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Initial Study on Safety Hazards by Heavy Transportation on Malaysian Roads

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Abstract: A pilot study was done to evaluate several road safety issues in Malaysia that are related to heavy transportation. The project consisted of survey, analytical calculations, and computer simulations. The survey was conducted to investigate the use of current active safety features like the warning signs, which include lights, light reflective stickers, and the color of canvas used on heavy vehicles. There were 55 responses collected that showed visibility of trucks was a problem in the dark. Fortunately, light reflective stickers could be an aid to passively illuminate the heavy vehicles and this has become law in Malaysia. Another issue is the slow speed like 40 km/h commonly maintained by heavy vehicles when climbing up hills with heavy load, which is a hazard since being too slow may cause a more severe rear-end collision damage. Additionally, computer impact analyses were also done by using ABAQUS, where several rear-end collisions between a car and a heavy vehicle were studied. Hence, a conclusion can be made that the slower the speed of a heavy vehicle, the higher the impact experienced by the car colliding from behind the truck. It is recommended that a long trailer truck has about 310 kW of engine power to pull a maximum load of 30,000 kg. Trucks are also suggested to maintain at least 60 km/h speed during hill climbing with a much lower load.

Keywords: Heavy vehicles; safety features, safe speed, overloading

1. Introduction

Every year, many tragic road and highway accidents are reported. In Malaysia, a lot of this become apparent during festive seasons and long vacations like school breaks. There are many reasons for this to happen. These include technical failures from design, assembly and utilization that relate to human error as the root cause. Usually, accident occurrences are not only caused by the unconscious behavior of human such as driving in drowsy state or emotional distress, but also by the inability of the human to see other vehicles on the road as well as the faulty use of safety features.

Generally, each mode of transportation has its own unique safety features. The safety features are capable to avoid unexpected things from happening such as collisions and road accidents in particular. Among the safety features used are passive safety, active safety, general safety, and environment where all these features are contained in the UN Regulations [1], which Malaysia had embraced 100 of the UN Regulations into the motor transportation law (Construction and Use) 1959, which are implemented through the Vehicle Type Approval (VTA) process. Even though

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Malaysia has followed these regulations, there are still some parties that compromise and ignore the safety features to gain advantages for their own interest. This attitude will affect in adverse consequences, which include accidents not only to them but also to other road users. Hence, this work touches several truck safety issues such as its visibility to other road users, the hazard of it traveling slow, and the related impact of crashworthiness when there is collision from the rear.

Furthermore, heavy vehicles safety issue is a very serious situation that needs to be considered by all road users even if it is not classified as major accidents on the roads. However, when one happens, heavy vehicles also contribute to the highest rate of fatal accidents. In 2014 alone, Malaysia recorded 57,430 accidents involving lorries, busses, and taxis [2]. Besides, the increasing number of heavy vehicle on the roads contribute to the traffic congestion in Malaysia especially during festive seasons or peak hours. In addition, heavy vehicles that are climbing slowly on the left lane up the hill is a sight that is commonly seen at any highway. This is due to the low performance of the powertrain systems that include the efficiency of its gearboxes and engine power. So, in order to avoid this from getting worse, improvements to heavy vehicles design and safety features need to be studied further.

The design for safety features is discussed where some of the existing safety features are reviewed and improved for this work. Among them is the use of active safety such as lights, light reflection stickers, and canvas that are studied whether it is appropriate to be used or not. Due to time constraint, the reflective sticker tape was selected to be the focus. Besides, the performance of heavy vehicles to carry loads when climbing the hill is also analyzed. Some required speeds for the heavy vehicle to climb the hill with certain load are recommended and studied. Then, simulations to predict how the collisions with the different speeds and masses of the heavy vehicles are also carried out.

