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Crashworthiness of Light Cab Commercial Vehicles: A Systematic Review on Frontal Collision Cases

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ABSTRACT – *Light cab commercial vehicles, which are also known as light trucks or technically as N1 category vehicles, are designed to carry loads below the maximum capacity of 3.5 tons. With the aim of maximizing cargo size, the occupant cabin has been pushed to the front as far as possible, thus the vehicle design appears as a "flat head" type. In general, the flat head structure has compromised the crashworthiness of these vehicles in the event of a frontal collision. The purpose of this study is to review the findings of previous studies on the crashworthiness of light cab commercial vehicles in the Asian region and to ascertain the level of driver injuries in a frontal collision. The results of several published studies on the crashworthiness of light cab commercial vehicles were analyzed via a systematic review. Preferred Reporting Items for Systematic Review and Meta-analyses, PRISMA-P guidelines were used to complete the review process. The inclusion criteria included studies of the crashworthiness of light cab commercial vehicles and passenger injuries published between 2000 and 2020 in PubMed, Taylor & Francis, and the ASME Digital Collection. In summary, it was found that four studies (31%) provided information on commercial vehicle driver behavior, seven studies (54%) vaguely described the crashworthiness of light cab commercial vehicles, and only two studies (15%) provided detailed information on the subject matter. The topic of N1 vehicle crashworthiness was found to be unattractive in the current academia, prompting necessary emphasis on the safety issues related to this type of commercial light truck.*

KEYWORDS: Crashworthiness, light cab commercial, N1 Vehicle, frontal structure

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1. INTRODUCTION

Due to the current economic growth in Southeast Asia, the sales of commercial vehicles are witnessing a sharp rise. Along with the food truck business, the popularity of e-commerce has led to a growing interest in courier and transport services (Mazlan et al., 2019; Yahya, 2021). These factors have increased the demand for light cab commercial vehicles. According to Ho and Manan (2019), commercial vehicles form the logistics industry backbone that drives a country's vibrant economy. Light cab commercial vehicles are also known as light-duty trucks or technically the N1 vehicles. They are designed to carry goods with a maximum weight not exceeding 3.5 tons. In general, each N1 category vehicle is designed to fulfill the aforementioned purpose. For light cab commercial vehicles including small lorries or panel vans, large cargo space is essential to carry as many goods as necessary. For this reason, the occupant cabin has been pushed forward as far as possible, making these vehicles to be commonly known as 'flat head type' vehicles. However, the structure of the flat-head type vehicle has compromised its occupants' safety in the event of a frontal collision. Therefore, it is believed that the vehicle poses more danger than initially presumed by road safety researchers. The frontal structure design comparison between the front engine type and flat head type vehicles is illustrated in Figure 1. The latter design will increase the risk of its occupant(s) sustaining serious and even fatal injury in a frontal collision. Hence, the current study aims to understand the crashworthiness performance of the flat-head type vehicle in an effort to reduce road injuries and fatalities due to this type of collision.

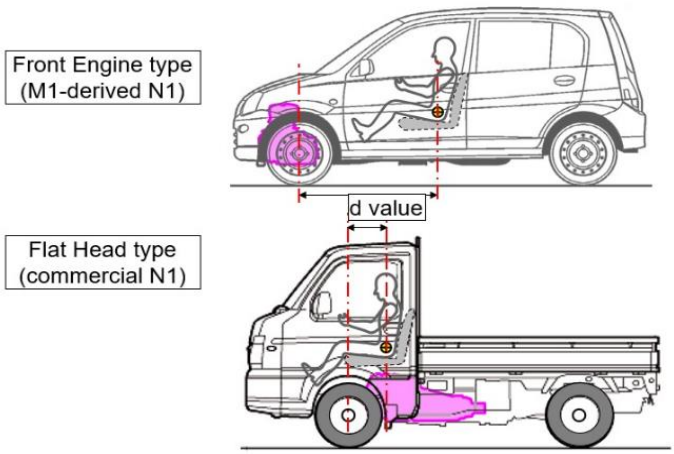


FIGURE 1: Structure design difference between front engine type and flat head type (JASIC, 2014)

