Assessment of Bus Interior Design in Malaysia

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Abstract: Road accidents involving bus in Malaysia is very alarming. National statistics showed that bus accident cases increased significantly at 48% between the year 2006 and the year 2008. This study focuses on design of bus concerning ergonomics factors to eliminate injury that may pose to bus passenger either in collision or non-collision event. Data source that used for this paper were obtained from bus a carried out at PUSPAKOM. This study managed to assess 224 samples and collected measurement for items stated in UN R36. Several design issues that can potentially contribute to passenger injury such as doors, seats, handrail and steps are highlighted and discussed in this paper. Findings from this paper revealed that current regulation already address the critical measurement to ensure passenger safety is taking care while in the bus. However, some related items seem to be obsolete and need to be revised accordingly.

Introduction

Road traffic accidents and injuries are well-known problems in developing countries such as Malaysia. Statistics by the Royal Malaysia Police (RMP) show that the average number of fatalities due to road traffic accidents is more than 6,000 per year. On top of that, the road mishaps involving commercial transportation had also increased significantly since 2000 [1]. Road accidents that involved buses in the public service vehicle category alone, had recorded a considerable increase of 48% within two years (2006 – 2008). These statistics should not be taken lightly since the increase in accidents involving commercial vehicle is significantly alarming and becoming one of the national road safety interests.

Generally, bus accident can be classified into two major events – non-collision and collision. The non-collision event can be defined so when the bus is not crashing with other vehicle or object and generally related to bus design [2]. A study done by Kirk *et al.* (2001) [3] had revealed that the proportion of bus passengers being killed or seriously injured in non-collision incident in the Great Britain is 64.3%. Whereas in Germany, the similar non-collision incident was 50%, with 70% of those cases were due to braking and 725 of the casualties were passengers older than 55 years. Furthermore, elderly female passengers are the most vulnerable group to be killed or severely injured, and the majority of them were travelling in short distance buses. On another note, study by Lagwiederet *al.* (1985) [4] showed that head injury is the most frequent with 27%, followed by injuries to chest with 19.2%.

There are several prevailing issues contributing to the injuries in non-collision incident such as such general interior design, heavy braking, operational and/or scheduling, as well as drivers' problems. However, due to lack of studies, these particular problems are still unknown in the Malaysia bus industries per se. Thus, this study aims to look at the issue of general interior design that presumably increases the risk in non-collision bus occupant injuries in Malaysia. The focuses in this study with regard to the occupants' movement are "boarding and exiting", "sitting" and "standing" while in or entering bus. In addition to that, this study also highlights the dissimilarity between Malaysian regulation known as C&U1 and UN regulations in terms of bus design.

¹Malaysia Motor Vehicles (Construction and Use) Rules, 1959

Methodology

A technical assessment was conducted at Periodical Technical Inspection (PTI), i.e. at PUSPAKOM Sdn. Bhd., in order to evaluate the general interior design of buses with regard to their construction. In this study, one PTI center was selected from four different regions in Malaysia. A survey form that has been developed based on UN R36² was used to collect the required information. UN R36 only applies to single deck rigid or articulated design and the design constructed purposely to carry persons exceeding 22 passengers, whether seated or standing. The assessment/inspection covered all safety aspect in bus general design, however for this paper, only several interior items selected to be discussed that directly related to ergonomics element. The main information acquired in this study is the measurements of physical general interior design (dimension) for: a) entrance and exit, b) Steps, c) Seating and d) Handrails.

Results

The assessment at four different PUSPAKOM's PTI centers had managed to collect 224 samples (buses). With regard to bus type, express buses and factory buses are the majority with 66 and 62 units, respectively. School bus was the lowest group that has been inspected, with only 39 units. The results for the measurements of physical general interior design (dimension) of the samples are described in Table 1 below. The dimensional measurement revealed that all samples were above the minimum requirement for both service (entrance) and emergency door as required by the regulations.