2. State-of-The-Art of Truck Safety in Malaysia

According to Craft [3], this kind of research focused on the incidents of heavy vehicles involvement in rear-end crashes by other vehicles. Most accidents resulted from a vehicle striking the rear of a heavy vehicle, usually in dark conditions. This might be that the driver of other vehicles could not vividly see there was a heavy vehicle in front of him or her own vehicle. Then, Sullivan examined the factors that influenced truck involvement in night time crashes, where the number of accidents occurring in rural areas were greater than that in urban areas [4]. Rural areas usually have insufficient lighting from streetlights as compared to that in urban areas, where with the presence of many other vehicles on the road also provide sufficient lighting to all road users. Furthermore, Sullivan and Flannagan had examined the influence of lighting conditions on rear-end crashes of heavy vehicles, where the likelihood of these crashes between any vehicles doubled during night time [5]. They found that fatal rear-end collisions involving heavy vehicles were nine times more likely in darkness than in light. The dark condition limits the view for road users to see clearly if there is insufficient light in the surrounding.

Besides, Friswell, Williamson & Irvine [6] found that heavy vehicles had higher potentials to be involved in crashes between midnight and dawn in their search to find patterns of heavy vehicles crashes in New South Wales (NSW) in four years. This happened because heavy vehicles usually start operating or moving on the roads at night to avoid congestion during daytime. Hence, the dark environment causes lower visibility and the driver drowsiness may result in accidents. Based on a study conducted in Australia, crashes that occurred during night time were more severe as compared to daytime crashes. In the dark, many heavy vehicles are less visible to other road users until they are dangerously close. Thus, one of the essential elements of a heavy vehicle safety is its good visibility in traffic.

Next, Chen, Chen & Wu in [7] stated the poor road conditions contributed to crashes on mountain highways caused by icy road surfaces, windy conditions, and graded curves. Hence, the conditions of roads also can cause accidents to heavy commercial vehicles. The gap from this research is that the crashes are always occurring at night and dark but there is no further explanation about any other dark conditions such as in heavy rains and serious haze pollution. Many road users may not see clearly enough the presence of heavy vehicle as well as the heavy vehicle drivers may not be aware of other vehicles either. Thus, the warning signs such as additional lights, light reflection sticker and canvas color are important as the safety features of heavy vehicles.

The American Association of State Highway and Transportation Officials reported that the road traffic crashes and their consequences are significant challenges to all societies in developed and developing country [8]. Developed countries are typically more advanced in road safety interventions, but as for developing countries, the use of road signs and law enforcement should be applied actively and rigorously. Some issues may arise such as the land use and town planning, population mixture, country roads and types of vehicles. Thus, this will improve the safety of the road as well as preventing any accident from occurring. The horizontal alignment of curves and other design features of road represent safety hazard for heavy vehicle drivers. The provision of guard rail barrier is one of them, which can benefit not only for heavy vehicles but other transportation modes as well.

There are many hilly roads in Malaysia where accidents often occur such as the road between Temerloh, Pahang and Gemas, Negeri Sembilan. Hence, the performance of heavy vehicles need to be fully understood by the drivers in order to prevent any unexpected incidents such as heavy vehicles being stranded at the hill due to the over loading. The Malaysian Road Transport Department (JPJ) published report by its Automotive Engineering Division [9] noted that most cases of overloading occurred in the more advanced states, where there were industrial areas and locations that had high forestry products or minerals such as timber, bauxite and coal. Most cases of excessive loads by heavy

vehicles in Malaysia from 2012 to 2016 happened in Selangor followed by Pahang, where Selangor is the industrious state while there is a large bauxite mining in Kuantan, Pahang. This situation is not only making the roads crowded but also causing accidents if the safety precautions are not emphasized. Besides, the road may be damaged by overloaded commercial vehicles moving through the roads repeatedly since overloading surely makes the large vehicles heavier than usual. This damaged road is another factor for road accidents.

Furthermore, other risks can be addressed through the design of safety features on heavy vehicle such as the use of on-board warning systems and crash avoidance technologies to improve the stability and control of the vehicles. Moreover, researchers at Kitami Institute of Technology also confirmed the effectiveness of retroreflective tapes in enhancing the visibility of heavy vehicles and reducing the perception reaction time in various lighting and weather conditions by 27% [10]. In dark conditions, retroreflective tape reduced side and rear impact crashes that involved fatality by 44%. Moreover, a report by the Malaysian Institute of Road Safety Research (MIROS) found that 69% of respondents agreed on the current use of Retro-Reflective Markers (RRMs) in Malaysia were not bright and effective enough [11]. Furthermore, 99% of road users agreed the effective RRMs were important to heavy vehicles and respondents also agreed with the statement that the brighter the RRMs, the safer the vehicles for the use on heavy vehicles.

