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Driver's Injury Severity in Light N1 Vehicles Derived from Crash Test

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ABSTRACT – *Light N1 vehicles, also known as Light Commercial Vehicles (LCVs), of two types are being considered for this study: panel vans and small lorries. This paper presents the causes of driver injury in light N1 vehicles derived from official ASEAN NCAP crash test data. Companies employ all sorts of vehicles to help expedite the delivery process, but having considered the large amounts of orders globally, keeping costs low is also of top priority. To overcome this problem, companies now employ the use of LCVs, which not only are smaller in size allowing them to maneuver through small lanes easily but are relatively inexpensive to run in comparison to their larger counterparts. LCVs fall under the N1 category of vehicles which is an EU classification of vehicles that are used to carry goods of maximum mass not exceeding 3.5 tons and they commonly can be found carrying goods either on the exposed cargo trunk or within a compartment at the rear of the vehicle. However, the structural integrity and crashworthiness performance of these vehicles were hardly a point of focus, and this increases the potential risk of severe injury or fatality among the occupants. The rising numbers of light N1 vehicles on public roads are of great concern due to the lack of technical data concerning stability and crash protection. To have a look into this issue, a detailed analysis of the ASEAN NCAP crash test result along with high-speed videos will determine the causes of the driver's injury during the frontal collision. The results of these tests would provide a detailed understanding of driver injury on the head, chest, and leg upon impact, and would then allow the development of effective countermeasures to enhance the safety level of this vehicle segment in the ASEAN region.*

KEYWORDS: Crashworthiness, ASEAN NCAP, crash test, N1 vehicles

1. INTRODUCTION

The automotive industry has grown at exponential rates over the past few decades. Newer designs of vehicles have been introduced over the past and development is still taking place as we speak. Having a wide range of vehicle types around the globe can often make it difficult to specify where each of these vehicles can be used. To help simplify this situation, vehicles have been categorized under various codes to identify them separately. The categorization is generally done based on the size of the vehicle itself but has been further broken down to the weight they can carry, the dimensions of the vehicle, and the design of the vehicle. The classification will allow regulations to be implemented according to the purpose of the vehicle. Table 1 below shows the list of categories available, and the type of vehicle associated with the category. This paper chooses to focus on and discuss the N1 category of vehicles, light-duty trucks. The vehicles in this category can also be addressed as light commercial vehicles (LCV) or light duty trucks which are commonly found in the form of "flat head type" and were designed to carry goods with a maximum weight not exceeding 3.5 tons.

TABLE 1: Vehicle categories

Categories	Type of Vehicle
L	Motorcycle
M1	Passenger vehicle
M2, M3	Bus
N1	Light duty truck
N2, N3	Heavy duty truck
O	Trailer

Source: Malaysian Road Transport Department (JPJ, n.d.)

The demand for N1 vehicles has been rising rapidly and has been projected to do so for the following decade. According to the Malaysian Automotive Association (MAA, n.d.), 54,108 commercial vehicles were registered in Malaysia in 2019 and 15,799 commercial vehicles up to March 2020. Ho et al. (2017), state that a commercial vehicle is the backbone of the logistics, which drives a vibrant economy of a country. However, the use of these vehicles also means a rise in accident rates with N1 trucks, and in Malaysia, the fatalities caused by traffic accidents involving N1 commercial vehicles are worrying. The General Insurance Association of Malaysia is concerned over the recent spate of accidents involving commercial vehicles. As reported by the Ministry of Transport (MOT, 2018), a total of 44,243 road accidents involving lorries and buses were recorded in 2018 only. By comparison of structure aggressive metrics, light N1 vehicles are among the lowest before the small passenger vehicles category. According to Jeon et al. (2017), truck occupants have a greater risk of serious injury than those of other types of vehicles in frontal crashes.

