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# Investigation of accident scenarios between pedestrians and city buses in Thailand

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## ABSTRACT

An accident between pedestrians and city buses is one cause of severe casualties in Thailand. To discover the causes of the city bus collisions with pedestrians, 22 accident cases which occurred in Bangkok and suburban areas from January 2012 to July 2013 were reconstructed and investigated. In this study, the impact speeds were estimated by data correction at the incident scene using the kinematic measurement device. Besides, these collision cases were categorized by the difference between low- and high-located windshield types with regards to the behavior and body region of pedestrian injuries. Moreover, it was discovered that pedestrian injuries were more severe at impact speeds of approximately at 20 to 50 km/h. However, the 90th percentile impact speed was not over 30 km/h. Moreover, there were 7 cases among 21 collisions (33%) in the early afternoon time (12.01am – 3.29pm) of driving period, which was almost the end of the morning shift. That was probably the result of long durations of driving, a condition which is a significant cause of fatigue-related accidents.

***Keywords:*** Accident scenarios; pedestrian; city bus.

## INTRODUCTION

In the last decade, the number of road accidents has steadily increased. Based on the statistical records of road accidents from the National Information Center of Thailand between 2003 and 2007, there were over 100,000 accident cases, 70,000 injured persons and 12,000 fatalities [1]. Traffic accidents were also considered as one of the top three public health problems addressed by the Thai Government. Therefore, there was a dramatic reduction of total accidents between 2008 and 2010. Despite the public's growth of awareness of road accident prevention due to the media, the number of fatalities increased after 2010. Pedestrians are a high-risk group for road accidents especially in urban areas. Pedestrian road accidents occur not only with the passenger cars, but also with public transportation vehicles. In a preliminary study from a Thai insurance company, it was revealed that 65% of road accidents in urban areas between 2010 and 2013 were found in public transportation, namely the "Bangkok Mass Transit Authority". The causes of injuries and fatalities among pedestrians were recorded. In addition, there is a rising trend of the accidents between city buses and pedestrians in Thailand. Victims of traffic accidents are frequently examined by practicing forensic medical persons in Thailand. Although city bus accidents are not encountered daily, most of the accidents between city buses and pedestrians are sufficiently severe to result in fatality. Moreover, head injury is one of the most common injury types, and can lead to long-term disability or death. This is relevant to international requirements from the decade of road safety strategy. Generally, there is a huge amount of studies available focusing on the accident avoidance measures of Heavy Goods Vehicles (HGV). Systems like Anti-lock Brake System (ABS), Electronic Stability Control [2] and Brake Assistance (BA) have led to a significant gain in safety in recent years. However, publications in relation to Vulnerable Road Users (VRU) of buses are rare. Most research focuses primarily on small trucks and Light Truck Vehicles (LTVs). For differences of injury patterns between flat-front and bonnet-front vehicles in Japan, Tanno, Kohno [3] investigated 101 cases of pedestrians who were struck by the front of a vehicle. The result represents that the frequency of chest injuries in flat-front vehicle collisions (30.3%) was significantly higher than that in bonnet-front vehicle collisions (11.8%). Lower leg fractures were more common in the bonnet-front vehicle collisions than in the flat-front vehicle collisions. The pedestrians who were struck by flat-front vehicles tended to sustain more severe injuries, particularly in the chest under lower impact speeds.