Therefore, this work recommends an improvement for the use of RRMs or the light reflection stickers in Malaysia. Apart from that, there is a research gap regarding heavy vehicles safety design where there is no research on the use of canvas or tarp for heavy vehicles. Although it is not crucial but if it is neglected, it can also endanger other road users. For example, if the canvas is not tied up properly, it might fall out and thus causing accidents. Besides, the color of installed canvas or tarp also needs to be studied as the green and dark colors do not help in detecting the presence of these slow-moving heavy vehicles. It is also common to see the dark canvas covering the reflective stickers that defeats the purpose of installing the stickers in the first place.

Another study in [12] focused on the issue of minimum speed on vehicles traveling on highways. It mentioned that although the percentage of slow-moving vehicles was small nationwide, they made up 9% of all highway accidents in the state of Florida during the course of the study. This can surely be related to our own experience here in Malaysia, where most of the very slow-moving ones are heavy commercial vehicles in busy highways. The minimum freeway speed in Florida was 40 mph or equivalent to about 65 km/h.

Hence, when developing new heavy vehicles, meeting the safety requirements is a must. These requirements are set not only by valid regulatory acts, but also by customer's needs. In addition, heavy vehicle manufacturers themselves must try to develop a variety of additional standard safety features that are intended to increase the safety of the heavy vehicles. The older heavy vehicles also need to be maintained and upgraded in safety features to make it safer and not harmful to other road users as well as themselves. The main purpose of vehicle safety is not only for the life and health of the vehicle crews, but also other road users like pedestrians, cyclists, motorists as well as other road facilities. In general, the goal is to minimize the likelihood of an accident and should this occur anyways, to ensure the protection of health and life.

3. Research Method

This work includes drafting up a survey focusing on heavy transportation visibility and computer simulations. The output is then analyzed to generate some solutions to the problems. A survey was conducted to get the views from respondents regarding safety features for heavy vehicle in Malaysia. This survey consisted of the statements on the use of light, light reflection sticker, and the color of canvas for heavy vehicles. The respondents participated were from different ages, professions, and genders.

3.1 Truck Detection Survey

The survey was made focusing on the most significant safety features for heavy vehicles. The new design of selected safety features is presented here. First, a survey was circulated to get the views from respondents regarding safety features for heavy vehicle in Malaysia. This survey consisted of the statements on the use of light, light reflection sticker, and the color of canvas for heavy vehicle. Among the questionnaires were as follows:

a) Safety features for heavy vehicles is an important element to prevent accident occurrence.
b) Other road users will be able to see heavy vehicles clearly if safety features such as the use of lights, light reflection stickers and canvas are used properly.
c) Mostly the additional light (side and back) on heavy vehicle is insufficient to be seen in the dark environment like rainy, cloudy and at night.
d) The appearance of light reflection sticker is important as an additional illumination to the existing lights on heavy vehicle.
e) The use of green/dark canvas is not suitable for heavy vehicles especially at night as dark colors limit their visibility to other road users

The respondents needed to react to the visibility of the displayed pictures in the survey. These questions were critical for defining the safety feature requirements. An effective cognitive ergonomic optimized the match between the

user, tasks, conditions, and equipment. Thus, the survey was conducted online in the Google Forms and the respondents were random people from the Ayer Keroh Campus and their wider circles of friends. Then the responses were analyzed to help in redesigning the safety features of heavy vehicles. Fig. 1 shows an example truck and trailer visibility is crucial in dark environment when accident is prone to occur.

Fig. 1 - The use of reflective strips to enhance heavy vehicle visibility [13]

3.2 Modeling Truck Dynamics

Next, in making sure that heavy vehicles are safe, the performance of heavy vehicles to carry loads when climbing the hill were analyzed by taking the Hino 300, 500, 700 Series, and the Mack Anthem as the model types in the study. Hino trucks are very commonly used in Malaysia for commercial transportation. When the long vehicle in Fig. 2 is traveling on a level road at its maximum speed v, all of the power P from its engine is used to overcome the power dissipated by the resistive forces, namely drag F_D and friction F_F. Therefore, the power can be found as $P = Fv/\eta$, where the right-hand side is the power generated by the engine pulling force minus the resistive forces. Here, transmission efficiency, η is included.

