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Safety Levels and Occupant Injury Risk for Light Commercial Vehicles in the ASEAN Region: Results of Crashworthiness Data

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ABSTRACT

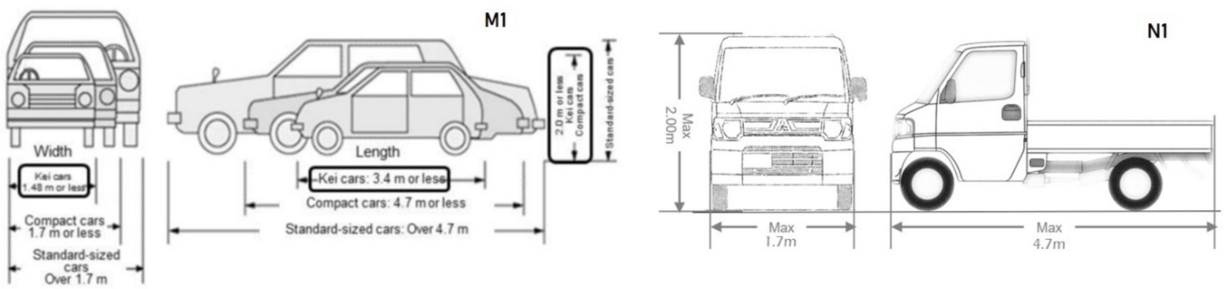
The logistics industry in Malaysia has greatly evolved in recent years. With regard to the freight industry, business operations depend on transportation service using commercial vehicles to deliver products in a timely manner. Technically categorised as N1 vehicle, the Light Commercial Vehicle (LCV) or light duty truck is designed to carry goods with maximum load not exceeding 3.5 tons. To maximize cargo size, the occupant cabin space has been pushed forward, hence, becoming a 'flat head type' vehicle. Nevertheless, the flat head vehicle fared poorly in terms of its crashworthiness performance during a frontal collision. In the ASEAN region, the automotive market for LCVs or the 'People Mover' trails behind passenger cars (M1 category) from the safety aspect where most small lorries or panel vans are sold with the lowest safety standards due to undemanding requirements and regulations imposed on this vehicle category. To examine the current issue surrounding this vehicles category in ASEAN, this paper shall discuss 1) the results of crashworthiness data for LCVs based on the assessment conducted by ASEAN NCAP and Japan NCAP and 2) review the leg injury analysis involving five LCVs tested by ASEAN NCAP. The vehicles with the worst performance for both NCAPs were compared, namely the TATA Super Ace (ASEAN NCAP) which came with no safety features, and the Daihatsu Hijet Cargo DX (Japan NCAP) which was equipped with ABS, airbag for both driver and front passenger, seatbelt pretensioner for driver and front passenger, as well as seatbelt load limiter for the driver and front passenger. The results showed that the driver and front passenger of the TATA Super Ace sustained very serious lower extremity, chest, and head injuries compared to Japan NCAP's low performing LCV. In addition, five LCV models (TATA Super Ace, Chana Era Star II, DFSK V25L, Suzuki Carry, and Cherry Transcab) were tested by ASEAN NCAP without the fitment of any protection to the driver and front passenger during frontal crashes. As a result, the occupants, especially the driver, faced a very high risk of sustaining serious lower extremity, chest, and head injuries. The crash test results led to all five LCV models tested being awarded zero-star safety rating. The injury analysis also proved that the driver fatality was greatly affected by severe injuries, or AIS 3+ in the head, lower extremity and chest. It can be concluded that the safety of LCVs in ASEAN is a cause for serious concern where improvements are urgently needed to ensure that this vehicle category is equipped with sufficient safety features.

Keywords: Commercial Vehicle; LCV; crashworthiness; ASEAN NCAP

INTRODUCTION

The logistics industry in Malaysia has greatly evolved in recent years. According to the World Bank Logistics Performance Index (LPI) in 2016, Malaysia had the highest LPI score after Singapore in the Southeast Asian region (Mordor Intelligence, 2019). With regard to the freight industry, most business operations currently depend on the transportation service using commercial vehicles to deliver products in a timely manner. In 2017, Malaysia's road freight transport industry delivered goods exceeding imports which accounted for 22.69 billion U.S. dollars. This was mainly due to growing popularity of e-commerce platforms in the country (Mordor Intelligence, 2019).

Technically categorised as N1 vehicle, the market for Light Commercial Vehicles (LCVs) or the 'People Mover' has been trailing behind passenger cars (M1 category) from the safety aspect; although various automotive players have striven to address the imbalance in this important vehicle segment. This statement is further proven upon seeing that the ASEAN automotive market offers different passive safety features between M1 (passenger vehicle) and N1 (good vehicles). As shown in Figure 1, the dimension comparison between passenger vehicle and LCV indicates that the maximum length for both vehicles must not exceed 4.7 meters. This requirement is applied to all types of LCV including pick-up trucks, panel vans and small lorries. In the ASEAN market, most small lorries or panel vans are sold with the lowest safety standards (with no airbags, seatbelt reminder, electronic stability control, etc.) due to undemanding requirements and regulations imposed on this vehicle category. A study by Alexander et.al 2004 found that little attention had been given to the safety performance of such vehicles both from the research and the regulatory point of view. With the increasing number of LCVs on the public road, it is high time for greater focus to be given to their safety performance.