In the United States of America, Ballesteros, Dischinger [4] focused on the influence of different vehicle front profiles on injuries with different regions of the human body. Based on statistical records, there is a correlation between injury patterns of VRU-LTV and VRU-HGV accidents. From the Maryland Trauma Registry information, it was revealed that cars, Sport Utility Vehicles (SUVs) and pickups caused a higher risk of serious injuries to the thorax and abdomen. However, there was a lower risk of injury at the region below the knee. Furthermore, Fildes, Gabler [5] indicated that 59% of the fatalities had an Abbreviation Injury Score (AIS) 4+ at torso based on statistical records of pedestrian injuries. Furthermore, Longhitano, Henary [6] used the Pedestrian Crash Data Study (PCDS) database to study injury patterns of pedestrians struck by different vehicle types. The injury patterns of VRU hit by either a passenger car or an LTV implied that extreme thoracic injuries frequently occurred between LTV and VRU collisions. Besides, the impact area for the passenger car was frequently found at the windshield and bumper, whilst for the LTV, it was at the hood and leading edge. For this reason, the assessment of frontal impact against pedestrians should be developed for city buses based on Thai law enforcement and international regulations in order to determine relevant parameters in frontal bus design criteria. To achieve such development, the impact speed and the accident scenarios between pedestrians and city buses were first investigated in Thailand. However, the accident situation in Japan obviously reveals the basic patterns as well as mechanisms of pedestrian and vehicle collisions [3]. For other factors of road accidents, the scenario is one of the contributory factors of road accidents, for example, bad weather route conditions as well as vehicle and driving problems [7, 8]. Driving at night reduces the visibility distance by 30 - 60 %, while average normal driving visibility distance is 300 meters. The visibility distance at night is reduced to about 150 meters. In cases of using mobile phones while driving very fast at night, reaction time increases around 75 %. From the normal range of reaction time (0.675 - 2 second), the thinking time will change to be 1.18 - 4.2 second instead [9].

## STATISTICAL RECORDS AND INVESTIGATION

### Statistical records

To initiate the development of public city bus assessment based on pedestrian injury criterion in Thailand, the primary records from a public bus insurance company were used for a preliminary study. The exactitude and the details of vulnerable road user's accident data were also investigated in this study. Taking into consideration the general cases in the urban areas of Thailand, the research methodology is based on pedestrian injuries caused by bonnet- and flat-front vehicle collisions. In a preliminary study, the insurance statistical records of each frequently occurring traffic accident were investigated. It was found that 46% (N3=22) of vehicle collisions involved buses of the Bangkok Mass Transit Authority (BMTA), which employs experienced drivers with legal standard licenses from 2011 to 2013 as shown in Figure 1. According to the forensic medicine report from the insurance database, there are various possible injuries and patterns caused by different front ends of buses. In the noticeable accidental cases from the vehicle damages and pedestrian injury levels, the kinematic data and impact position from BMTA bus collision are investigated in-depth.