To conduct a study on the structural strength and occupant protection and safety of N1 vehicles, five models of light commercial vehicles with the least amount of safety features sold in the ASEAN region were tested by ASEAN NCAP at MIROS PC3 lab. The safety standard assessment would involve analyzing the injury scores that were obtained from the sensors installed in various body regions of the dummies such as the head, chest, and leg. A color-coded injury diagram, that was introduced and adapted from Euro NCAP protocols, would be used to indicate how specific body regions performed in the test (Kassim et al., 2018). The five vehicles tested consist of two models of panel vans, Chana Era Star II and DFSK V25L along with three models of small lorries, Chery Transcab, Suzuki Carry, and TATA Super Ace. Table 2 below shows the specifications of the five models of N1 vehicles tested by ASEAN NCAP. It is observed that all of the mentioned N1 vehicles received an appalling zero-star rating for the ASEAN NCAP assessment. Table 2 below shows a breakdown of the details of the tested vehicles along with the ASEAN NCAP rating for each. Certainly, the tested vehicles had not been produced to the global safety standards and its occupant's protection performance was highly questionable.

TABLE 2: The specifications of N1 vehicle models

Specifications	Chery Transcab	Suzuki Carry	TATA Super Ace	DFSK V25l	Chana Era Star II
Year Built	2017	2017	2018	2019	2019
Model Year	2017	2017	2018	2019	2019
Vehicle Category	Small Truck	Small Truck	Small Truck	Panel Van	Panel Van
Engine Capacity	1.1 L	1.6 L	1.4 L	1.3 L	1.3 L
Kerb Mass	1,041 KG	1,107 KG	1,260 KG	1,255 KG	1,115 KG
Steering Airbag	Not installed	Not installed	Not installed	Not installed	Not installed
NCAP rating	Zero Star	Zero Star	Zero Star	Zero Star	Zero Star

In 2020, Malaysia introduced ECE R29 as a safety regulation on frontal protection for N1 vehicles as mentioned in Table 3. This regulation was found to have been implemented in Europe since 2011. Woodrooffe and Blower (2015) stated that in January 2011, Regulation 29 (R29) took effect concerning the protection of the occupants of commercial vehicles under the N1 category.

TABLE 3: Regulations used in various countries

Regulations	Light Commercial Vehicle				
	Malaysia	**Japan**	**Europe**	**USA**	**Australia**
Frontal impact	ECE R29	Article 18	ECE R29	FMVSS No. 208	ADR 69
Year implementation	2020	1998	2011	June 2012	July 1998
NCAP	ASEAN NCAP	JNCAP	Euro NCAP	US NCAP	ANCAP
Star rating for tested N1 vehicle	Zero star	4-Star	-	-	-

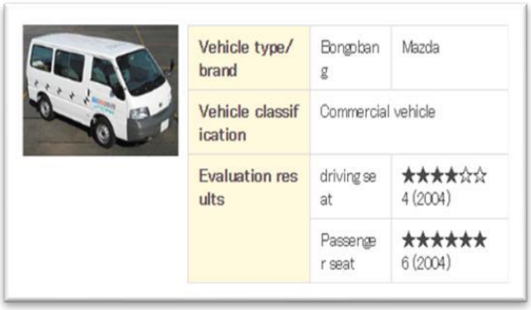
In Japan, Article 18 was implemented as a vehicle safety regulation for LCVs. According to Sukegawa and Matsukawa (n.d.), the guidelines for crash tests of buses and trucks can evaluate occupant injuries similar to frontal impact regulation for passenger cars in Japan (Article 18, Safety Regulation for Road Vehicles). Moreover, vehicles under this category were allowed to serve particular routes on regular timetables only (Flath, 2000). Thus, it shows that regulations implemented in Japan regarding motor vehicles are fairly strict especially when it comes to the usage of N1 vehicles on public roads. As reported by the Japan Automobile Manufacturers Association (JAMA, 2008), 60% of panel vans or minivans in Japan were used primarily for commercial purposes, 39% for passenger transport, and the remaining 1% for other purposes. Further detailed research has shown the usage of small trucks or mini-trucks concerning each sector, where 40% were used in agricultural work such as paddy farming while 56% were used for carrying goods and the remaining 4% were for other job descriptions. Vehicles of this category have been restricted to operate in certain areas only. Doing so allows better control of vehicles on the road, imposing speed limits and further restrictions that would help reduce accidents and in turn, save lives.