Over the last few years, there has been a worrying trend of crashes involving commercial vehicles. As reported by the Ministry of Transport Malaysia (MOT, 2018), some 44,243 road accidents involving commercial vehicles were recorded in 2018. The most common accident type involving these vehicles is the frontal collision. Further, the Insurance Institute for Highway Safety and the Highway Loss Data Institute (IIHS-HLDI) stated that frontal crashes were the most common type of crashes resulting in fatalities (IIHS, 2020). It was also contended by Khorashadi et al. (2005) that head-on collisions increased the odds of road injury and even fatality by an estimated 83 percent compared with other crash types. Although road crashes cannot be completely prevented, their number can be reduced to an acceptable figure through appropriate engineering remedial actions and management approaches (Ganguly et al., 2014). Therefore, it is imperative to investigate the capability of the light cab commercial vehicle frontal structure in a collision as the structure and stiffness of these vehicles differ from passenger cars. Such differences stem from the fact that the former is purposely built to transport goods (Jeon et al., 2017). Further, it is also noted that the crash compatibility of a vehicle mainly depends on its structural design which refers to the horizontal distance from the center of the frontal wheel to the center of gravity of the driver, or the ‘d-value’. The distribution of the ‘d-value’ of each vehicle type is presented in Figure 2.

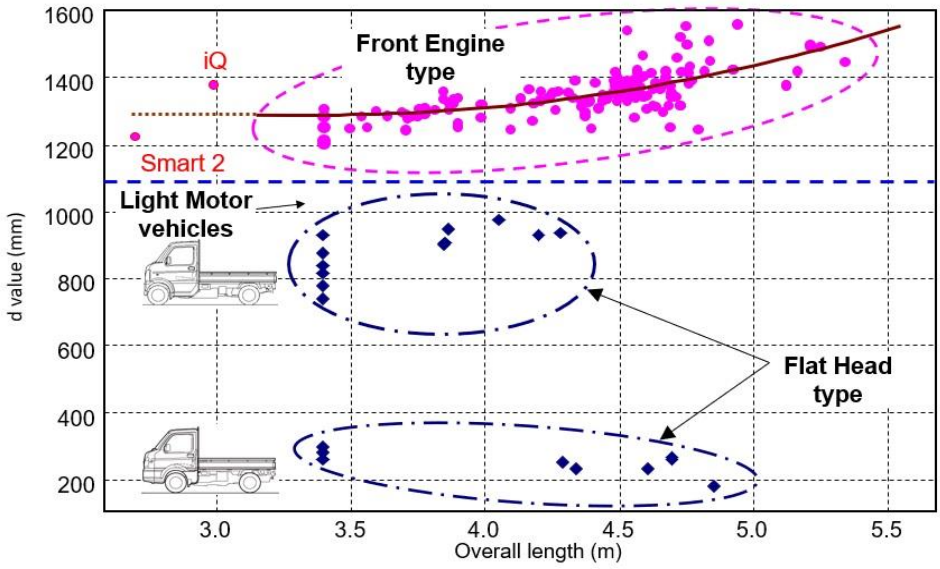


FIGURE 2: Distribution of horizontal distance, ‘d-value’ of each vehicle type (JASIC, 2014)

In Malaysia and across Southeast Asia, there is an obvious lack of safety regulations pertaining to commercial vehicles entering the automotive market (Omar & Awang, 2012; RTD, 2017; Wahab et al., 2017). For this reason, the light cab commercial vehicles sold in the region might provide somewhat limited occupant protection in road crashes. This is quite frustrating considering that the matter has persisted over the last two decades. In fact, long ago, Berg et al (2003) argued that the safety performance of goods vehicles had received little attention from both the research and regulatory viewpoints. As shown in Table 1, a market survey of several light cab commercial vehicles showed that 80% of the vehicle models sold in Malaysia were below minimum safety requirements. The price of vehicle brands from China and India was the lowest, in the range between MYR 10,000 and 20,000, but the vehicles came with fewer safety features compared to models from Japan. Such a price tag will surely influence the purchasing decision of many small and medium-sized entrepreneurs to lower their overhead costs. However, the main purpose of having these vehicles is for transporting goods on a daily basis, which unfortunately will lead to serious concerns regarding their on-the-road safety.