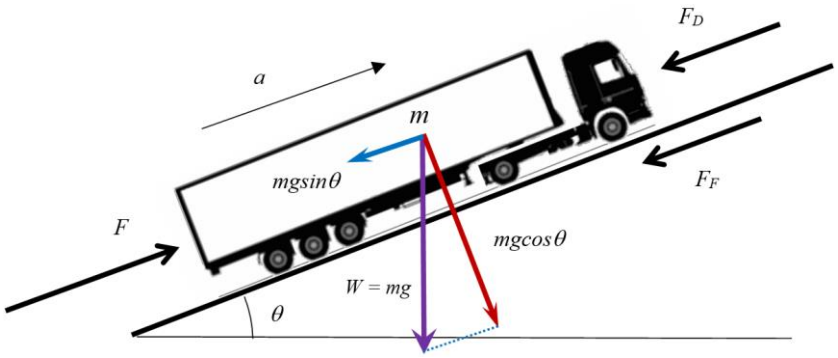

Fig. 2 - A free body diagram of the truck climbing a slope

Hence, the resulting equations are:

$$F = \eta \frac{P}{v} \tag{1}$$

which leads to

$$\frac{\eta P}{v} - F_F - F_D - mg\sin\theta = ma \tag{2}$$

where

$$F_F = \frac{\mu mg\sin\theta}{n} \tag{3}$$

and

$$F_D = \frac{\rho v^2 C_D A}{2} \tag{4}$$

The velocity v is the desired velocity of the vehicle climbing up the θ^o incline. n is the number of wheels on the vehicle. The frictional force F_F resists the motion of the truck going forward or uphill. Resistance may also include wind drag F_D [15]. Here in Eq. (2), the left-hand side represents the force output of the truck, whereas the first term represents the force generated by the engine and the power is spent to overcome the component of the car's weight acting down the slope. The suggested speeds like 80, 60, and 40 km/h can be studied for the drivers where they need to drive maintaining those speed to pass the hill smoothly. Muchuruza & Mussa [12] discovered that slow vehicles – below about 65 km/h or 40 mph – could actually contribute a lot to road accidents. Rear collision could also be tied up to the increase in the Gross Vehicle Weight (GVW), since the heavier the trucks, the slower they travel [9]. Hence, by knowing how slow any vehicle can travel is crucial for road safety. Other road users also will move up the hill smoothly without the presence of heavy vehicles obstructing the way at the hills and the usual congestion caused by heavy vehicles also can be reduced.

Next, by taking the dark condition such as at night, bad weather with rainy, hazy or cloudy conditions, the use of these safety features are really important in order to prevent any unexpected incident. This was proven by the survey that had been done where most respondents agreed on the safety features for heavy vehicles was an important element to prevent accident occurrence. They also agreed on the statement where other road users would be able to see the heavy vehicles clearly if safety features such as the use of lights, light reflection stickers and canvas were properly used.

However, there are still many deficiencies with the usage of safety features in Malaysia. Some of them is the insufficient additional light (side and back) on heavy vehicle where most respondents agreed on this lacking would limit the visibility of heavy vehicles. Besides, the appearance of light reflective sticker can be disturbed by dust or dirt covered on the surface of stickers and the use of old and faded light reflection sticker also can affect its appearance. Most respondents agreed on the appearance of light reflective sticker was important as an addition lighting to the existing light on heavy vehicle. Apart from that, they also agreed on the use of green or dark canvas was not suitable anymore for heavy vehicles especially at night as dark colors limited the detection by other road users.

As for the second objectives, calculation was made to find the performance of heavy vehicle to carry loads when climbing the hill by taking the Hino and Mack trucks as the main model types in the study. The speed required for the heavy vehicle to climb the hill with certain load would be identified. The data of the models were gathered from the website of Hino Motors Sales (Malaysia) Sdn Bhd.