When comparing both ASEAN and Japan crashworthiness performance on these light commercial vehicles, the average scoring for the ASEAN market was a zero-star rating whereas a 4-star rating (driving seat) was reported for the Japanese market. On the other hand, no records were found in Europe as Euro NCAP does not intend to assess vehicles within this category. The majority of variants in Europe have a GVW greater than 3.5 tons (Euro NCAP, 2015). Based on Table 4 below, it is observed that N1 vehicle safety in Japan is significantly better compared to that of the ASEAN region. Having such ratings helps us understand that commercial vehicles in Japan have been equipped with adequate safety features and structural design characteristics to protect the occupants from fatal injuries. The presence of airbags in the vehicle tested by JNCAP has aided the safety of the driver which is quite the opposite of the vehicle tested by ASEAN NCAP. The lack of an airbag has caused serious injuries to the dummy which allows a conclusion on the benefits of the presence of, what we now consider a basic safety feature, an airbag. Airbags are effective in reducing serious injuries when involved in frontal crashes. With this information, Malaysia should take the safety of occupants in light commercial vehicles into consideration and modify regulations to ensure the reduction of deaths and serious injuries especially since the rising number of these vehicles are being used on roads and highways daily.

This paper observes the crashworthiness performance of light N1 vehicles tested by ASEAN NCAP. Dummy injury data during the frontal offset crash test has been analyzed to identify the common cause of severe injury or fatality to the light N1 vehicle driver.

TABLE 4: Star rating for JNCAP and ASEAN NCAP

JNCAP	ASEAN NCAP



Vehicle type/ brand	Bongoban g	Mazda
Vehicle classif ication	Commercial vehicle	
Evaluation res ults	driving se at	★★★★☆☆ 4 (2004)
	Passenge r seat	★★★★★★ 6 (2004)

Source: JNCAP

Source: ASEAN NCAP

2. METHODOLOGY

Comparison between five different models of light N1 category vehicle known as LCV, Chana Era Star II, DFSK V25L, Chery Transcab, Suzuki Carry, and TATA Super Ace. These five models have been tested by ASEAN NCAP to understand its crashworthiness level. However, the research focuses on the injuries endured by the occupants upon frontal crashes only. According to the Insurance Institute for Highway Safety and The Highway Loss Data Institute (IIHS-HLDI), a frontal crash is the most common type of crash resulting in fatalities. As reported by the Royal Malaysian Police (RMP) from year 2013 to 2015, most of the accidents that occurred in Malaysia involving N1 category vehicles were frontal collisions, along with loss of vehicle control that could also lead to rear-end collisions.

The measurement of the injury on the head, chest, and tibia of the five N1 vehicle models in frontal offset collision was derived from ASEAN NCAP crash test data by analyzing the kinematic movements of the dummy from the high-speed crash test video. Figure 1 shows the methodology process. The tests were conducted at MIROS PC3 crash lab in Melaka, Malaysia from year 2016 to 2019. Structural deformation of the vehicles during the impact is also of focus and observation.

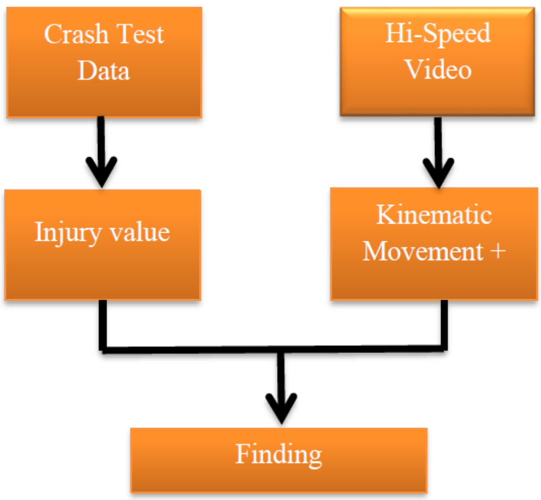


FIGURE 1: Research methodology

3. RESULTS AND DISCUSSION

Having conducted the frontal impact crash test for all five sample vehicles a detailed study on the results allows a better understanding of the damages incurred by both the vehicle and the dummy. Analysis of the results is focused on injuries to the dummy and structural deformation of all five N1 vehicles. Areas of interest about injury on the dummy are focused on the head, chest, and leg. The impact values were obtained by the sensors installed which will measure and proceed to store dummy responses either by physical impacts or the movement of body parts during the crash. The frontal structure deformation will justify the severity of the injury and its corresponding scores.