Source: Japan Mini Vehicle Association

FIGURE 1. Dimension comparison of passenger vehicle (M1) and light commercial vehicle (N1)

The dimension requirement for this vehicle category has led to poor LCV frontal design. To maximize cargo size, the occupant cabin space has been pushed further forward, hence, resulting in the 'flat head type' vehicle. A number of significant studies in the U.S associating light truck vehicle (LTV) with accidents with another vehicle revealed that 81 percent of fatalities in such crashes were to occupants of the passenger car or the least aggressive vehicle (Gabler & Hollowell, 2000). The difference in structure between M1 and N1 category vehicles is illustrated in Figure 2, indicating the disadvantage of LCV with regard to the proportion of the crumple zone. In general, the structure of a flat head type vehicle worsens its crash performance during frontal collisions. Thus, the vehicle is much more dangerous than initially presumed. In the world's emerging markets including ASEAN countries, the vehicles on sale are not uniformly regulated. The WHO 2015 Status Report revealed that only 40 countries worldwide have applied all of the most important vehicle safety standards (, 2015). In fact, the findings by Gwehenberger (2002) pointed that intrusions in the lower part of the driver's cab led to injuries to the lower limbs while abdominal injuries were caused by the steering wheel.

The lack of effective vehicle safety regulation has contributed to higher road casualty rates in emerging markets including the ASEAN region and will continue to have an impact unless targeted and efficient interventions are planned and implemented immediately. Each year, approximately 50 million people are injured while another 1.3 million are killed on the roads due to road traffic accidents. More alarming is that most road traffic deaths and injuries have occurred at low and middle-income countries (ASEAN etc.) where 90 percent of the world's road traffic fatalities are taking place (WHO, 2018).

The number of traffic-related fatalities also incurs high costs far beyond the human toll. In 2009 only, the Malaysian government had spent RM 9.3 billion as a result of traffic accidents (Hamdan & Daud, 2014). Surprisingly, data of road casualties from Royal Malaysia Police (PDRM) in 2018 showed the number of accidents involving goods vehicles (lorry, 4WD, and van) was higher compared to

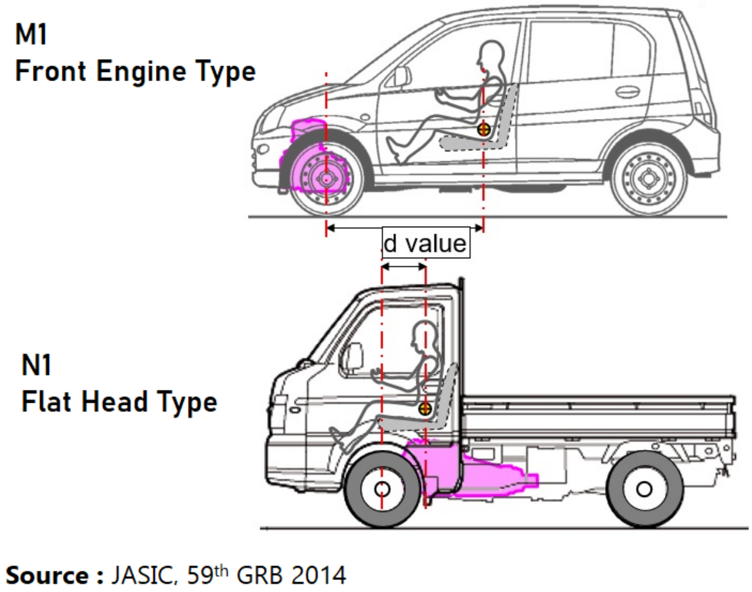


FIGURE 2. Structure design different between M1 (front engine type) and N1 (flat head type)

accidents involving motorcycles and passenger cars. Even though occupants of the goods vehicle category still registered a lower number in terms of fatalities, there is an increase of serious injury every year. In 2018 alone, a total of 181 major crashes (with high casualties) were recorded involving good vehicles, thus placing the vehicle segment as the third highest following motorcycles and passenger cars. This indicate that crashes involving goods vehicles are a serious road safety conundrum.

In Malaysia, annual statistics show that the average number of goods vehicles (used by logistic, courier company etc.) is significantly higher or approximately three times greater compared to passenger cars as reported by PUSPAKOM (TCC, 2016). The summary of road casualties for 2018 in Table 1 shows that there was a total of 327 goods vehicles (lorry, 4WD, and van) involved in fatal crashes, while another 181 were involved in serious injuries, and 262 were involved in minor injuries to the driver or passengers.

Therefore, this study seeks to explore the overall crashworthiness performance with regard to the goods vehicle category, especially LCVs sold in the ASEAN region. Occupants' injury scale during crash tests will help in the benchmarking process between ASEAN and Japan LCVs performance and thus, will allow for greater understanding of the safety level of this vehicle category.

TABLE 1. Total Number of Casualties by Type of Vehicle, 2018

Type of Vehicle	Type of Casualties		
	Death	Serious	Minor
Motorcycle	4128	1947	3738
Motorcar	1167	556	916
Pedestrian	407	156	192
Lorry	**192**	**69**	**88**
Bicycle	122	28	71
4WD	**88**	**64**	**116**
Van	**47**	**48**	**58**
Bus	39	42	61
Other vehicles	94	54	137
Total	6284	2964	5377

METHODOLOGY

CRASHWORTHINESS DATA

The study compares the safety levels and occupant injury risk of LCVs tested by ASEAN NCAP and Japan NCAP. The crashworthiness data for these LCVs were acquired from the result of frontal offset tests performed by the respective NCAPs. The vehicles involved in this study are as follows:

TABLE 2. Safety Comparison of Tested LCV

ITEM	ASEAN NCAP	Japan NCAP
Vehicle Type	Flat front type (engine below the driver's seat/ half position)	
Vehicle Category	Small Lorry/Minivan/Panel Van	
Model	i. TATA Super Ace ii. Chery Transcab iii. Suzuky Carry iv. Chana Era Star v. DFSK V25L	i. Daihatsu Hijet Cargo DX ii. Atrai Wagon iii. Honda N-Van*
Rating	0-star	4-star (driver's seat) 5-star (passenger's seat)
Specification (LxWxH)	3,993 x 1,607 x 1,908 mm (± 300mm)	3,395 x 1,475 x 1,875 mm
Engine Capacity	1083 – 1300 cc	659 cc
Safety Features	None	i. ABS ii. Airbag for driver and front passenger iii.Seatbelt Pretensioner for driver and front passenger iv. Seatbelt load limiter for driver and front passenger v. Autonomous Emergency Braking (AEB)*