TABLE 1: Price of light commercial vehicles sold in Malaysia

Brand	Model	Type	Price (MYR)	Safety Features	
				SRS	ABS
Daihatsu	Gran Max	Panel Van	69,232.20	Dual	Yes
	Gran Max	Semi Panel Van	72,512.20	Dual	No
Nissan	NV200	Panel Van	72,888.00	Driver-side	Yes
	Navara	Single Cab	85,639.17	Dual	-
Suzuki	Suzuki Carry	Small lorry	53,086.00	-	-
Toyota	HiAce	Panel Van	103,000.00	Dual	Yes
DFSK	V25L	Panel Van	60,000.00	-	-
Chana	Era Star II	Panel Van	49,142.81	-	-
TATA	Super Ace	Small lorry	49,990.00	-	-

The objectives of this study are:

1. To ascertain the number of published studies on the crashworthiness of light cab commercial vehicles in the Asian region, and
2. To determine the severity of light cab commercial vehicle drivers' injury in frontal collisions based on the published studies

2. METHODOLOGY

2.1 Data Sources and Search Strategy

A systematic review was employed to ascertain the number of studies on the crashworthiness of light cab commercial vehicles in the Asian region. A keyword search was performed to identify all the relevant published studies between the years 2000 and 2020. Preferred Reporting Items for Systematic Reviews and Meta-analyses, PRISMA-P guidelines were used to complete the systematic review process as recommended by Shamseer et al. (2015). Several electronic databases including PubMed, Taylor & Francis Online, and ASME Digital Collection were utilized to select the relevant studies. For this particular study, three main databases were chosen for specific reasons. Pub Med was deemed the most useful as the search engine had access to more than 30 million journal papers and provided full-text links to the publisher web sites. On the other hand, Taylor & Francis Online was able to provide fully open-access journals that were very useful in the reviewing process of the study. From a mechanical engineering viewpoint, ASME digital collection was also important as it contains some of the most prestigious engineering journals and conference papers aside from being the largest technical repository in the world. Added together, all the databases presented access to more than 5,000 journals.

Other than these databases, grey literature on Google Scholar as well as publications by the Malaysian Institute of Road Safety Research (MIROS) including the International Journal of Road Safety (IJRS) were also chosen for this review. In the end, the findings of the review will highlight the research gap that exists in the literature and present a new angle for future studies related to the crashworthiness of light commercial vehicles. Although it may not be fully considered as a full-text review, the system

applied here shall be able to collate all relevant evidence that fits certain predetermined eligibility criteria to answer a specific research question.

Next, several keywords were inserted in the search bar to obtain correct information on the relevant studies. The main criteria for this study included light commercial vehicles, frontal structures, and crashworthiness. Table 2 below shows the keywords that were used in the process of reviewing the published studies. Some Boolean operators were used to combine the keywords and to broaden the search results. Examples of these operators were “OR” and “AND”. Furthermore, software including Zotero was utilized to identify the duplication of publications in the electronic databases.

TABLE 2: Keywords searched in several databases

Database	Keywords	Results
PubMed	(safety OR crashworthiness* OR crash OR deformation OR crash test OR front structure* OR frontal offset) AND (light truck OR light commercial vehicle OR panel van OR minivan OR mini truck OR light cab commercial OR light N1 vehicles* OR commercial vehicle*) AND Asia	95
Taylor & Francis Online	(safety OR crashworthiness* OR crash OR deformation OR crash test OR front structure* OR frontal offset) AND (light truck OR light commercial vehicle OR panel van OR minivan OR mini truck OR light cab commercial OR light N1 vehicles* OR commercial vehicle*) AND Asia	4
ASME-Digital Collection	(safety OR crashworthiness* OR crash OR deformation OR front structure* OR frontal offset) AND (light truck OR light commercial vehicle* OR panel van OR minivan OR mini truck) AND Asia	2

2.2 Study Selection

Once the retrieved articles were pooled using Zotero software, duplication of the published studies could be identified. Next, the titles and abstracts of the studies were independently screened. Full texts of eligible articles were retrieved and sufficiently assessed against predetermined inclusion criteria. Any disagreement over the eligibility of certain studies was resolved through consensus. Original studies regarding the crashworthiness of light cab commercial vehicles were included if they met the selection criteria detailed in Table 3 whereas Figure 3 shows the PRISMA flow diagram to highlight the screened, excluded, and included articles.