3.1 Dummy Injury Data

As shown in Table 5 below, the resultant injury on the head of the dummy is certainly severe for the Chana Era Star II and DFSK V25L. These panel vans have a higher value of resultant acceleration at 3m/sec along with a higher value of Head Injury Criteria (HIC15). This value shows that the driver of these panel vans would sustain serious fatal injuries to the head and chest leaving chances of survival minimal. As for the leg of the dummy, it can be observed that the Tata Super Ace has the highest value of tibia index in comparison to the other four models which would cause the driver of this vehicle to sustain serious injuries to the tibia upon frontal collision.

TABLE 5: Driver's injury on five models of N1 vehicle by ASEAN NCAP

<table>
<tr><th colspan="3" rowspan="2">Driver's Injury</th><th colspan="2">Panel Van</th><th colspan="3">Small Lorry</th></tr>
<tr><th>Chana Era Star II</th><th>DFSK V25L</th><th>Chery Transcab</th><th>Suzuki Carry</th><th>TATA Super Ace</th></tr>
<tr><td rowspan="2">Head</td><td colspan="2">HIC 15</td><td>560.1</td><td>1,358</td><td>595.61</td><td>395.37</td><td>839.78</td></tr>
<tr><td colspan="2">Resultant Acc. 3 m/sec- g</td><td>98.37</td><td>141.51</td><td>80.53</td><td>72.18</td><td>85.4</td></tr>
<tr><td>Chest</td><td colspan="2">Chest compression - mm</td><td>43.72</td><td>33.99</td><td>33.44</td><td>35.65</td><td>33.48</td></tr>
<tr><td rowspan="4">Tibia</td><td rowspan="2">Tibia Index (upper)</td><td>Right</td><td>0.57</td><td>0.57</td><td>1.36</td><td>0.33</td><td>1.65</td></tr>
<tr><td>Left</td><td>1.69</td><td>0.34</td><td>0.96</td><td>0.21</td><td>2.62</td></tr>
<tr><td rowspan="2">Tibia Index (lower)</td><td>Right</td><td>0.30</td><td>0.30</td><td>0.96</td><td>0.16</td><td>2.13</td></tr>
<tr><td>Left</td><td>1.73</td><td>0.31</td><td>1.06</td><td>0.12</td><td>0.93</td></tr>
</table>

3.2 High-Speed Video

The high-speed video serves the purpose of allowing an in-depth study of the collision. The video could be watched repeatedly and can also be set at different frame rates to slow down or speed up the crash. These videos are stored for future reference. This paper will analyze and study the high-speed video of the sample vehicles recorded by the ASEAN NCAP Crash Test. From this video, we can analyze the performance of the vehicles, the structure deformation, and the dummy condition before and after the crash. Below are some action shots taken of the five sample vehicles before and after the crash test ('d-value' is the horizontal distance between the front axle and the driver's hip-point; the crumple zone is an area on the frame of a vehicle that is designed to crumple or deform when external force impacts the vehicle).

3.2.1 Chery Transcab (Small Lorry)

Chery Transcab falls under the category of small lorry/truck, it functions as a goods carrier and could also be used to carry passengers. The Chery Transcab is designed with an open rear trunk, like that of pick-up trucks, to allow better utilization of space to carry cargo. Figure 2 shows the vehicle and the position of the dummy before the impact. Through observation, the horizontal distance between the front axle and the driver's seat R-point is approximately 600±mm. From a visual inspection standpoint, the crumple zone (yellow region) seems inadequate to effectively distribute energy throughout the vehicle and protect the occupants during frontal collision.