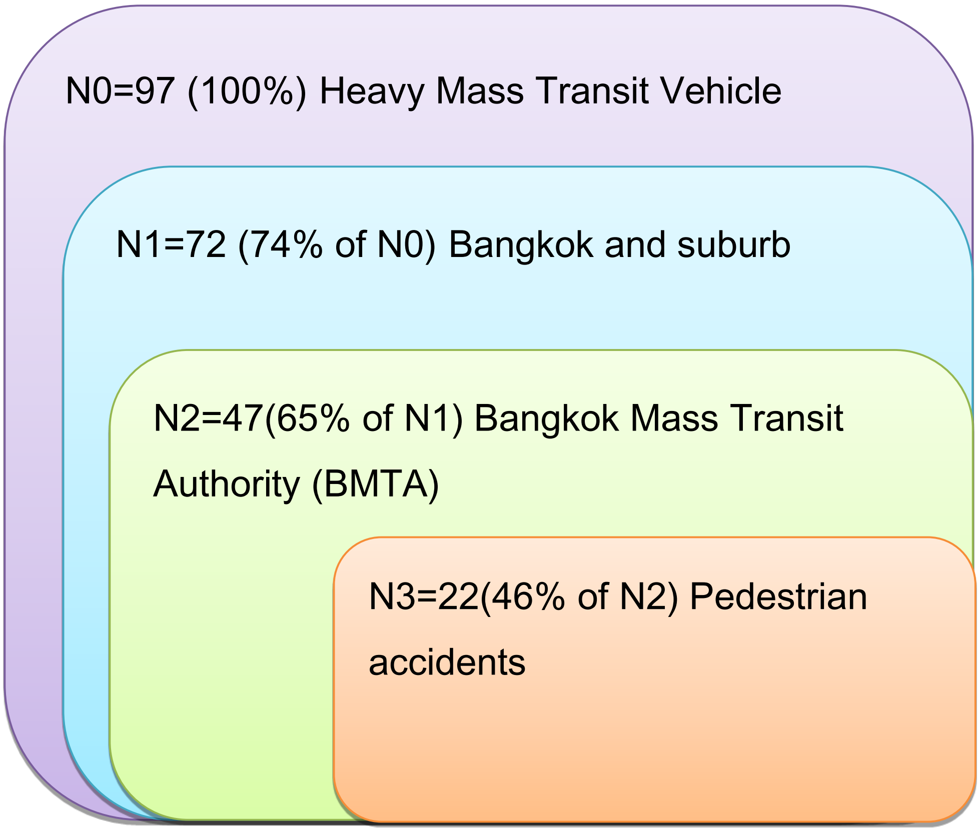



Figure 1 Accident information.

**Scenario investigation**

There are 22 pedestrian-city bus collision cases which have been fundamentally investigated, all of which occurred in Bangkok and suburban areas from January 2012 to July 2013. In all of these cases, the victims were walking or standing when they were struck run-over by the front of a vehicle. These instances excluded the cases of people who had been and the victims who were struck by the side or rear parts of a vehicle. This information is supported by the insurance company and the Bangkok Mass Transit Authority (BMTA) and subsequently, an on-scene examination was performed. At the incident scenes, the identical locations were investigated to estimate the impact speed of the vehicle as shown in Figure 2. Furthermore, the working day, time period and city bus were also estimated. Regarding accident data, pedestrian-city bus collisions were investigated in 19 (86.3%) out of the 22 cases using a kinematic measurement device called VC4000 (Figure 3), a performance and braking test computer [10] which was used to investigate vehicle speed. So, the acceleration, speed and distance information from the incident place were recorded as shown in Figure 2. However, there were 3 incident cases of 22 cases which occurred in the bus garage where the travel speed is very low. Thus, these cases were omitted for incident reconstruction. By collecting collision scenarios, not only impact speed and deceleration but also speed limit feasibility was measured.

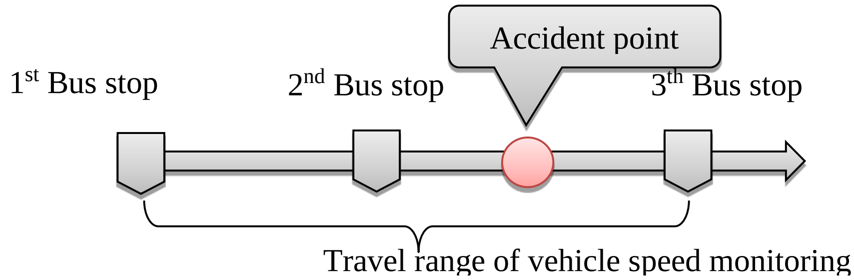
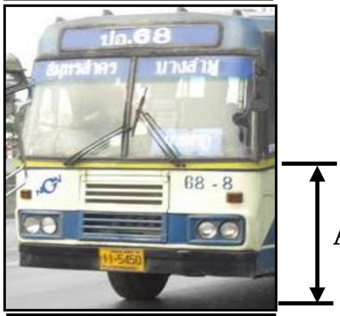
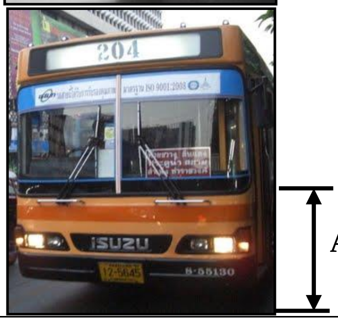



Figure 2. Incident simulation of bus impact speed for travel range of vehicle speed monitoring.


Figure 3. Kinematic measurement of public bus using VC4000.