NCAP DUMMY CRITERIA IN FRONTAL IMPACT TEST

The frontal offset crash test is considered the riskiest scenario in any vehicle collision event. Research by Sukegawa et. al at Japan Automobile Research Institute (JARI) reported that in 2001, numerous truck driver fatalities were caused by frontal collisions where the truck driver was often injured in the chest and abdomen by the steering wheel. To produce the injury data, instrumented dummies were used as occupants in the crash tests. For the purpose of exploring any potential improvements to LCVs, dummy injury was analyzed for both the ASEAN NCAP and Japan NCAP crash tests, and was then compared. Since the estimation of fatality risk in impacts of 64 km/h was only based on a few crash tests and the total reduction in fatalities was unreasonable, no numerical estimate was made for fatality reduction. However, crash test experts believe that the percentage change in the reduction of injuries or fatalities can be applied for the development of safer vehicles.

As specified in a research report by Accident Research Center, Monash University (1997), the New Car Assessment Program (NCAP) claimed to represent almost 60% of real-world crashes by including results from both full and offset frontal impact tests. Figure 3 shows the NCAP injury criteria limit for the frontal offset impact test. It should be noted that the crash test programs do not represent the full range of crash circumstances and abilities of a particular vehicle to protect its occupants.

JURY SEVERITY SCORE (ISS) AND ABBREVIATED INJURY SCALE (AIS)

The Injury Severity Score (ISS) is an anatomical scoring system providing an overall score for patients with multiple injuries (Javali, et al. 2019). ISS can be determined by the Abbreviated Injury Score (AIS), an anatomically-based injury severity scoring to classify injury by body region on a six-point scale. Table 3 shows an established manual that contains detailed descriptions of all the injuries normally found in the event of car crashes. Each injury is ranked based on the severity, namely 1 for minor cuts and bruises; 3 for serious injuries that require immediate medical treatment or may be life threatening; and 6 which will likely result in fatality.

It is found that threat to life is essentially the sole criterion used in deriving the AIS scores, and the functional relationship between ISS and fatality rates was explained by Stevens' psychophysical function (Huang & Marsh 1978). In addition, Huang & Marsh (1978) suggested that the probability of death could then be calculated as a measure of the total severity of multiple injuries and be presented in percentage.

Adult Occupant Protection | **AOP Assessment Protocol Version 2.0**

Dummy	Region	Points	Criteria	
Frontal Impact against ODB with 40 % Overlap @ 64 km/h				
H III 50 % front	Head, Neck	4	HIC_{15} < 500; a_{3ms} < 72 g $M_{y,extension}$ < 42 Nm $F_{z,tension}$ < 2.7 kN @ 0 ms / < 2.3 kN @ 35 ms / < 1.1 kN @ 60 ms $F_{x,shear}$ < 1.9 kN @ 0 ms / < 1.2 kN @ 25 – 35 ms / < 1.1 kN @ 45 ms	max. 16 points
		0	HIC_{15} > 700; a_{3ms} > 80 g $M_{y,extension}$ > 57 Nm $F_{z,tension}$ > 3.3 kN @ 0 ms / > 2.9 kN @ 35 ms / > 1.1 kN @ 60 ms $F_{x,shear}$ > 3.1 kN @ 0 ms / > 1.5 kN @ 25 – 35 ms / > 1.1 kN @ 45 ms	
	Chest	4	Deflection < 22 mm; VC < 0.5 m/s	
		0	Deflection > 42 mm; VC > 1.0 m/s	
	Femur, Knee	4	Axial $Force_{compression}$ < 3.8 kN Knee Displacement < 6 mm	
		0	Axial $Force_{compression}$ > 9.07 kN @ 0 ms / > 7.56 @ 10 ms Knee Displacement > 15 mm	
	Tibia Foot	4	TI < 0.4; Axial $Force_{compression}$ < 2 kN Pedal rearward displacement < 100 mm	
		0	TI > 1.3; Axial $Force_{compression}$ > 8 kN Pedal rearward displacement > 200 mm	

Source : Safety Companion 2020 (Carhs)

FIGURE 3. ASEAN New Car Assessment Program (NCAP) scoring criteria for frontal ODB test

TABLE 3. Detail description of AIS score

AIS Score	Injury	Example	AIS% Probability of Death
1	Minor	Superficial laceration	0
2	Moderate	Fractured sternum	1 - 2
3	Serious	Open fracture of humerus	8 - 10
4	Severe	Perforated trachea	5 - 50
5	Critical	Ruptured liver with tissue loss	5 - 50
6	Maximum	Total severance of aorta	100

At the current stage in vehicle passive safety assessment, the higher percentage of star rating is determined by the score for three criteria, namely:

1. Head Injury Criteria (HIC)
2. Chest deceleration
3. Femur load/ Lower Extremity

For any test vehicle to receive a high star rating which indicates good passive safety performance, all three criteria must be below the level that specifies a 10-percent chance of severe injury (< AIS 3).

CLINICALLY SERIOUSLY INJURED (MAIS3+) ROAD CASUALTIES

A casualty that sustains an injury score of 3 or higher on the AIS is classified as clinically seriously injured (MAIS3+). The MAIS3+ estimates are usually based on hospital admission data, where the AIS scores associated with the patient's injuries are used to determine whether the patient has sustained a MAIS3+ injury.

