3: Sign post viewed in the video recording while the bus exiting a side bus stop.

Based on study by Sleath et al. (2006), the difference of rear swing out performance of the actual and design bus is 28%. As the difference is quite small, the predicted impact from the observation may be otherwise (safe) for long bus. The results will be slightly different from the actual 15-m bus where the longer wheelbase and shorter rear overhang would show better rear swing out performance<sup>4</sup>. Whilst the analysis was qualitative, the method will not be able to confirm the predicted impact of long bus rear swing out performance. Nevertheless, near miss impact shall suggest better on-road long bus rear swing out performance.



Figure 4: The bus excessive imaginary line at the rear encroached into the adjacent lane during left turn manoeuvre at intersection.

The finding was supported by earlier studies conducted by Af Wählberg (2004) and Goh

et. al (2014) of low speed accidents involving bus. The studies found that the road accidents statistical data involving bus shows that hitting objects and other vehicles are the most frequent incident during low speed maneuver. Meanwhile, a bus rear swing out hitting pedestrians is the most less frequent incident and may be appropriate to be conducted at bus terminals.

The ability of remotely control the start/stop of the video recording had favorably saved the action camera battery consumption. Besides, the driver may perform their driving behavior naturally which contributed to an accurate data collection that represents real life driving situation. In context of long distance route assessment, this method is practical as the bus does not need to stop whenever making maneuver into intersections, roundabouts and bus stops.

However, assessing vehicle rear swing out impact on long distance route may need modification to source the power to the action camera from the bus. Independent battery of the action camera will only could stand to a maximum of two hours and traveling time that took more than two hours will need the bus to make stop and replace the battery.

This method also will be appropriate to be used on any vehicles. In case of assessing the exact long bus (15 m) for example, the video camera view angle can be set to represent 1 m distance from the bus rear. Any infrastructure that was viewed in the recording will be identified as a near missed incident. In order to minimize the risk of damages, modification can be made accordingly from the near missed evidence.

Besides overall length of vehicle, there are other factors that influenced the rear swing out value such as length of wheelbase and rear overhang, type of rear axles, drivers' skills and type of chassis. Drivers skills for example are very important in minimizing the impact on vehicle rear swing out especially large vehicle. Further study was recommended to investigating the need of further or special training for large vehicles [8]. Currently, the existing Public Service Vehicle (PSV) driving license holder was deemed to be sufficient to drive the long bus in Malaysia.

While the vehicle wheelbase and rear overhang will also have a great influence over its rear swing out value. The rear swing out movement recorded in this study was from a total of 6.7 m which is more from its wheelbase. Thus, recording the video from the exact 15-metre bus will give a totally different and much reliable result as the wheelbase is longer with almost the same rear overhang.

Based on authors observation, even driving a normal 12-metre buses may cause damages to the infrastructures and the bus body. Even though the damages may be caused by other factors, Figure 5 shows the damages mark on the

bus body caused by rear swing out of a normal 12-metre bus. Therefore, allowing a single rigid, long buses of 15-metre to operate in Malaysia may require the drivers to undergo a special training.



Figure 5: Damages mark on the left rear side of a 12-metre bus.

The adoption of UNR in regulating heavy vehicles for Malaysia may suggest that the government had partially adopted Performance Based Standards (PBS) regulation. Developed countries such as Australia and New Zealand have implemented the Performance Based Standards (PBS) regulation for their heavy commercial vehicle which includes bus [9]. The main objective of implementing PBS regulation in Australia for example was to increase the loading capacity without compromising safety [10]. Based on the Australian PBS regulation, maneuverability performance measures are tail swing (rear swing out), frontal swing, low speed swept path and steer tire friction demand [11]. These performance measures are also limited to a specific performance threshold based on different type of road categories.

## 6. Conclusions

This study has successfully demonstrated a new practical method of assessing long bus rear swing out impact using on-board video camera. Further research can be conducted on the long-distance route that could prove the practicality employed in this study. However, the methodology is not perfect until the findings being compared with the findings obtained from the exact single-rigid 15 m bus using the same method. It will be interesting to compare the results of this study with the result obtained from the exact long bus to evaluate the difference.

The challenges of operating single rigid, long bus (15 m) on the roads that design for a maximum overall length of 12 m vehicles is to identify the route that may cause damages to the infrastructures. Therefore, a sound and practical on-road assessment is crucial to ensure a smooth operation of such long bus.

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