Table 1: Comparison of height and width of doors for different classes

	Type of door	Class	UN R36 (mm)		Compliance, N (%)	Status
			Height (min)	Width (min) Single/double		
1	Service door	Class I ³	1800	650	224 (100)	Pass
		Class II ⁴ and III ⁵	1650	650/1200	224 (100)	Pass
2	Emergency door	All	1250	550	224 (100)	Pass

Table 2: Assessment of technical requirement for emergency door

	Technical requirement for service door	Status	Compliance, N (%)
1	No obstruction at emergency path	Yes	132 (58.9)
		No	92 (41.4)
2	Emergency door shall open inside and outside when stationary	Yes	187 (83.5)
		No	37 (16.5)
3	Warning audible device to driver when emergency exit open	Yes	62 (26.7)
		No	162 (73.3)
4	Emergency door marker	Yes	193 (86.2)
		No	21 (13.8)

Furthermore, there are several technical requirements that need to be fulfilled for emergency door for safety reason. Table 2 shows the general requirement for emergency door based on UN R36. For '*no obstruction at emergency path*' requirement, 92 buses or 41.4% failed to comply with the requirement. Meanwhile, among the four items assessed, the '*warning audible device to driver when emergency exit open*' item was not up to satisfactory level and the compliance on that item was only 27%. Lastly, for the requirement of the "*emergency door marker*", most of the inspected buses (86.2%) were well-equipped with the marker.

²Uniform Provisions Concerning the Approval of Large Passenger Vehicles with Regards to Their General Construction (UN R36)

³Vehicles constructed with areas for standing passengers, to allow frequent passenger movement

⁴Vehicles constructed principally for the carriage of seated passengers, and designed to allow the carriage of standing passengers in the gangway and/or in a standing area which does not exceed the space provided for two double seats

⁵Vehicles constructed exclusively for the carriage of seated passengers

There are three seat configurations designed for buses i.e., forward facing, in pairs facing seats (forward and backward) and side facing seats. The typical facing forward seat configuration regularly can be found in most of type of buses especially in express bus and the facing type usually designed for short distance bus or stage bus. Table 3 shows measured variable features for bus passenger seat according UN R36. For width of seat, the average cushion width was 453 mm in which the study recorded the minimum and maximum measurement were 400 mm and 670 mm, respectively. Based on the total 224 buses inspected, only 3 or 1.3% buses were below the requirement of UN R36, however, 1.3% figures are still acceptable according to C&U whereby the minimum width of the seat required is only 380 mm. In term of seat spacing, the average measurement was 738 mm, and this was above the minimum requirement for UN R36. Furthermore, it shows that the average cushion depth is 418 mm and 5.4% is below the minimum requirement, 350mm (based on UNECE regulation). Only, 12 buses or 5.4% of the sample's recorded the cushion depth of minimum 350mm based on UN R36. However, it is worth to note that this cushion depth requirement is not stated in the domestic C&U Rules. Measurements for facing distance were all above regulations' requirement with the average dimension measured was 1430 mm.

Table 3: Dimensioned comparison of passenger seat, steps and handrails of inspected samples against and UN R36

	Element		Variable feature	UN R36 (mm)	Average dimension inspected (mm)	Compliance, N (%)
1	Seat	Width of seat (single)		400= class I and II 450 = class III	453	221 (98.7)
		Seat spacing		650=class I 680=class II & III	738	224 (100)
		Cushion depth		350=class I 400=class II&III	418	212 (94.6)
		Facing distance		1300	1430	224 (100)
2	Steps	Height of first step from ground		Maximum 360=class I 400=class II & III 430=mechanical suspension solely	230	224 (100)
		Depth of step		Not less than 300	364	224 (100)
3	Handrails	Door entrance handrail	Height of handrail from the or each step	Minimum =800mm Maximum = 1100mm	900	220(98)
		*Standing passenger handrail	Height of handrail from the floor	Minimum = 1500mm Maximum = 1900mm	1740	224(100)