Figure 4 shows the breakdown by road user type of admissions to hospital for traffic accidents where the patient either survived or died after 30 days of being admitted in England from 1999-2011, as acquired from a report by the Department for Transport Great Britain (Lloyd et al. 2016). From the total number of people admitted to hospitals in the United Kingdom with a clinically defined serious injury following a road traffic accident, it was found that LCVs MAIS3+ was recorded at 14%. The data showed that LCV category was among the vehicle type with high MAIS3+. Further, the Department of Health and Human Services found that driving trucks was one of the occupations with the highest accident rate in the U.S. (Gregory M.S et al. 2007).

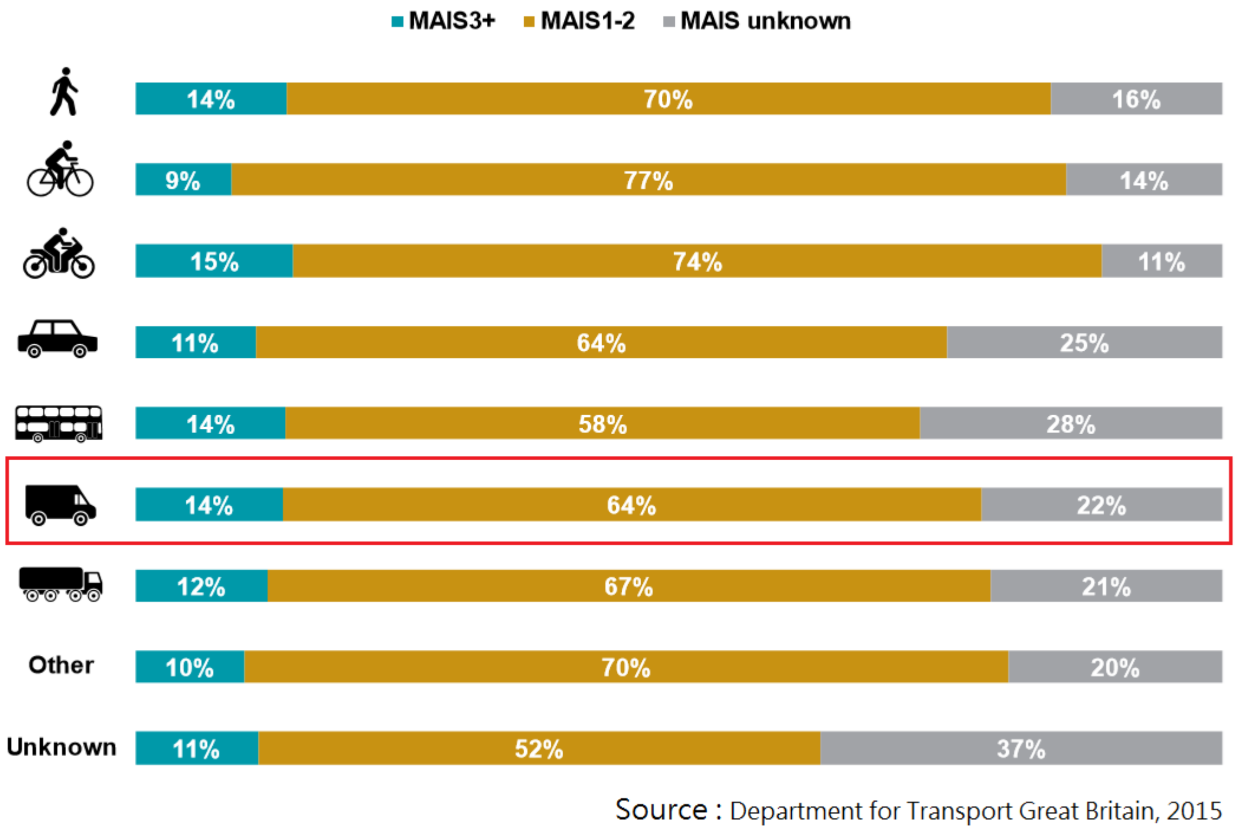


FIGURE 4. MAIS road casualties in England (1999 - 2011)

RESULTS AND DISCUSSION

Due to limitation and restriction of data from Japan NCAP, only certain information was allowed to be used. Availability of injury data posed a challenge in our effort to benchmark the injury to the driver or front occupant. Thus, only some body regions with higher risks of injury were compared including HIC15, Chest and Lower Leg. Finally, from the total of five LCV models tested by ASEAN NCAP, the TATA Super Ace was chosen because its average injury was the highest while the LCV with the worst performance according to Japan NCAP's tests was the Daihatsu Hijet Cargo DX with 4-star rating. The detailed information of the crashworthiness performance for both vehicles is shown in Table 4.

TABLE 4. The Comparison of Dummy Injury Severity During Frontal Offset Test

Frontal Offset Collision	TATA Super ACE		Daihatsu Hijet Cargo DX	
	Driver	Passenger	Driver	Passenger
HEAD				
Peak Resultant Acceleration - g	93.09	53.34		
HIC15	839.78	509.03	303	
Resultant Acc. 3 msec exeedence - g	85.40	52.87		
NECK				
Shear level exceeded - kN	0.57	1.18	0.35	
Tension level exceeded - kN	2.86	2.03	1.72	3.31
Extension - Nm	27.97	15.21	26.01	
CHEST				
Compression - mm	33.48	0.85	27.01	
KNEE, FEMUR and PELVIS				