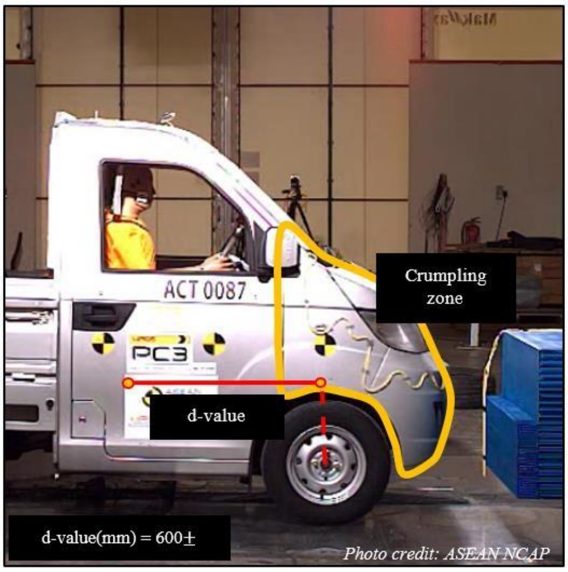


FIGURE 2: Pre-crash image of Chery Transcab

Figure 3 shows the deformation of the frontal structure of Chery Transcab during impact. 50% of the driver's survival space had been destroyed. The intrusion into the cabin was extensive resulting in higher injuries to the dummy's legs. The injury value for the upper tibia index is 1.36 for the right and 0.96 for the left tibia. The lower tibia index was 0.96 for the right and 1.06 for the left. The figure also depicts the initial contact between the dummies and the steering. Observations show that upon impact the dummy's head thrusted towards the steering wheel and the lack of an airbag caused severe head injury resulting in the HIC15 value to be 595.61 and resultant acceleration at 3m/sec to be 80.53G.

FIGURE 3: Chery Transcab image at t = 0.1ms during impact with driver close-up view

3.2.2 Suzuki Carry (Small Lorry)

The Suzuki Carry falls under the category of small lorry. This vehicle was sold in Thailand, Indonesia, Malaysia, Myanmar and Vietnam markets. The model comes with a semi-forward flathead-type design. This particular vehicle was tested in the year 2017 with no safety features offered, thus scoring no points in the Safety Assist pillar assessment.

Figure 4 shows the frontal design structure of Suzuki Carry. When compared with other N1 vehicles that have been tested, Suzuki Carry has the largest crumple zone, which is assigned as the yellow region, as well as the largest d-value at 800±mm.

FIGURE 4: Pre-crash image of Suzuki Carry

Figure 5 shows the results of the crash test on Suzuki Carry. The head of the dummy nearly came in contact with the steering wheel as the seatbelt held the dummy well. This also proves that a larger crumple zone can absorb the energy and transfer it throughout the vehicle better. We can see that the dummy's position concerning the door frame, steering wheel, and panel after the crash test indicates that the driver's crumple zone was maintained reasonably well. The dummy only happens to have a slight chest compression of 35.65mm. Moreover, intrusion into the driver's space was minimal, and all leg and foot-related injury measures were low. Figure 5 also shows the dummy's head hit the B-pillar of the truck during rebound. Having only a slight hit to the B-pillar as well as zero contact with the steering wheel, the head injury value of the dummy in Suzuki Carry was low. The resultant acceleration and HIC15 are 72.18G and 395.37respectively. This allows a conclusion that having a larger d-value benefits occupants in terms of collision safety, restricting the driver from having contact with the steering wheel or the front compartment and also maintaining a safe distance when a crash occurs.

FIGURE 5: Suzuki Carry image at t = 0.1 ms during impact with driver close-up view

3.2.3 TATA Super Ace (Small Lorry)

TATA Super Ace is one of the N1 vehicles that was designed with a full-forward cabin. This flat-head type vehicle was introduced in the Malaysian market in the year 2018. The frontal design is also known as the full forward flat head type.

Figure 6 shows the condition of the Tata Super Ace before the crash test. When compared to the other model of the N1 vehicle, the TATA Super Ace has the smallest d-value between the front axle and the driver's seat which is between 200mm to 300 mm. From initial visual analysis, it can be seen that the driver's leg was placed within the crumple zone (yellow area). The design of the TATA Super Ace is particularly not safe as the dummy position was mostly in the survival space.