*Based on 158 buses (express bus excluded)

Class I refer to vehicle constructed with areas for standing passengers, to allow frequent passenger movement

Class II refer to vehicle constructed principally for the carriage of seated passengers, and designed to allow the carriage of standing passengers in the gangway and/or in an area which does not exceed the space provided for two double seats

Class II refer to vehicle constructed exclusively for the carriage of seated passengers [5]

Based on assessment, the average height for the first step recorded is 230 mm and maximum dimension measured to be 260 mm. In term of depth of steps, the average dimension measured was 364 mm where is above the minimum requirement specified. In term of depth of steps, the maximum and minimum depth of each step measured to be 430 mm and 340 mm, respectively, depending on class of bus. From the assessment, it shows that the stage bus had minimum

dimension in term of height of first step from the ground. This is due to most of the stage buses, steps have three or less step to reach the bus floor, and approximately 46% from the stage buses are consider as low floor bus type. It can be concluded that the height and depth of steps were within the range for both regulations.

Based on the survey, there is three type of handrails design installed in the bus, which the first design is a hollow structure along the entrance steps (design 1), the second one is a vertical handrail located at the entrance door either at side or at middle (design 2) and the third type of handrail is stand-alone type (design 3). The function of all type of designs is the same, to assist or guide occupant during boarding or alighting or to prevent passenger falls during moving bus. Almost 90% of the assessed buses were using the handrail along the steps design type in the bus, which the average measurement is 900 mm height from the step. However, there is approximately 4 buses or 2% of the buses did not comply with UN R36 in term of height but still valid in Malaysia since there is no dimension requirement stated in C&U rules. The remaining 10% of the assessed bus discovered it was equipped with vertical handrail type and this type of handrail commonly observed in stage bus type. Meanwhile, for standing passenger handrail, the express bus were excluded due to non-existing of handrail. Therefore, only 158 buses accessed. Results show that the average measured height for handrail from the floor was 1740 mm, which the measurement within range stated in both regulations.

Discussion

Previous study by Petzall J. [6] highlighted that the entrance width is recommended to be 700 mm, which would suit passengers with mobility difficulties. The suitable dimensional door is importance to avoid discomfort or hazardous to occupant such as trapped by the opening or closing door while boarding or alighting the bus. Besides, the dimension of the door also play an important rule to ensure passengers can entering and leaving without striking their heads on the door. Warning audible device is important item in bus as it is used to alert the driver and other passengers whether the door is open or close. For example, in 2007, MIROS crash investigation team had investigated the non-collision accident whereby a passenger standing next to emergency door suddenly fell out when the bus negotiated with a curvy road and died due to head injury. Based on the investigation, there is no audible warning device or other signal to driver to notify whether the emergency door close properly or suddenly opened. From the inspection, it is revealed that the door mostly obstructed by passenger seat and dustbin. The presence of such of obstruction at emergency path might interfere with the evacuation process during emergency. Furthermore, based on the inspection, it revealed that the 16.5% of the emergency doors could not be open from either of the bus. This situation could cause more panic among the occupant during post collision or bad incident and might delay the evacuation process of victims. One of the major issues related to the emergency exit is its reliability in evacuating the victims during accident (post-collision) situation especially in rollover whereby it could give the most severe injury to occupant [7].

Passengers travelling by bus usually spend most of their time sitting especially during long hours travelling. Therefore, the design of the seat will be important in determining how safe and comfortable passenger. Seat dimension and design is important to ensure passengers safe while seated. Apart to give comfort for passenger, a good seat also can give protection and reduce the injuries when accident occurs. Injuries occur to passengers while seated for a number of reasons. A study done by J.A. Levis [9] revealed that the most common injuries to seated passengers occurred as a result of striking the seat top rail or seat back in collisions. The main part of body injuries is the head, neck and legs while the others part of body expose of low injuries. In addition, seating anchorage play important rule to prevent passengers from thrown forward in a frontal collision. MIROS in-depth investigation reveals that significant contribution in term of causality due to poor seat anchorage [10]. Besides, based on the inspection, it shows that 95% of assess bus not equipped with seatbelt. Only five percent of the bus equipped with the seat belt obviously from express bus type. Legally, the seatbelt is not a compulsory item in bus but since late 2008, Road Transport Department (RTD) strengthen the law by make it as requirement for bus builder to install. The