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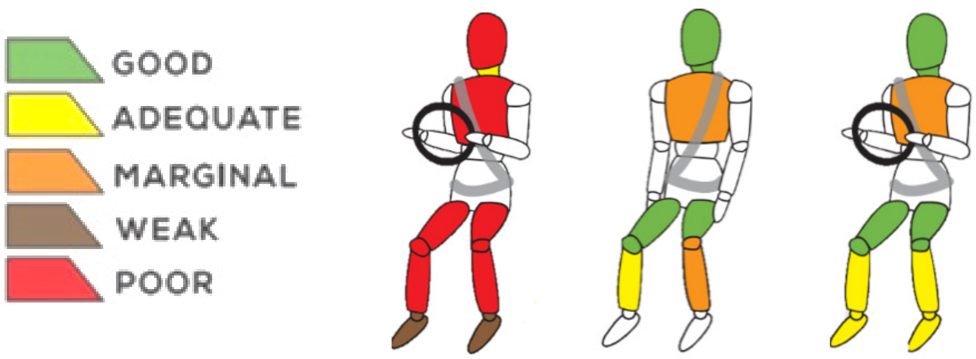
Left Knee Slide - mm	24.68	0.41		
Left Femur Compression level exceeded - kN	8.61	0.09	1.25	0.19
Right Knee Slide - mm	0.65	2.18		
Right Femur Compression level exceeded - kN	7.52	3.38	1.89	0.13
TIBIA				
Left Upper Compression - kN	1.50	0.99	0.55	
Left Lower Compression - kN	1.47	0.78	0.26	
Left Upper Tibia Index	2.62	0.91		
Left Lower Tibia Index	0.93	0.47		
Right Upper Compression - kN	1.61	1.66	0.63	
Right Lower Compression - kN	2.19	2.01	0.33	
Right Upper Tibia Index	1.65	0.45		
Right Lower Tibia Index	2.13	0.55		



The TATA Super Ace was tested by ASEAN NCAP in 2018. In Table 4, it is shown that the driver of the vehicle faced a high risk of sustaining very serious lower extremity, chest and head injuries. The TATA Super Ace had minimum safety standard and MAIS 3+ injury was expected during impact. Lower extremity injuries were mainly caused by the instrument panel and cabin floor. The most serious injuries were on the thigh, knee, lower leg and foot. Meanwhile, the chest and head injury were caused by contact with the steering column. Moreover, the absence of complete Supplementary Restrain System (SRS) such as airbag had worsened the situation.

The Daihatsu Hijet Cargo DX, on the other hand, was tested by Japan NCAP in 2005. The vehicle was equipped with complete SRS including airbag for both frontal occupants. The reduction in Head Injury Criterion (HIC) was predicted due to the presence of airbags which was required in the Japan NCAP's frontal offset test procedure. MAIS3+ injuries to lower extremity were not expected for the flat head type vehicle. The difference in percentage of injury risk to the drivers of both vehicles was compared to better understand the advantages of airbags. As shown in Table 4, the dummy injury risk is presented using colour-coding to aid understanding.

In the ASEAN NCAP test, injury to the TATA Super Ace driver was recorded at 839.78 HIC15 for the head, 33.48 mm for chest compression and an average of 1.76 kN for lower leg injury which were equivalent to MAIS 3+. This indicated over 10% risk of fatality. Meanwhile, in the Japan NCAP test, results for the Daihatsu Hijet Cargo DX showed that the occupants were two times better protected during a frontal offset crash. The driver and passengers only experienced minor injuries. Head injury value, HIC15 for the driver was recorded at 303.0, which was twice lower than the maximum permitted value. The chest compression value was 27.01mm, while the average for femur load, right tibia and left tibia rate was 1.57kN, 0.48kN and 0.96kN respectively.

Overall, the chances of a fatal or serious injury (to the driver) MAIS > 3+ due to head injury in a frontal offset crash for small lorries sold in the ASEAN region (with minimum safety features available in the market) was calculated at 1.199, compared to 0.433 for small lorries in Japan. Based on the result, it can be clearly seen that during a frontal impact crash, the driver would sustain serious lower extremity injury with a probability of 0.861 for LCVs in the ASEAN region, compared with only 0.125 for LCVs in Japan. As expected, occupant in the driver's side registered a slightly higher probability of getting injured compared to the passenger's side. In view of this, the probability of a serious injury or fatality in a frontal impact crash for a small lorry in Southeast Asia is about three times greater than for a similar vehicle type in Japan; with the head injury risk to the driver in the ASEAN region almost double compared to the passenger.

Nevertheless, the most critically impacted body region during the crash was the lower extremity with the risk of injury (to Southeast Asian driver) found to be almost 96% greater compared to the passenger. Figures 5 and 6 show actual images of ASEAN NCAP test dummy sustaining serious injury during the frontal crashes. As expected of flat head type vehicles, driver injury to the lower body region was the highest after a frontal offset collision with MAIS 3+, followed by injury to the head and chest. A similar injury pattern was observed for each of the tested vehicles leading to the conclusion that the driver of all the five LCV models sustained the highest MAIS 3+ for the lower extremity and head body regions.

FIGURE 5. ASEAN NCAP's small lorry dummy injury in frontal offset crash test

FIGURE 6. ASEAN NCAP's panel van; dummy injury in frontal offset crash test

Specifically, in most frontal collisions, the presence of airbag in a LCV could lessen the head injury sustained by the occupants. By comparing the data in Table 4, it can be seen that the airbag in the Daihatsu Hijet Cargo DX managed to reduce the impact energy to the driver's head by more than 60% in terms of HIC15 value compared to the TATA Super ACE. Thus, crash test data revealed that the availability of drivers' airbags, combined with seat belts (with pre-tensioner etc.) could reduce head impact and the stress placed on the throat as pointed by Morschheuser, (2000) in Johann et al. (2002). This finding also verified an earlier study by NHSTA in 1996 on the effectiveness of airbags. The study found that 27% of fatality reduction was estimated for light truck with airbags during frontal crashes (Kahane, 1996).

For serious-to-fatal injury and belts "as used", injuries to the head, chest and leg were substantially lower for vehicles with airbags. However, leg injury reduction for the Daihatsu Hijet Cargo DX was assumed to be influenced by other factors as well. Analysis on the leg injury suggests that the structure of the LCV affected its crashworthiness performance. Since the drivers in both vehicles were belted, the injury risks by body region were considered comparable when seatbelts were used. For the driver of the TATA Super ACE, it is believed that there was no chance of survival in a frontal crash upon sustaining a very serious-to-fatal injury to the chest, head or lower extremity.