Using insurance data as secondary source, pedestrian data such as age, sex, and body region injury patterns from the victim's medical records were obtained. The severity of the pedestrian injuries was assessed using the Abbreviated Injury Scale (AIS) and the causes of death were provided by medical doctors. Moreover, the city buses' overall of front end characteristics such as length, height, and width, as well as the front structure, were also measured. In this study of current buses, each vehicle was measured and classified into one of two groups according to the location of the windshield as shown in Table 1. The first group is the High-location windshield type (A>132cm) and the second group is the Low-location windshield type (A<132cm). Comparison of the windshield location effect on pedestrian injuries and the relationship with impact speed between the two groups was considered. In 22 cases (6 samples in the Low-location windshield group, 16 samples in the High-location windshield group), the causes of all injuries sustained by each pedestrian were diagnosed by medical forensic organizations. Cases where they were unable to determine the cause of an injury will be listed as unknown causes.

Table 1. Comparison of windshield locations.

| No. | Example Pictures | A dimension (m) | Bus Classification | |
|---|---|---|---|---|
| | | | Passenger-Service Type | Windshield Type |
| 1 |  | 1.51 to 1.62 | Non-air conditioned class | High-location |
| 2 |  | 1.32 to 1.55 | Air conditioned-old model class | High-location |
| 3 |  | 1.24 to1.31 | Air conditioned-new model class | Low-location |

## RESULTS AND DISCUSSION

### Collision scenarios between city buses and pedestrians

In this study, 21 city bus collision cases were analyzed, 6 involved victims (AIS based level: 1 critical and 5 moderate victims) who were struck by low-location windshield type buses. There were 15 victims involved (AIS based level: 2 maximum, 3 critical and 9 moderate victims) who were struck by high-located windshield type buses as shown in Table 2. Regarding this information, all victim deaths occurred with buses that had a high-located windshield type on the right side of front end bus. Furthermore, there were 52 and 48 percentage of accident possibility on left and right side of front end buses respectively. This study revealed that there was no significant influence of left or right side of front end bus and pedestrian age.

Table 2 Experimental results and medical report data of city bus collision with pedestrian

| No. | Bus classification | | Incident Time | Age (years) | Injury of body region | AIS based Level | Side of front end | Speed (km/hr) |
|---|---|---|---|---|---|---|---|---|
| | Passenger-Service type | Windshield type | | | | | | |
| 1 | Non-air conditioned class | High-location | 21.30 | 15 | Tourer | Moderate | Right | 19.84 |
| 2 | Air conditioned-new model class | Low-location | 18.00 | 26 | Head and face | Moderate | Right | 10.61 |
| 3 | Non-air conditioned class | High-location | 6.00 | unknown | Shoulder | Moderate | Left | 16.19 |
| 4 | Non-air conditioned class | High-location | 14.00 | 40-50 | Head | Critical | Right | 11.71 |
| 5 | Non-air conditioned class | High-location | 13.30 | 48 | Head | Critical | Right | 20.63 |
| 6 | Non-air conditioned class | High-location | 19.40 | 59 | Chest and intrathoracic | Maximum | Right | 19.22 |
| 7 | Non-air conditioned class | High-location | 19.58 | 30-40 | Shoulder and elbow | Moderate | Right | 19.53 |
| 8 | Non-air conditioned class | High-location | 8.00 | 45 | Shoulder | Moderate | Left | 16.18 |
| 9 | Air conditioned-new model class | Low-location | 6.10 | 20-30 | Head | Moderate | Right | 27.31 |
| 10 | Air conditioned-new model class | Low-location | 5.45 | 45 | Elbow and back | Moderate | Left | <10 |
| 11 | Air conditioned-old model class | High-location | 6.10 | 52 | Tourer and knee | Moderate | Left | <10 |
| 12 | Non-air conditioned class | High-location | 15.05 | 32 | Leg and knee | Moderate | Left | 2.67 |
| 13 | Non-air conditioned class | High-location | 7.00 | 30-40 | Head | Moderate | Left | 27.65 |
| 14 | Non-air conditioned class | High-location | 9.40 | 37 | Head and clavicle | Moderate | Left | 18.94 |
| 15 | Air conditioned-new model class | Low-location | 12.50 | 51 | Head and intrathoracic | Critical | Left | 22.43 |
| 16 | Non-air conditioned class | High-location | 1.15 | 30-40 | Head | Maximum | Right | 48.55 |
| 17 | Non-air conditioned class | High-location | 9.05 | unknown | Unknown | Moderate | Left | 20.64 |
| 18 | Air conditioned-new model class | Low-location | 13.30 | unknown | Unknown | Moderate | Left | 14.75 |
| 19 | Non-air conditioned class | High-location | 12.30 | 16 | Unknown | Moderate | Left | 17.57 |
| 20 | Air conditioned-new model class | Low-location | 22.30 | 37 | Head and body | Moderate | Right | 38.28 |
| 21 | Non-air conditioned class | High-location | 12.45 | 23 | Head and intrathoracic | Critical | Right | 24.26 |