FIGURE 6: Pre-crash image of TATA Super Ace

Figure 7 shows the action shot during the t = 0.01 ms of impact. It can be observed that the driver's survival space or the crumple zone did not sustain the impact well. The impact had destroyed approximately 86% of the residual space. Observation shows that upon collision the dummy's head thrusted towards the steering wheel and the lack of an airbag caused severe head injury during impact. As seen from Table 5 the HIC15 value is 839.78 and the resultant acceleration is 85.4G. There was small compression to the chest (33.48mm) due to the impact of the steering wheel and compression of the seat belt. Figure 12 shows the post-crash view from the driver's side. Due to the driver's seating position being in the crumple zone and smaller d-value, the intrusion of the frontal compartment consequently trapped both dummy's legs. The highest injury value of the tibia index was recorded as shown in Table 5. For the right leg, the upper tibia index is 1.65 while the lower tibia index is 2.13. For the left leg, the upper and lower tibia index are 2.62 and 0.93 respectively.

FIGURE 7: TATA Super Ace image at t = 0.1 ms during impact and dummy post-crash position

3.2.4 Chana Era Star II (Semi-panel Van)

Chana Era Star II is a semi-panel van that was built and produced in the year 2019. This vehicle does not come with airbags and does not have any other safety assist technology such as Antilock Braking System (ABS) or Seatbelt Reminder (SBR). Figure 8 shows the design of the vehicle's frontal structure before the impact. The 'd-value' of Chana Era Star II was measured to be between 300mm to 500mm while the crumple zone had been indicated with the yellow line.

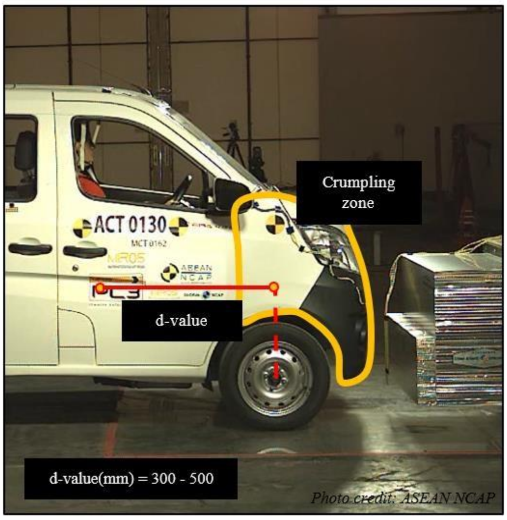


FIGURE 8: Pre-crash image of Chana Era Star II

Figure 9 shows the action shot taken during the driver-side offset frontal crash test at t = 0.1ms. As seen in the figure, can be observed that the frontal structure of this model was unable to withstand the impact well. The driver's survival area has lost 80% of its initial compartment. Both the door frame and the A-pillar are seen to have deformed extensively. Further study on the dummy had shown that, upon impact, there was a direct collision between the dummy's head and the steering wheel. This, along with the movement of the driver seat forward from its initial position, has caused the dummy to be trapped in a very tight space. This test shows that the lack of an airbag has severely impacted the dummy causing the head to collide with the steering. Thus, the chances for the head to collide with any stiff structure (under various conditions) are high. The value of resultant acceleration was at 3m/sec and HIC15 for this model is 98.37G and 560.1, respectively.

FIGURE 9: Chana Era Star II image at t = 0.1ms during impact with driver close-up view

Figure 10 shows the impact on the legs as a result of the massive intrusion into the driver's cabin. The driver's lower extremity had sustained severe injuries with the upper tibia index value recorded at 0.57 and 1.69 for the right and left respectively followed by a lower tibia index of 0.30 and 1.73 for the right and left respectively. The obtained values were above the NCAP threshold limits.

FIGURE 10: Post-crash tibia position

3.2.5 DFSK V25L (Semi-panel Van)

The DFSK V25L is a semi-panel van that was built and produced in 2019. The design of DFSK V25L in Figure 11 is found to be like that of the Chana Era Star II. The frontal structure of the DFSK V25L is commonly addressed as a semi-flat-head design. The d-value for this model is found to be 500±mm. Similar to the previous tested models, the crumple zone had been indicated with the yellow line, and with a closer study the crumple zone of the DFSK V25L is found to be smaller than that of Chana Era Star II, which from a visual analysis standpoint, seem insufficient to effectively absorb and distribute the energy from the impact.