Evaluation of the crash test data revealed that the presence of driver's airbag, combined with seatbelt usage (with pre-tensioner, etc.) can reduce head impact and pressure to the throat (Gwehenberger, Langwieder, Bromann & Zipfel 2000). However, the effort to connect the driver's injury or fatality (resulting from vehicle having no airbag) in small lorries or panel vans with the available accident database system in Malaysia was unsuccessful. There was limited information about LCV accidents in Malaysia during the study period. Therefore, the best assumption was made to estimate the general circumstances which would reflect the local scenario.

LEG INJURY ANALYSIS OF LCVS IN ASEAN NCAP ASSESSMENT

An analysis to estimate the risk of leg injuries in relation to structure design of the flat head type vehicle was also performed. Instead of depending only on energy absorption crash pillar, ideal d-value measure could be helpful in eliminating the serious-to-fatal injury during a frontal offset test. The d-value is the horizontal distance between the dummy h-point (dummy hip seating position) to the front axle. Again, it was assumed that introducing a developed design by extending the crumple zone of the flat head type could potentially reduce leg injury rate sustained by a driver in a 64 km/h offset frontal crash. It was also assumed that the severity of leg injuries was expected to reduce by increasing the d-value for each tested vehicle. As mentioned in previous research by Stucki, Hollowell and Fessahaie (1998), drivers with air bags in full barrier type impacts below 48 km/h faced a lower risk of leg injury compared to those in offset impacts. Finally, it was estimated that by introducing a minimum safety standard on LCV, namely airbags, the severity of leg injuries could potentially be reduced from AIS 3+ to at least AIS 2. Table 5 shows the lower leg (tibia) injury recorded during the frontal offset test. R-point is the vertical distance between dummy hip point to the ground.

TABLE 5. LCV tested by ASEAN NCAP; driver Tibia index

Model	d-value (mm)	r-point (mm)	Tibia index injury			
			Upper		Lower	
			Left	Right	Left	Right
Chery Transcab	600±	600±	0.96	1.36	1.06	0.96
Suzuki Carry	800±	800±	0.21	0.33	0.12	0.16
TATA Super ACE	200-300	<600	2.62	1.65	0.93	2.13
Chana Era Star II	300-500	600±	1.69	0.57	1.73	0.30
DFSK V25L	500±	700-800	0.34	0.57	0.31	0.30

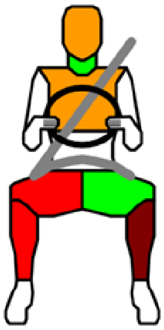
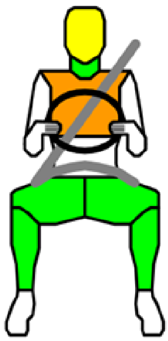
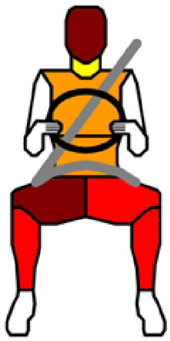
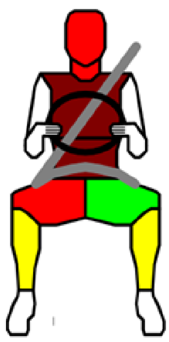
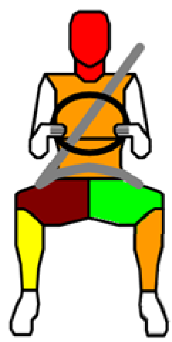
The total performance of each vehicle was then measured according to the injury scale score as illustrated in Table 6. The safety score was finalized in the form of a "star rating" ranging from 0 to 5 stars. The final rating would combine the passive and active safety assessments. The passive safety performance comprised an evaluation of the vehicle restraint system including seat belts and air bags, that were rated for their effectiveness in preventing fatalities and reducing injury severity in crashes. Nevertheless, NCAP assessment did not include adjustment for differences in driver characteristics and crash circumstances between vehicle models that might have confounded the results presented. Due to the limited data, the adjusted analysis was not achieved.

Based on ASEAN NCAP test results as shown in Table 5, all the five LCVs, namely the Chery Transcab, Suzuki Carry, TATA Super Ace, Chana Era Star and DFSK V25L were tested without the fitment of any protection to the driver and front passenger during the frontal crashes. The front occupants especially the driver face a very high risk of sustaining serious lower extremity, chest and head injuries. To aid the readers' understanding, Figures 7 and 8 display a sample color-coded injury diagram for the Chery Transcab and DFSK V25L by indicating specific body region performance.

In summary, all the LCVs tested by ASEAN NCAP were awarded zero-star rating in crashworthiness assessment as shown in Figure 9.

All the LCVs or N1 vehicles tested by ASEAN NCAP registered massive damage especially on the driver's side. The frontal compartment of each vehicle was totally deformed and post-crash rescue of the occupants was delayed as the occupants were pinned inside the vehicle. The crash impact on 40% of the frontal zone destroyed the vehicle structure especially for the LCV with d-value below 800 mm. Most of the vehicle A pillar structure had totally buckled. It was not a surprise to see severe damage to the flat head type vehicle which was designed with very small crumple zone. The crash energy during the impact was transferred to the occupants' compartment resulting in no space for the lower body part of the driver.