The mean ages for both the low-location windshield type buses and the high-location windshield type buses are identical at 37 years old with Serious AIS-based level. The average impact speed of bus is assumed since the city bus should be typically decelerated by a bus driver before the incident. From the experimental study of bus speed at the incident, there are 19 cases which were not over a speed of 30 km/hr (as the 90th percentile) while only two cases were over 30 km/hr. The median impact speeds from the low- and high-located windshield types of public buses were at 22 km/h and 20 km/h, respectively. Table 3 shows the cumulative frequency of impact speed for each type. It also reveals that there are two significant parameters: the windshield location and the impact speed of the public bus. In accordance with data in Table 2, the adequacy of the developed relationship was tested using the analysis of variance (ANOVA) technique to suggest the significant additional factors. The ANOVA technique was used to ensure that the order function and regression model was adequate, as well as testing the significance of the model coefficients ANOVA was related to the independence of data and its uniformity. Table 4 and Figure 4 show the results of ANOVA for time period and windshield type response. The P statistic conveys that terms with P-value ≤ 0.05 are significant to experiment response and the probability level is over 95%, while terms with P-value ≥ 0.05 are insignificant to the response.

Table 3. The cumulative frequency data based on the impact speed and windshield types of the tested public buses.

| Impact speed (km/hr) | Low-location windshield type | | High-located windshield type | | Total |
|---|---|---|---|---|---|
| | n1 | % of T1 | n2 | % of T2 | % of T1 and T2 |
| <10 | 1 | 17 | 2 | 14 | 15 |
| 11-20 | 2 | 33 | 7 | 50 | 45 |
| 21-30 | 2 | 33 | 4 | 29 | 30 |
| 31-40 | 1 | 17 | - | - | 5 |
| >40 | - | - | 1 | 7 | 5 |
| | 6 (Total: T1) | | 14 (Total: T2) | | |

Table 4. Analysis of variance for windshield type.

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Height | 1 | 57.78 | 57.78 | 4.72 | 0.045 significant |
| Error | 16 | 196.00 | 12.25 | | |
| Total | 17 | 253.78 | | | |
| Model Summary | | | | | |
| S | R-sq | R-sq(adj) | R-sq(pred) | | |
| 3.5 | 22.77% | 17.94% | 7.21% | | |

Besides, comparison between the low- and the high-located windshield cases with the similar bus speed, as shown in Figure 5, revealed that the low-location windshield city bus collision with a pedestrian caused a critical condition at 22.43 km/hr of impact speed (left side of frontal bus), while the high-located windshield city bus collision with a pedestrian caused a fatality of the victim at 19.22km/hr of impact speed (right side of frontal bus), which was lower. It can be concluded that the location of windshield plays a major role in the injury mitigation. Furthermore, the concordance between windshield location and average human height of Thai people is shown in Table 5.