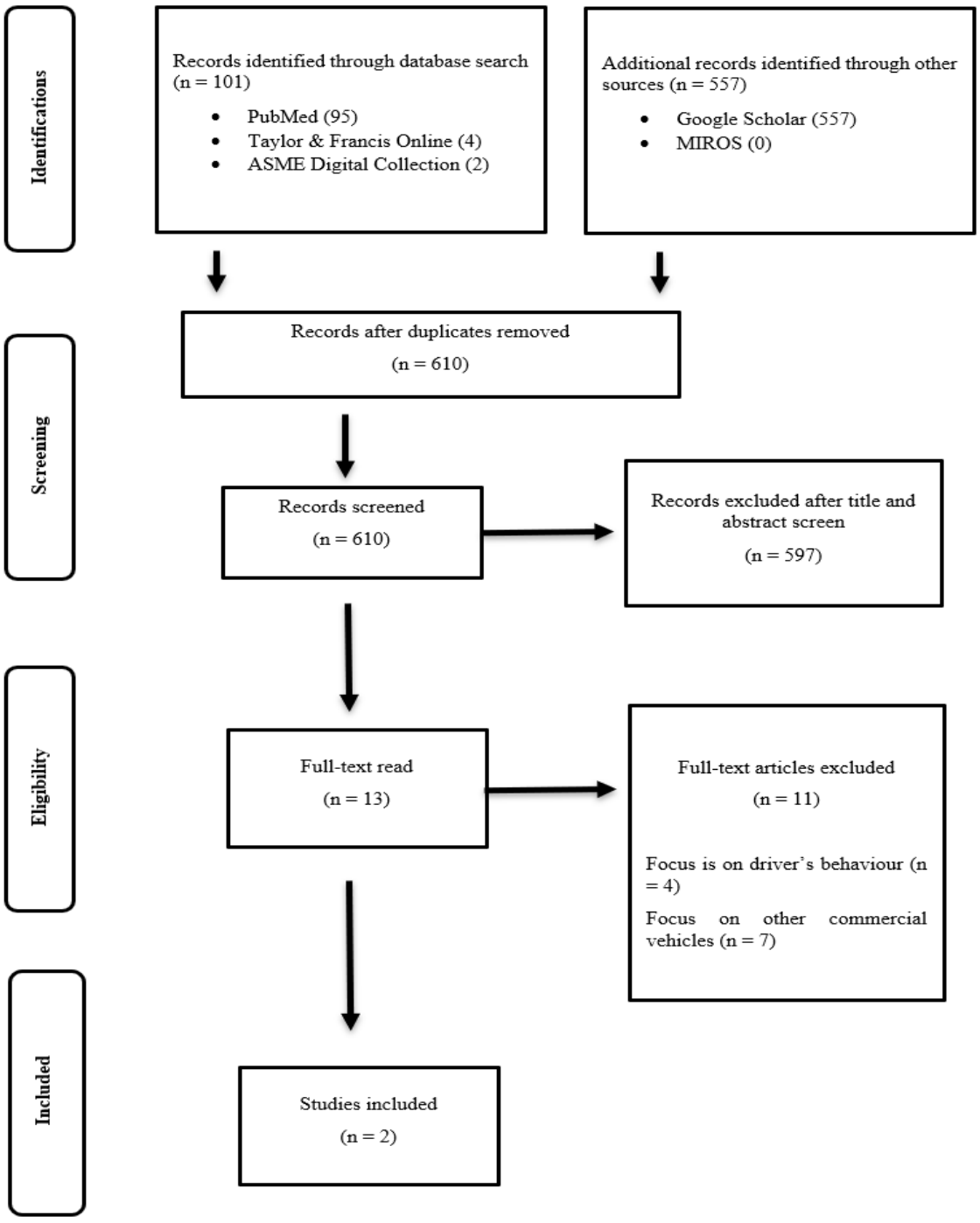
TABLE 3: Selection criteria

Inclusion Criteria	Exclusion Criteria
Original articles	Driver behavior
Focus on the structure of light cab commercial	Other commercial vehicle (large truck, bus, taxi)
Driver of the vehicle’s severity	Driver age

2.3 Data Extraction

Data were collected with respect to the published studies’ design, setting, number of subjects, data collection method, scope, and main findings. A narrative synthesis was completed covering all the included studies and reporting the key points of each study. A flow chart of search strategies using the PRISMA-P method is illustrated in Figure 3.

FIGURE 3: Flow of search strategies using PRISMA-P method



3. RESULTS AND DISCUSSION

The initial search retrieved a total of 658 studies published between 2000 and 2020. Following the removal of duplicate studies across the three databases, 48 were excluded and 610 papers were assessed by title and abstract screening. Of these, 597 did not fulfill the eligibility criteria leaving only 13 articles eligible for full-text screening. Four studies (31%) presented information regarding the behavior of commercial vehicle drivers; seven studies (54%) provided an unclear description of the crashworthiness of light cab commercial vehicles, while only two studies (15%) gave detailed information about the subject matter.