TABLE 6. Summary of LCV driver injury rating without modifier

	CHERY Transcab	SUZUKI Carry	TATA Super ACE	CHANA Era Star II	DFSK V25L
Rating without modifier **Points** * 4.000 * 2.670 - 3.999 * 1.330 - 2.669 * 0.001 - 1.329 * 0.000					

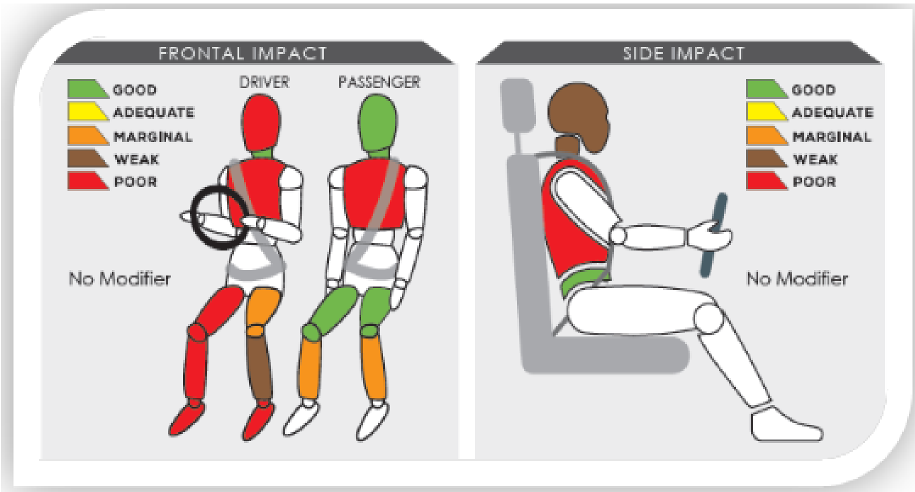


FIGURE 7. Chery Transcab dummy injury severity during frontal offset and side impact crash test.

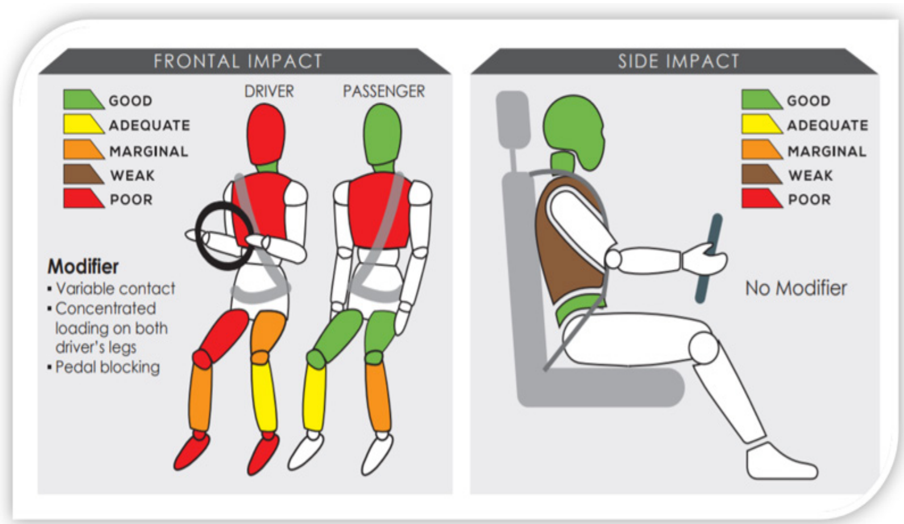


FIGURE 8. DFSK V25L dummy injury severity during frontal offset and side impact crash test.

FIGURE 9. Light LCV crashworthiness assessment rating

All the LCVs or N1 vehicles tested by ASEAN NCAP registered massive damage especially on the driver's side. The frontal compartment of each vehicle was totally deformed and post-crash rescue of the occupants was delayed as the occupants were pinned inside the vehicle. The crash impact on 40% of the frontal zone destroyed the vehicle structure especially for the LCV with d-value below 800 mm. Most of the vehicle A pillar structure had totally buckled. It was not a surprise to see severe damage to the flat head type vehicle which was designed with very small crumple zone. The crash energy during the impact was transferred to the occupants' compartment resulting in no space for the lower body part of the driver.

CONCLUSION

Both the driver and front passenger in the TATA Super Ace sustained very serious lower extremity, chest and head injuries compared to the driver and front passenger of the Daihatsu Hijet Cargo DX. The TATA Super Ace came with minimum safety standard and the driver injuries were caused by contact with the steering column. The absence of SRS such as airbag contributed to severe injury especially to the thigh, knee, lower leg and foot. It could also be seen from the results that the probability of a serious injury or fatality in frontal impact for small lorries tested by ASEAN NCAP was three times greater than for a similar type of vehicle in Japan, while head injury risk of frontal impact for a Southeast Asian small lorry driver was almost double compared to the front passenger.

As for the leg injury analysis for LCVs assessed by ASEAN NCAP, all five models, namely the Chery Transcab, Suzuki Carry, TATA Super Ace, Chana Era Star and DFSK V25L posed a very high injury risk to the occupants' lower extremity, chest and head. Consequently, all the LCVs were awarded 0-Star rating.

These results proved that the safety performance of LCVs in Malaysia was very worrying and immediate improvement were needed by fitting safety features in the vehicles. Clearly, the market for LCVs in Southeast Asia is far behind in terms of safety compared to the same vehicle segment in Japan. As explained earlier, the Daihatsu Hijet Cargo DX tested by Japan NCAP was equipped with safety features including ABS, airbag for both the driver and front passenger, seatbelt pretensioner for the driver and front passenger, as well as seatbelt load limiter for the driver and front passenger. It is hoped that Malaysia can emulate Japan by ensuring that LCVs are better equipped with such safety features. It is also recommended that more comprehensive studies of the operational characteristics of LCV drivers in Malaysia can be done, aside from studies of the relevance of regulations ECE R29 and ECE R94 for this vehicle type. ECE R29 regulation uses a pendulum which is propelled or swung with an energy of 29.4kJ. Meanwhile, ECE R94 is a dynamic crash test with a vehicle speed of 56km/h.