government of Malaysia slowly educates the bus builder the important of seatbelt to make it available in each new bus [11]. Retrofitting of seatbelt to current buses on the road would not be cost effective due to increase of the cost to modify the bus structure so that the seatbelt can work effectively [12]. Study by G. Belingardi et al. [13] shows that the 3-pointed belt system could prevent the head injury among the passenger and 2-pointed belt increase the passenger security under rollover.

This study revealed that all assessed buses were in regulations tolerance in term of dimensional for steps requirement. However, there is some differentiation in term of steps condition. The results show that approximately 90% were in good condition and some of the buses install an anti-slip material at each step to avoid passenger tripped. Meanwhile, the remaining 10% of the assessed buses have poor condition of floor, i.e. too slippery, no anti-slip material and broken floor. This condition might cause injury to passenger. Data from Austria showed that the boarding and alighting cause about one-third of fatal injuries [14]. The height of the first step is critical, hence there a vary dimension of first steps height. The height of step was set to be maximum due to ergonomics factor in order to make passengers having no trouble when alighting and boarding the bus. The design is to ensure passenger alighting and boarding safely. Study conducted by Petzall [6] suggested that the ideal of height steps for normal bus is between 150 to 200 mm with the depth step between 200 to 300 mm.

Handrail designed to provide support for passengers in their bus journey, thus it should provide enough grip and be available to passengers at every stage of their bus journey from boarding to alighting. In the bus, there are difference configurations or design such as handrail for the entrance, seating and standing passenger. Handrails at entrance and exit are assisting tools for elderly person and those have mobility difficulties to board or get off the bus. Previous study done by Shaw [15] described that the important of handrail for elderly users and suggested that the design of handrail should consider the characteristics of rail including the shape, placement, positioning, texture and visual qualities. Standing passenger's configurations involve short distance bus such as stage and school bus. In this study, it shows that all dimension required for the handrail is within the UN R36. However, in term of condition of the handrails, it reveals that 15% was not in good condition i.e. not functioning, rusted, broken, loose etc. Due to these issues, passengers that using the bus might get injury if an accident occur.

Conclusion

Bus occupant safety should continue to be of concern to all stakeholders from industry and government in order to reduce fatalities due to road accidents. Despite the statistics related to bus accident is less as compared to road accidents involving other types of vehicle, bus accident often create public attention through mass media whenever it occurred. The purpose of this study is to provide information on current situation of bus accident as well as its design and construction with regards to ergonomics issues since bus is a common public transport in Malaysia. The information covers road accident statistics and current design and construction of bus. The differences between the two regulations - UN R36 and C&U Rules - are not substantial. It is noted that most of the items needed are covered in both regulations. However, some items in the C&U Rules seem to be generic in delivering the information to the readers (public) and some of the rules are not up to date with current international standard regulations.

In term of issues with regards to ergonomics factor, boarding, alighting, and seating or leaving a seat, were common actions while travelling with the bus. Findings from previous studies show that elder passengers are vulnerable group users who commonly exposed to injury. To overcome these issues, the bus builder should consider all aspects in designing bus including safety and comfort, not only to cover elderly users only but also for all range of age groups. With the results presented, it is hope that related government or non-government agencies can convince bus industry to improve bus safety as well as comfort towards eliminating non-collision incident in bus. In the long run, occupant fatality in bus accident can be reduced significantly. Moreover, further in-depth and focused researches on the causes of injuries resulted from bus accidents should be conducted since buses are considered as popular commercial transportation in Malaysia.

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