The emphasis of this systematic review is on the crashworthiness of light commercial vehicles including small lorries, panel vans, k-trucks, and minivans. Using PRISMA-P guidelines, only two articles were found directly related to the subject matter, namely the crashworthiness of light cab commercial vehicles. One particular study by Jeon et al. (2017) was based on crash injury, whereas Hitosugi and Matsui (2015) dealt with accident data. Both these studies used the Maximum Abbreviated Injury Scale (MAIS) as a reference along with the Injury Severity Score (ISS) sustained by the occupants.

In their study, Hitosugi and Matsui (2015) posited that the injury severity of k-truck drivers and passenger vehicle occupants in frontal collisions largely depended on the collision speed and mean of delta-V. Injury comparison for both vehicles showed there were no significant differences in the ISS and MAIS 2+. The implementation of vehicle regulations on cab commercial vehicles in Japan since 1998 was the main reason for the similarity in terms of injury patterns. K-trucks in Japan had excellent passive safety performance in addition to the presence of airbags and advanced frontal structure. The findings of a similar study confirmed that Japanese k-trucks met the standard safety performance required in the United States and Europe regarding frontal collisions (Hitosugi & Matsui, 2015). This vehicle type has become popular in Asia especially in Japan as it was convenient to drive and presented economic benefits such as low purchase price, tax, and favorable fuel economy. At the same time, Japanese authorities had made efforts to ensure the safety of the occupants by controlling the area of k-trucks use. In 2018, Japan Automobile Manufacturers Association (JAMA, 2008) reported that minivans and mini wagons in the country were used primarily for commercial operations (around 60%), whereas 39% of the vehicles were used for transport. This included 40% of small trucks used in agricultural work while 56% were used in paddy plantations. This trend assisted in the monitoring of the vehicles in specific areas, thus helping to control the vehicle speed. Further, vehicle speed was found to significantly contribute to accident severity. Therefore, all these regulations seemed to have enhanced the safety performance of k-trucks in Japan.

The study by Jeon et al. (2017) reported that occupants of truck vehicles (TVs) sustained more serious abdominal and lower extremity injuries which led to higher ISS, compared to non-TVs occupants. The reasons for the serious injuries to TV drivers in frontal crashes included the vehicle's heavy curb weight, no airbag deployment, and driver position. To overcome this problem, Ferguson and Schneider (2008) advised drivers to sit at least ten inches from the steering wheel thus reducing the time of impact between the head and the steering wheel. Further, it was reported that only 3.4% of airbags were deployed in frontal crashes involving TVs. In 2005, Huber et al. (2005) argued that second-generation airbags were effective in preventing deaths. At present, it is still relevant to emphasize the steering wheel airbag as a means to prevent head, chest, and other severe injuries during road collisions. Nevertheless, save for some reputable brands from Japan, most light cab commercial vehicles sold in Southeast Asia are not equipped with a frontal airbag.

TABLE 4: Results of searching

Authors	Year of Study	Study Design	Outcomes	Key Findings/Suggestions
Jeon et al.	2017	Hospital Data	▪ Rate of airbag deployment was only 3.4% in frontal crashes. ▪ Installation angle of the steering wheel on a truck vehicle. ▪ Crumple zone in a truck vehicle is considerably small.	▪ Increasing the size of the crumple zone. ▪ Increase the size of the steering wheel rim. ▪ Legislative efforts to develop a safety system.
Hitosugi & Matsui	2014	Accident data	▪ The chest and lower extremities were the regions with the highest AIS score followed by the neck, head, face, upper extremities, and abdomen.	▪ K-trucks provide similar safety for drivers involved in frontal collisions as standard vehicles. ▪ Further research based on real-world accidents is needed.

4. CONCLUSION

To conclude, this study has managed to present evidence that serious injuries were sustained by light cab commercial vehicle drivers in the event of frontal collisions. Major injuries were sustained on the lower extremity and chest body region followed by head trauma. Severe damage to the occupant compartment was also found to be caused by the light cab vehicle's small crumple zone. However, the number of studies in this review was insufficient to provide a sound conclusion regarding the overall safety performance of the light cab commercial vehicle. Through this review, only two studies were identified to be directly related to the topic of the crashworthiness of light cab commercial vehicles. Both studies analyzed injury data of vehicle occupants using MAIS and ISS. Nevertheless, there is still an obvious lack of research pertaining to the passive safety of commercial vehicles using crash data in the Asian region. In addition, the findings of this review seem to reaffirm the suggestion by Berg et al. (2003) that the safety performance of goods vehicles has received little attention from both the research and regulatory viewpoints. This is quite frustrating, considering that studies on other commercial vehicle types such as taxis, buses, and heavy trucks have gained attraction in academia. The authors propose that future studies consider crash test data from the New Car Assessment Programs (NCAPs) around the world to observe and analyze light cab vehicle occupant injuries, aside from investigating its frontal structure deformation. Through such an endeavor, potential improvements could be made to enhance the safety of light cab commercial vehicles to reduce injury and even fatality in the event of a road crash.