3.3 Crashworthiness Simulation

This final part describes briefly on the simulation on the use of safe speeds for heavy vehicles by using ABAQUS, a computer aided engineering (CAE) application, using its Dynamic Explicit feature. For simplicity, the simulation treated the road as horizontal, where the emphasis was on the interactions of speeds between the car and heavy truck. After finishing the analysis of the survey and simulations, the proposed solutions were used to recommend the design of safety features and speed for heavy vehicles in Malaysia.

An important aspect in ABAQUS is setting the properties by choosing Property in the Module taskbar. Then click Special, Inertia, Create, Continue and select RP in the drawing. Set Isotropic of car which is the mass with 850 and 8500 for truck. In ABAQUS, the properties of material need to be insert manually. First, click Create Material, change the name to the material that have been chosen which is Steel. Then click General and insert Density with 7850. As for the Mechanical properties, there are two characteristics that must be filled in which are Elasticity-Elastic and Plastic-Plasticity as shown in Table 1 below.

Table 1 - The steel properties for the vehicle bodies in ABAQUS

Elastic		Plastic	
Young's Modulus (GPa)	**Poisson's Ratio**	**Yield Stress (MPa)**	**Plastic Strain (mm/mm)**
200	0.3	300	0
		420	0.04
		470	0.12
		500	0.19
		530	0.25

In the simulation, the part of car and heavy vehicle need to be drawn by clicking the Create Part icon in ABAQUS workbench. The dimension of car is based on the Perodua Axia SE Variance as on Fig. 3(a) and for heavy vehicles is chosen from the U-Haul Rental Trucks as shown in Fig. 3(b). The value will be converted to meter, m because in ABAQUS the unit is specified by the user where all dimensions need to be consistent, such as length and force in m and N, whereas Young's Modulus is in N/m.

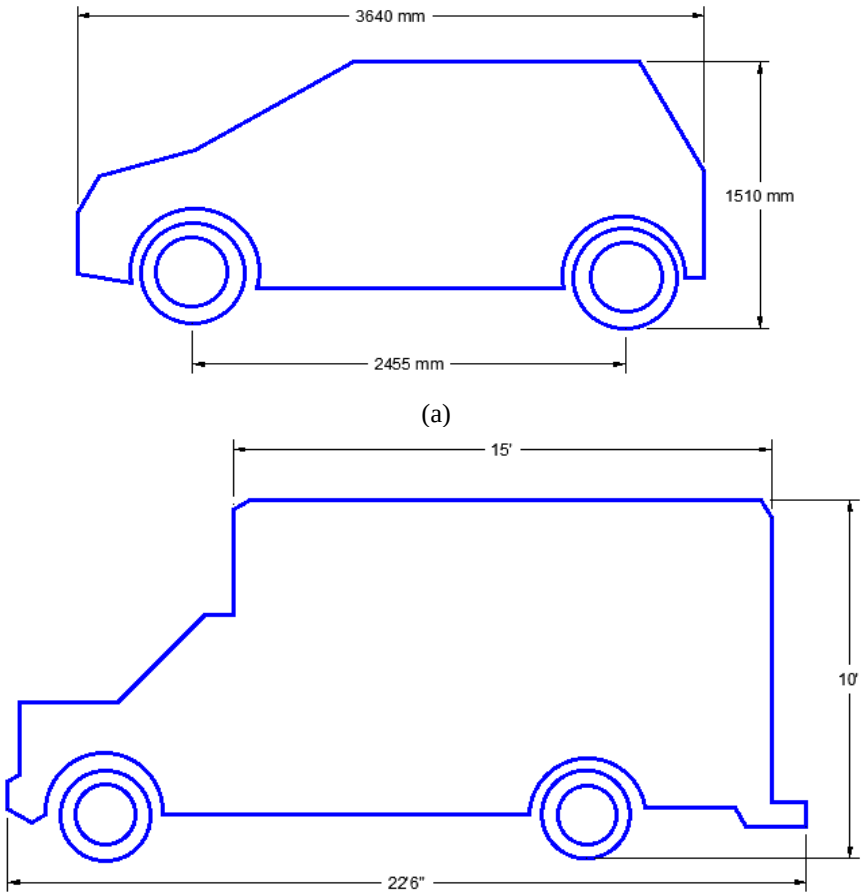

Fig. 3 - Dimensions of (a) the Perodua Axia in mm and (b) the transportation truck in feet and inches [14]