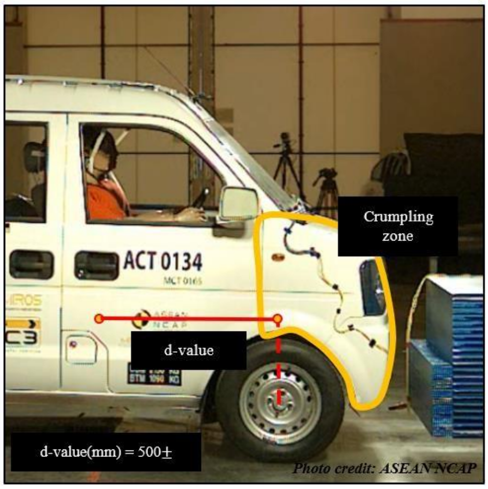


FIGURE 11: Pre-crash image of DFSK V25L

Figure 12 shows the action shot taken during the offset frontal crash test on the driver's side. Just like the previous model tested the front of the vehicle was unable to maintain its structural integrity which had further impacted the door frame and the A-pillar. Further study of the body structure has shown that the severity of the impact was due to the smaller crumple zone region, causing an inefficient energy distribution throughout the vehicle.

Figure 13 shows the condition of the dummy from within the cabin after the crash test. The effects of impact had severely compressed the cabin space trapping the dummy between the steering wheel and driver’s seat. Observation shows that upon impact the dummy’s head thrusted towards the steering wheel and the lack of an airbag caused severe head injury. The HIC15 value was recorded as the highest at 1,358 while the resultant acceleration at 3m/sec was 141.51 G. From Figure 13 we can also see the dummy’s leg is trapped within the compartment causing injuries to the tibia. As shown in Table

5 above, the upper tibia index value is 0.57 on the right and 0.34 on the left. The lower tibia index is 0.30 and 0.31 for the right and left respectively.

FIGURE 12: DFSK V25L image at t = 0.1 ms during impact with driver close-up view

FIGURE 13: Post-crash image of DFSK V25L driver

3.3 Structure Integrity

Figure 14 shows the result of the N1 vehicle crash test by ASEAN NCAP, of all five models. It can be seen that the percentage of intrusion on the crumple zone is different for each model. Suzuki Carry was recorded with the minimum deformation on the frontal structure. Although this was the case, all of these vehicles had obtained zero-star ratings. This has proven that the structural integrity of the front of a vehicle highly contributed to the occupant's injury.

Even though a tensile test had not been conducted on these vehicles it can be seen that the structural deformation of the five models tested vary even though the impact speed is the same. The major assumption was the level of material strength used for each model. Chana Era Star II, DFSK V25L, and Chery Transcab were from China, Suzuki Carry from Japan, and TATA Super Ace from India. The results from this research can also allow a conclusion that the model from Japan might use better materials and structural design for the chassis allowing the deformation to be within tolerable range maintaining the crumple zone reasonably well.

The body of trucks are usually made of aluminum, steel, fiberglass, or other composite materials (Engineering360, n.d.). The materials used are usually ductile where they can be subjected to large strains before they fracture. Figure 15 below shows a typical stress-strain curve obtained from a tension test, showing various features. Truck bodies are under the category of plastic deformation because it is a permanent deformation of metals due to the movement of dislocations on the slip system.