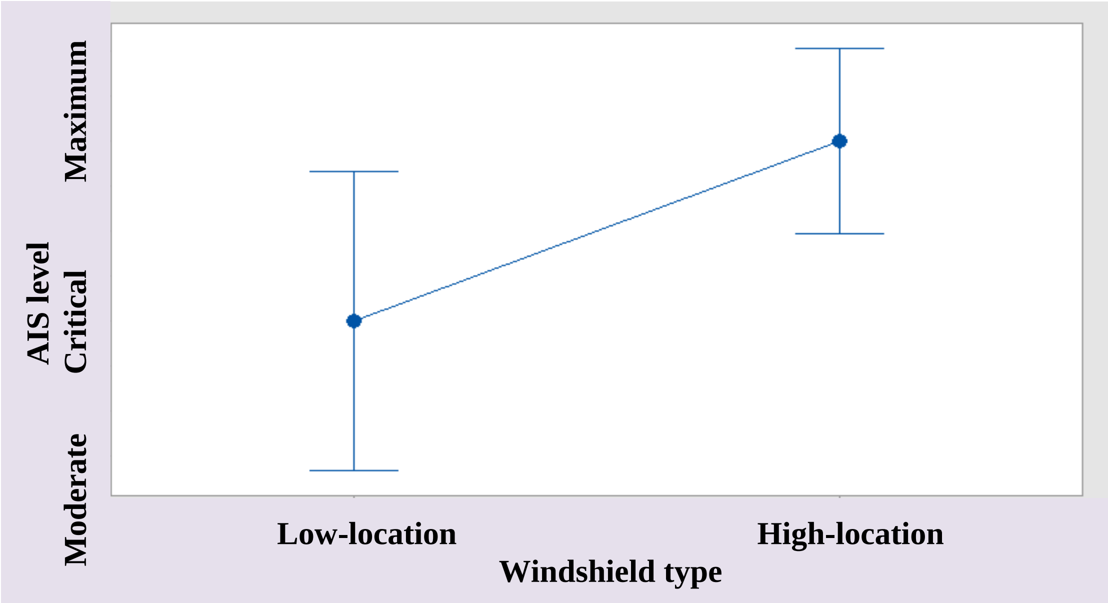



Figure 4. Height of windshield type VS effect (AIS based level).


Figure 5. The low- and the high-located windshield city bus collision damage from hitting pedestrians.

**Body region injury of pedestrian**

In Table 2, an in-depth examination of 21 total cases of bus pedestrian collisions shows that there were 15 victims who had low-located type injuries and 6 victims who had high-located type injuries. Injuries of the head and chest of victims were the most common region in both low-and high- located windshield types of buses. The frequency of head injury was significantly higher in the high-located windshield type (66%) than in the low-located windshield type (26%) as shown in Table 6. However, 7 victims (47%) sustained injuries at the chest or abdomen in the Low-location windshield type, compared to one victim (17%) in the high-located windshield type. Furthermore, there was no difference in the frequency of injury to lower extremities between the two types, though there was a difference in the distribution of lower extremity fractures. In total, one case of lower extremity fracture was observed among 15 cases (7%) in the Low-location windshield type, whereas there was one fracture case out of 6 cases (17%) in the high-located windshield type (see Table 6).

Table 5. Concordance of average human height [11] of Thai people and position of windshield on bus.

| Age(year) | Average human height (cm) | | Windshield type (cm) | |
|---|---|---|---|---|
| | Male | Female | Low-location | High-location |
| 16-25 | 171.36 | 159.32 | 124 to 131 | 132 to 162 |
| 26-35 | 170.98 | 158.28 | | |
| 36-45 | 169.49 | 157.27 | | |
| 46-59 | 168.17 | 155.56 | | |
| More than 60 | 165.57 | 153.49 | | |

Table 6. Body region injury of pedestrian.

| Body region injury | Low-location windshield type (n1) | (% of T1) | High-location windshield type (n2) | (% of T2) |
|---|---|---|---|---|
| Head | 4 | 26 | 4 | 66 |
| Chest | 7 | 47 | 1 | 17 |
| Lower extremity | 1 | 7 | 1 | 17 |
| Other | 3 | 20 | - | - |
| Total | 15 (T1) | 100 | 6 (T2) | 100 |

Most of the severe head injuries (AIS>3) in both types mainly occurred as a result of contact area between the head and the windshield frame and/or the A-pillar. Regarding the information from the experimental study of bus speed and medical records, fatalities were only found in the high-located windshield type, with the body region injuries (head, chest and abdomen) induced by the front frame. On the another hand, there were no fatalities in case of the low-location windshield type in which there was only one critical victim at the body region injuries (head and abdomen) induced by the windshield and front frame of bus.