4. Results and Discussion

4.1 Survey on the Importance of Detection

The safety features that need to be emphasized in redesign or recommended a change is the light reflection stickers. This is because light reflection stickers can be an additional source of illumination besides the lights on heavy vehicles which was supported by works of [10]-[14]. Although the lights on heavy vehicles are not sufficient, light reflection stickers can be an aid to increase the visibility of the heavy vehicles if the light reflection stickers are used properly. As for the use of canvas, it is insignificant since the canvas is slightly up above the view of human eyes rendering it less urgent to be changed. Besides, the lower body of heavy vehicles is supposed to be occupied with light reflective stickers, which make the heavy vehicles visible to others. The authors think that brighter color canvases would be a better investment by truck companies. However, a generous amount of reflective stickers can be a quick fix to enhance the visibility of heavy trucks. The chart in Fig. 4 illustrates the results from this survey that was answered by 55 respondents of various ages, gender, and professions. Unfortunately, no statistical analysis was done on this finding. Hence, the bottom line from this survey is that the heavy vehicles need to be detected visually even in dark conditions.

4.2 Reflective Sticker Standards

Next, another survey regarding the obviousness of light reflection stickers was conducted to find out which design is more obvious to other road users see the presence of heavy vehicles on the roads. Current light reflection stickers that followed the Malaysian Standard which is MS 828:2011, is good enough, but Type 5 is too small to be seen clearly. Hence, the new design recommends that it should be bigger and the material used is still retroreflective sheeting but need to be standardized with honeycomb pattern so as to be the same as the other type of light reflection stickers. This

seems to agree well with the findings in [10] that showed 10 cm reflective tapes had better visibility. The recommended changes in design of light reflection stickers are presented in Fig. 5. This suggestion is a culmination of works such as the driving simulation at the Kitami Institute of Technology [10], the red and yellow sticker standard set by the Malaysian Road Transport Department [16], as well as experimental study using white and red DOT-C2 markers with honeycomb pattern by Sunway & Welcher [17].