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REFERENCES

Berg, A., Rücker, P., Groer, M., Niewöhner, W., Sferco, R., Fay, P., & Schriever, T. (2003). Safety of light commercial vehicles in the light of the results of accident analyses and testing. In 18th International Technical Conference on the Enhanced Safety of Vehicles (ESV) (pp. 19-22).

Ferguson, S. A., & Schneider, L. W. (2008). An overview of frontal air bag performance with changes in frontal crash-test requirements: findings of the Blue Ribbon Panel for the evaluation of advanced technology air bags. Traffic Injury Prevention, 9(5), 421-431.

Ganguly, R., Gupta, A. K., & Mishra, M. (2014). Traffic Volume and Accident Studies on NH-22 Between Solan and Shimla, India. European Scientific Journal.

Hitosugi, M., & Matsui, Y. (2015). Safety of the Japanese k-car in a real-world low-severity frontal collision. Traffic Injury Prevention, 16(1), 90-94.

Ho, J. S., & Manan, M. A. (2019). A study on commercial vehicle speeds and its operational characteristics. Journal of the Society of Automotive Engineers Malaysia, 3(4), 100-110.

Huber, C. D., Lee, J. B., Yang, K. H., & King, A. I. (2005). Head injuries in airbag-equipped motor vehicles with special emphasis on AIS 1 and 2 facial and loss of consciousness injuries. Traffic Injury Prevention, 6(2), 170-174.

IIHS (2020). About Our Tests. The Insurance Institute for Highway Safety and The Highway Loss Data Institute (IIHS-HLDI) (1996-2020). Retrieved from https://www.iihs.org/

JAMA (2008). Trends in mini-vehicle use: results of JAMA's' Fiscal 2007 Survey. Japan Automobile Manufacturers Association, Inc. Retrieved from http://www.jamaenglish.jp/

JASIC (2014). Japan proposal for flat front light N1 vehicle. In 59th GRB, JASIC.

Jeon, H. J., Kim, S. C., Shin, J., Jung, J. Y., Lee, K. H., Lee, H. Y., & Kim, H. J. (2017). Risk of serious injury of occupants involved in frontal crashes of cab-over-type trucks. Traffic Injury Prevention, 18(8), 839-844.

Khorashadi, A., Niemeier, D., Shankar, V., & Mannering, F. (2005). Differences in rural and urban driver-injury severities in accidents involving large-trucks: an exploratory analysis. Accident Analysis & Prevention, 37(5), 910-921.

Mazlan, N. A., Yahya, W. J., Ithnin, A. M., & Laili, M. A. (2019). A study of Malaysian motorcyclists' behaviour from the perspective of pickup truck. Journal of the Society of Automotive Engineers Malaysia, 3(3).

MOT (2018). Statistik pengangkutan Malaysia. Kemeterian Pengangkutan Malaysia. Retrieved from http://www.mot.gov.my/my/Statistik%20Tahunan%20Pengangkutan/Statistik%20Pengangkutan%20Malaysia%202018.pdf

Omar, N. H., & Awang, A. (2012). Masalah halatuju industri bina semula kenderaan perdagangan di bawah semakan Dasar Automotif Nasional 2009 (The pathways problem of commercial vehicles rebuilt industry under the review of National Automotive Policy 2009). e-BANGI, 7(1), 94.

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

Shamseer, L., Moher, D., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., ... & Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ, 349.

Wahab, M. A., Jawi, Z. M., Hamid, I. A., Solah, M. S., Latif, M. M., Isa, M. M., ... & Hamzah, A. (2017). Automotive consumerism in Malaysia with regard to car maintenance. Journal of the Society of Automotive Engineers Malaysia, 1(2), 137-153.

Yahya, W. J. (2021). Pandemic COVID-19 effect on future courier technologies. Journal of the Society of Automotive Engineers Malaysia, 5(1), 2-4.