FIGURE 14: Light N1 vehicle crash tested by ASEAN NCAP

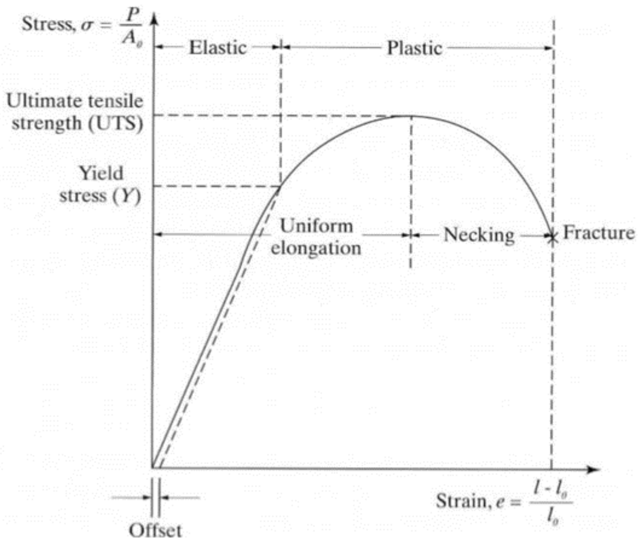


FIGURE 15: Stress-strain curve

Based on the law of physics, after the elastic region, necking will occur to the materials of the vehicle. Wu and Xin (2008) stated that the most of impact energy is absorbed by the front of the frame. Therefore, an improvement should be made to the material used at the front frame of the N1 vehicles to compensate for the lack of safety features such as airbags. As mentioned by Kang and Kim (2015), a structure should have sufficient continuity to offer an alternative path to stability of the structure even if a vertical load-resisting element is removed. This is important to prevent progressive collapse on the front structure of the vehicle.

4. CONCLUSION

From the high-speed video analysis, it is understood that having adequate horizontal d-value and crumple zone is crucial for the driver’s safety when it comes to frontal collisions. Ferguson and Schneider (2008) advised that drivers were to sit at least ten inches from the steering wheel.

Also, the driver's position was an additional force associated with serious abdominal injuries in frontal crashes (Jeon et al., 2017). This can reduce the time of impact between the head and the steering wheel. According to Travelers Risk Control (n.d.), the law of physics confirms that if you are driving at 50 mph, and a crash causes the car to stop immediately, passengers will continue moving at 50 mph causing fatal injuries. Having a larger crumple zone helps to transfer some of the vehicle’s kinetic energy into controlled deformation at collision indirectly allowing the vehicle to take a little longer before stopping. The difference in dummy injury and structural deformation between Suzuki Carry and Tata Super Ace proves this theory.

The absence of an airbag in the steering wheel is also one of the causes of driver’s injury. Huber et al. (2005) study shows that second-generation airbags are very effective in preventing deaths. Manufacturers must equip airbag steering wheels as this helps to prevent head, chest, and other severe injuries during collision.

In conclusion, N1 vehicles with minimum safety features that are currently being used in Malaysia have proven to be unsafe. All vehicles tested have failed resulting in a zero-star rating from ASEAN NCAP as a result of serious injuries on the head, chest, and leg of the dummy along with other factors. The safety level of these vehicles is found to be lower than the minimum safety standard applied by UN vehicle regulations. The lack of regulation mandating vehicles in this category within Malaysia to be equipped with minimum active safety features has resulted in poor crashworthiness performance and may potentially result in fatal injuries for the occupants upon frontal collision. It is also observed that the head injury was primarily caused by the steering wheel. Vehicle safety systems require restraints such as seatbelts and airbags to reduce the severity of injury and costs of motor vehicle crashes (Yaser, 2015).

The poor rating for these vehicles can be further justified by the lack of any other safety features, this meant no additional points were included in the final assessment. Four out of five tested models have poor structural integrity causing massive intrusion to occupant compartments leading to severe driver injury. The dummy in TATA Super Ace was recorded as the most severely injured, especially at the tibia as well as the head body region. The crumple zone and ‘d-value’ are found to be significant when designing N1 vehicles, especially ‘flat head type’ vehicles. It has been proven that a well-designed crumple zone could manage energy generated in the event of a crash, by distributing it effectively throughout the chassis, thus preventing deformation of the occupant space and injuries to occupants (Jeon et al., 2017).

There are many potential ways to overcome the issues faced by the vehicles tested. Although this being said, the implementation of these changes would involve the party of concern to incur costs. Some said fixes may be cheaper than others, such as the implementation of a bull bar welded to the chassis or the installation of aftermarket passive safety sensors. Other more expensive solutions could be to install a roll cage to the cabin of the vehicle or equip airbags within the vehicle (done by the manufacturer). These suggestions, in theory, should help protect the passengers better but the effectiveness of these concepts would only be beneficial if the user or manufacturer decides to make the change. The ultimate way to guarantee the change is by mandating it. If the regulations given to manufacturers who produce N1 vehicles are such that passenger safety is of utmost importance, manufacturers who wish to sell within the Malaysian market would have to abide by the law, leading to safer operations on the road.

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