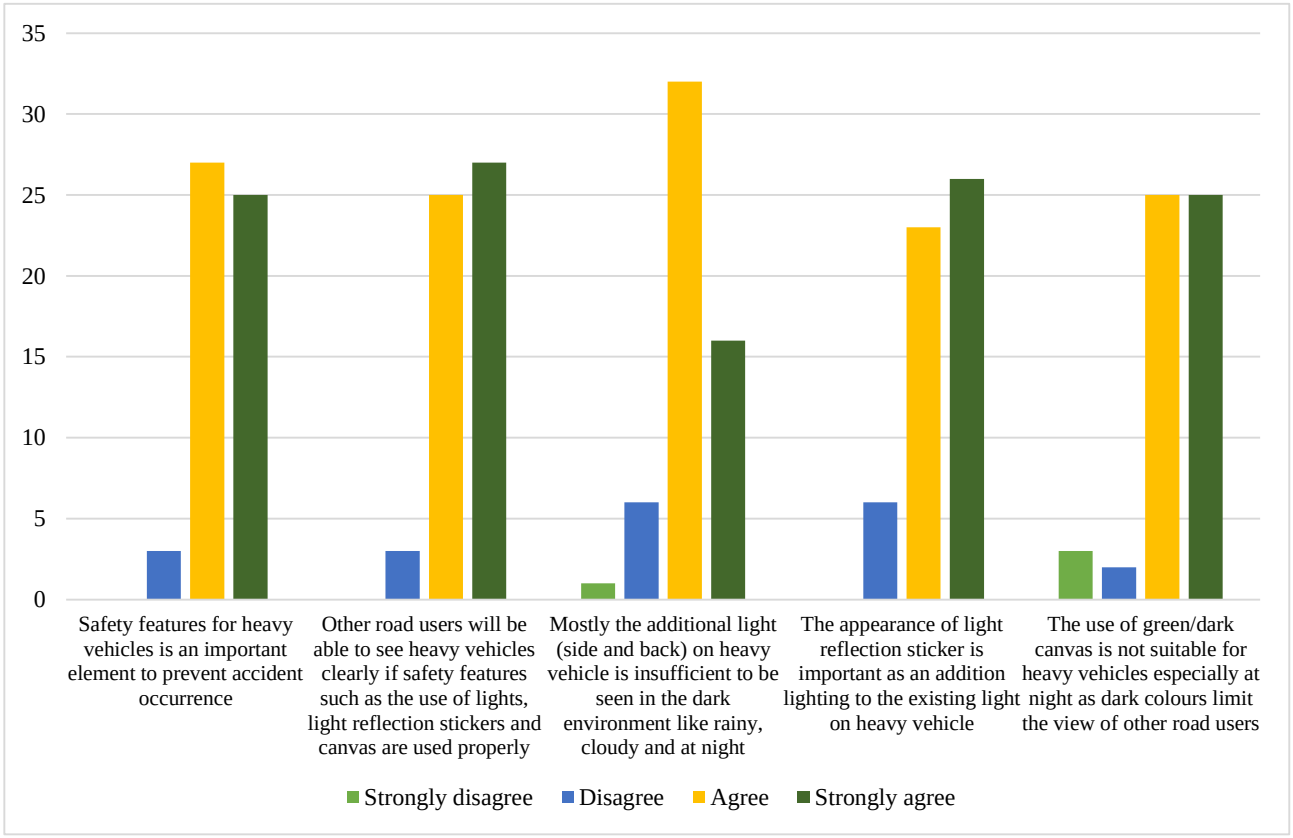

Fig. 4 - Responses to the survey statements

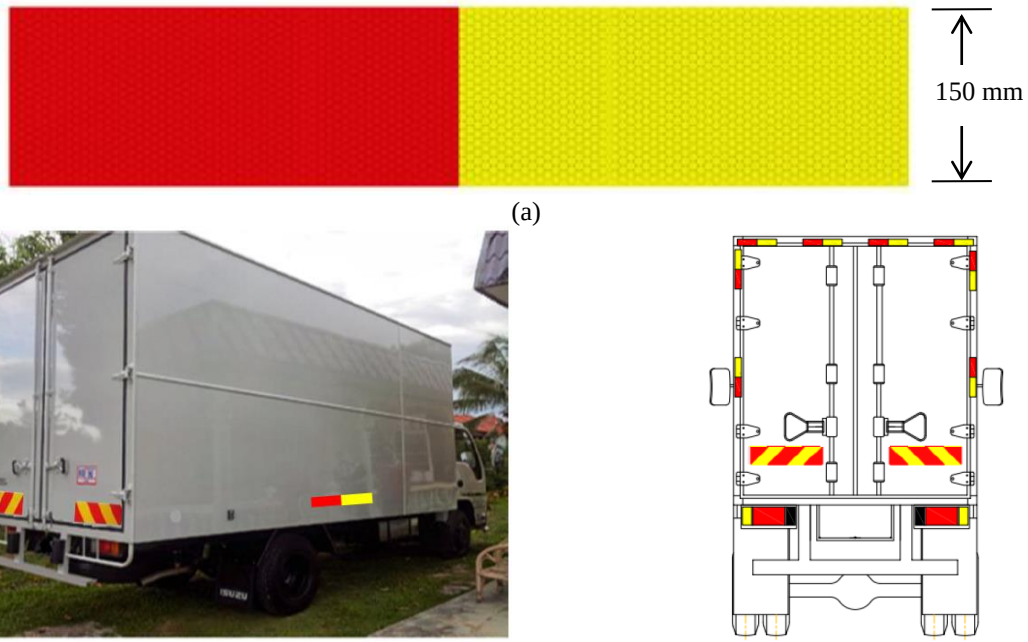

Fig. 5 - (a)The recommended safety sticker design for truck rear; (b) Placement styles of RRM [14]

4.3 Truck Speed Analysis

The next aspect is to find the suggested optimized speed for maximum masses allowed for the heavy vehicle in climbing a slope. Hence, by manipulating Eq. (2) with a low-speed transmission efficiency η = 0.9, the mass can be found as:

$$m = \left[\eta \frac{3600P}{v} - F_D \right] \left[\frac{1}{\frac{\mu g \cos\theta}{n} + g\cos\theta + a} \right] \tag{5}$$