**The Parameters which Encourage City Bus Collisions with Pedestrian**

From the total 21 cases, the time-shift period of the incidents of city bus collisions with pedestrian was also investigated. In Bangkok traffic police operations, the 24-hour time period is classified into 6 durations (see Table 7). There were two durations of the high accident frequency (5.30am -8.00am and 12.01am – 3.29pm). In the first duration (5.30am -8.00am), 6 cases among 21 collisions (29%) occurred. This is the rush hour time in which the urban people hastily go to work with lack of circumspection. In the second duration, 12.01am – 3.29pm, 7 cases among 21 collisions (33%) emerged. From a primary inquisition, the drivers who work in the morning shift need to finish their work immediately. Thus, they are not only careless, but also have a higher tendency of fatigue that induced the traffic accidents. Based on the result presented in Table 7, the adequacy of the developed relationship was tested using the analysis of variance (ANOVA) technique as seen in Table 8 and Figure 6. Furthermore, the in-depth information represents that midnight to dawn (00.00am – 5.30am) is the interval time of the highest rates of death, for which the same is true for the early evening (3.30pm – 9.00pm). Besides, both of interval times were also the periods where drivers speed more than other durations on road. These data are similar to the fatal school bus crash data in the United States of America. A majority of the school bus–related fatal crashes occurred between 6 am to 9 am and 2 pm to 5 pm [12].

Table 7. Relativity between time periods and other parameters.

| Time periods | | Frequency | | Average Speed | Maximum AIS based level from incident cases |
|---|---|---|---|---|---|
| | | n | % of T | km/hr | - |
| (1) | 0.00am-5.29am | 1 | 5 | 48.55 | Un-survival |
| (2) | 5.30am-8.00am | 6 | 29 | 20.70 | Moderate |
| (3) | 8.01am-12.00am | 2 | 10 | 19.79 | Moderate |
| (4) | 12.01am-3.29pm | 7 | 33 | 16.29 | Critical |
| (5) | 3.30pm-9.00pm | 3 | 14 | 16.45 | Un-survival |
| (6) | 9.01pm-11.59pm | 2 | 9 | 29.06 | Moderate |
| | **Total** | 21 (T) | 100 | | |

Table 8. Analysis of variance for time period using ANOVA.

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Time | 5 | 1148.2 | 229.64 | 3.83 | 0.020 significant |
| Error | 15 | 900.5 | 60.03 | | |
| Total | 20 | 2048.6 | | | |
| Model Summary | | | | | |
| S | R-sq | R-sq(adj) | R-sq(pred) | | |
| 7.74800 | 56.05% | 41.39% | * | | |

In this study, we analyzed 22 city bus collision cases with pedestrians in detail and classified the differences between low-location and high-located windshield type with regards to the behavior and body region of pedestrian injuries. Compared to the frequency of fatal accidents in the high-located windshield type, fatal accidents involving the high-located wind shield type were significantly more common. When the cause of death was observed, it was found that the upper body regions, i.e. head and chest, were subjected to high risk of injury. Besides, the same frequency of body region injuries occurred with the low-location windshield type but the injury tendency was less severe.

These injuries are probably influenced by the location of windshield. Because the front-end of city bus is almost flat and perpendicular to the road, the location of windshield and the boned structure is significantly correlated with the trunk of the pedestrian. Moreover, the lower incidence of lower leg fractures implies that the impact forces did not concentrate on the lower legs as mentioned by [13].