It is hoped that with all the study findings, various counter measures and potential improvements can be introduced to enhance the safety performance of LCVs in the ASEAN region. Moreover, enhancements can be made to better protect LCV vehicle drivers, e.g. via construction of better driver cabin, and adding supplementary restrain system. Fortunately, Malaysia will become the first country in ASEAN to adopt regulation No. 29 in 2020 (JPJ VTA 2017). This is a good sign for vehicle safety development in the country. Such an effort is in line with the target of both the United Nations and the Malaysian government to reduce global road crash fatalities. Overall, the findings in this study did not represent the whole vehicle category and it is hoped that the study may provide a temporary guidance as regards the N1 vehicle category until a more definitive safety measure can be identified or developed by future researchers.

As Malaysia moves toward becoming a developed and high-income nation, the motorization in the country has increased exponentially. Popularity of food trucks and e-commerce platforms have also led to the high demand of the transport and logistics industry, especially in respect to the LCV category. This has increased traffic exposure which then leads to more road traffic crashes. It is hoped that Malaysia can emulate Japan by ensuring that LCVs are equipped with better safety features. It is also recommended that more comprehensive studies of the operational characteristics of LCV drivers in Malaysia can be conducted, aside from studies of the relevance of regulations ECE R29 and ECE R94 for this vehicle category.

The number of lives saved and potential lives to be saved may not be easily derived via an accident report or case-by-case examination. Even with vehicle crash test data, it would be exceedingly difficult and highly subjective to foresee the extent of fatality or severe injury in any road crash event. Based on the literature study, although road crashes cannot be completely prevented, the crash rate can be reduced to a certain degree through appropriate engineering remedial actions and road safety management (Ganguly, Gupta & Mishra 2014).

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DECLARATION OF COMPETING INTEREST

None

REFERENCES

Alexander Berg, Peter Ricker. Markus Groer, Walter Niewohner. 2004. Safety of Light Commercial Vehicle in the light of the results of accident analyses and testing DEKRA Automobil GmbH, Stuttgart Germany. (No 181).

Gabler, H. & Hollowell, W. 2000. The crash compatibility of cars and light trucks. *Journal of Crash Prevention and Injury Control*. 1. 10.1080/10286580008902550.

Ganguly, R., Gupta, A. K. & Mishra, M. 2014. Traffic volume and accident studies on NH-22 between solan and shimla. *European Scientific Journal*: 248 - 254.

Gregory M. S and Michael H. Belzer. 2007. Truck Driver Occupational Safety and Health. Department of Health and Human Services. National Institute for Occupational Safety and Health. US

Gwehenberger, J., Langwieder, K., Bromann, G. & Zipfel, D. 2000. Injury Risk for Truck Occupants due to Serious Commercial Vehicles Accidents – Results of Real-World-Crash Analysis.

Hamdan, N. & Daud, N. 2014. Estimating cost ratio distribution between fatal and non-fatal road accidents in Malaysia. AIP Conference Proceedings, V1605: 1051-1055.

Huang, L. C., & Marsh, J. C. 1978. AIS and Threat to Life. *American Association for Automotive Medicine, 22nd Conference, and the International Association for Accident and Traffic Medicine, VII Conference* (pp. 242-254). Morton Grove: Association for the Advancement of Automotive Medicine (AAAM).

Javali, R. H., Krishnamoorthy, Patil, A., Srinivasarangan, M., Suraj, & Sriharsha. 2019. Comparison of injury severity score, new injury severity score, revised trauma score and trauma and injury severity score for mortality prediction in elderly trauma patients. *Indian Journal of Critical Care Medicine: peer-reviewed, official publication of Indian Society of Critical Care Medicine:* 73-77.

Johann Gwehenberger, Klaus Langwieder, Guido Bromann & Dieter Zipfel. 2002. Injury Risk for Truck occupants Due to Serious Commercial Vehicles Accidents; Results of Real-World Crash Analysis. German Insurance Association, Institute for Vehicle Safety (Germany)

Joksch, H. 1993. Velocity change and fatality risk in a crash – a rule of thumb. *Accident Analysis & Prevention* 25(1): 103–4.

Jabatan Pengangkutan Jalan Malaysia. 2017. Bahagian Kejuruteraan Automotif JPJ, Garis Panduan Kelulusan Jenis Kenderaan (VTA) (Pindaan) 2017. 4-123.

Kahane, C. J. 1996. *Fatality Reduction by Air Bags: Analyses of Accident Data through Early 1996.* Washington, D.C.: NHTSA.

Lloyd, D., Baden, P., Mais, D., Marshall, A., Bhagat, A., & Wilson, D. 2016. *Reported Road Casualties Great Britain: 2015.* London: Department for Transport National Statistics.

Mordor Intelligence. 2019. *Malaysia Road Freight Transport Market.* Retrieved from Mordor Intelligence. https://www.mordorintelligence.com/industry-reports/malaysia-road-freight-transport-market

Morschheuser K. 2000. Airbags in trucks, vehicle airbags - milestones in occupant safety with residual risk, Conference in the House of Technology, München, 23.-24. März 2000

Stucki, S. L., Hollowell, W. T., & Fessahaie, O. 1998. Determination of Frontal Offset Test Conditions Based on Crash Data. *Proceedings of I6th ESV Conference,* (pp. Paper No. 98-SI-O-02).

Sukegawa, Y., Matsukawa, F. & Masuda, N. 2001. Experimental Research on Truck Driver's Safety in Frontal Collision. Japan: Japan Automobile Research Institute & Japan Automobile Manufacturers Association Inc.

Transport and Climate Change project (TCC). 2016. Malaysia Stocktaking Report on Sustainable Transport and Climate Change. ASEAN - German Technical Cooperation. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

WHO. 2015. *Global Status Report on Road Safety 2015.* Switzerland: World Health Organization.