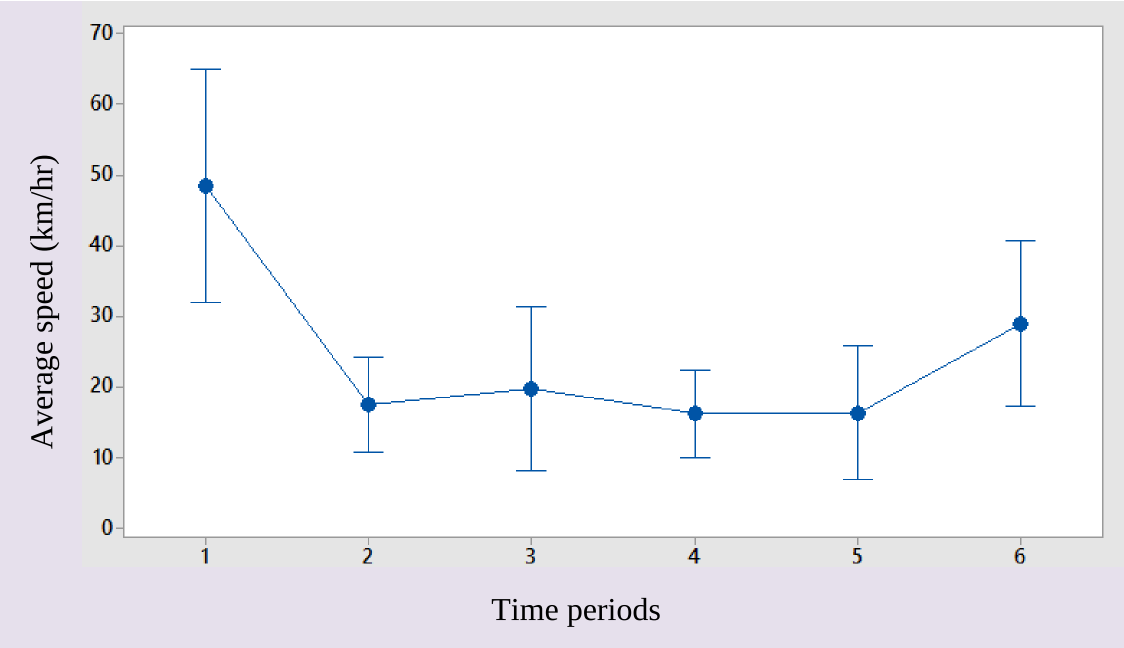



Figure 6. Time period vs. average speed.

Therefore, the pedestrian who has been struck by a city bus tends to have the load of impact spread over a larger body area and also is usually affected above the center of gravity of the pedestrian [14]. Of the parameters which make city bus collisions with pedestrians, impact speed of the bus is more likely one of the most important factors influencing the severity of pedestrian injuries. In city bus collisions, pedestrian injuries are more severe at impact speeds of bus approximately at 20 to 50 km/h. However, the $90^{th}$ percentile impact speed was not over 30 km/h. Not only impact speed but also fatigue and driving performance [15] are the major causes of road traffic accidents [16]. Regarding city bus information in urban areas, 7 cases among 21 collisions (33%) emerged in the early afternoon time (12.01am – 3.29pm), which was near the end of the morning shift. The long duration of driving condition is probably a significant cause of fatigue-related accidents. Self-rated fatigue and sleepiness conditions are typically found in the last hour of driving sessions [17], which also affect the tendency of accidents [18]. Nevertheless, 301 bus drivers (mean age = 39.1, SD = 10.7 years) completed a structured and anonymous questionnaire measuring personality traits, attitudes toward traffic safety and self-reported aberrant driving behaviors [19]. Therefore, it is recommended that, in order to mitigate the inadequacy of driving materials, the management needs to increase the awareness of the bus drivers of the factors that may lead to poor performance. Further studies involving other factors should be undertaken to increase the resources in their support. It is also hoped that this finding will help to increase awareness among bus drivers so that their performance is improved, thus leading to fewer accidents [20].

## CONCLUSIONS

In conclusion, accidents between pedestrians and city buses were investigated within 22 accident cases. In accordance with this study, these collision cases were classified by the difference between low- and high-located windshield types with regards to the behavior and body region of pedestrian injuries. Therefore, the future design for better city buses should consider the windshield height. Moreover, it was demonstrated that $90^{th}$ percentile impact speed was not over 30 km/h. It seems that this value could be used as the critical velocity of redesign city buses. Nevertheless, there was a 33% occurrence in the early afternoon time (12.01am – 3.29pm) of driving period, which was almost the end of the morning shift. That was probably due to the long duration of driving condition, which is a significant cause of fatigue-related accidents. Accordingly, the length of driving time of the work shift schedule should be considered.

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