At first, the hill slope is taken to be 0°, which means a flat road. Table 2 lists these values where the masses are calculated at an assumed acceleration of 0 m/s^2, the frictional forces from wind drag is estimated [15] and traction force with the coefficient μ taken to be 0.5 per tire. MACK is another semi-truck brand that is very widely used in the USA. Also, in this simulation, the traveling speed of the truck is of concern in order to haul the maximum load they are designed to pull. The powerful engine could haul higher load, but the regulation limits the overall mass to 80,000 pounds or about 36,000 kg. The frontal area is estimated at 90% from the product of height and width of the trucks.

Table 2 - Suggested speed while pulling maximum loads for trucks on a flat road

Model Variant	Hino 300 XZU720L8	Hino 500 FL8JW1A	Hino 700 SH1ERRA	MACK Anthem
Assumed number of wheels	6	18	26	18
Gross Combined Weight (kg)	8,500	27,000	55,000	36,000
Max power (kW)	114	210	309	376
Traveling speed (km/h)	**80**	**80**	**80**	**80**
Height (m)	2.24	2.76	3.015	2.86
Width (m)	2.06	2.49	2.49	2.41
Estimated area (m^2)	4.15	6.19	6.76	6.20
Estimated drag, F_D (N)	884.32	1317.06	1438.74	1320.93
Calculated Max Mass (kg)	**4,566**	**26,378**	**58,709**	**51,035**

Hence, if the trucks are moving at 80 km/h, each maximum load for a Hino 300 series truck is 4,566 kg, Hino 500 series is about 26,378 kg while Hino 700 series is 58,709 kg. The values are close to the maximum weights (actually, masses) specified by the truck makers. With 376 kW engine, MACK Anthem can travel the fastest. It could tow over 51,000 kg even though the Gross Combined Weight (GCW) is just 36,000 kg. Generally, to move faster, the load should be decreased. However, the problem arises when a truck becomes overloaded and the available power is not enough to go fast enough. Hence, they become a hindrance on the road. This is worse when at hills. The more extreme slope is about 2° that is equivalent to 3.49% slope, which is below the suggested to be the maximum gradient of 6% for heavy trucks [8]. Assume the acceleration is 0 m/s^2 that means constant velocity while the drag coefficient of 0.704 is used as suggested in [15]. Table 3 shows that the MACK truck can haul the most load at the desirable speed of 60 km/h. This concludes that higher engine output is crucial in order to pull larger loads especially uphill. Engine torque is also an important criterion here.

Table 3 - Traveling truck climbing 3.49% slope and the resulting masses

Model Variant	Hino 300 XZU720L8	Hino 500 FL8JW1A	Hino 700 SH1ERRA	MACK Anthem
Assumed number of wheels	6	18	26	18
Gross Combined Weight (kg)	8,500	27,000	55,000	36,000
Max power (kW)	114	210	309	376
Max torque (Nm)	429	892	1903	2522
Traveling speed (km/h)	**60**	**60**	**60**	**60**
Height (m)	2.24	2.76	3.015	2.86
Width (m)	2.06	2.49	2.49	2.41
Estimated area (m^2)	4.15	6.19	6.76	6.20
Estimated drag F_D (N)	497.43	740.84	809.29	743.02
Calculated Max Mass (kg)	**4,881**	**17,243**	**29,905**	**31,822**

4.4 Finite Element Analysis Results

In addition, this issue can be related to the safe speed on the normal road where simulations on it had been done in ABAQUS/CAE using the Dynamic Explicit application. The impact analyses between heavy vehicles and car were divided into three sections, which were for masses of 8,500 kg, 26,000 kg, and 55,000 kg. These masses were from the studied models of Hino 300, 500, and 700 Series. The speed and mass of the car were maintained at 120 km/h and 850 kg respectively. The results are displayed in Figs. 6 through 8. These results are only for the 26,000 kg Hino truck since there is limited space to report here. More detailed results are available in [14]. From these results, it agrees with common sense that as the truck becomes slower, the resulting stress in the car from the rear collision increases. This also means the damage becomes more severe as the truck travels slower.

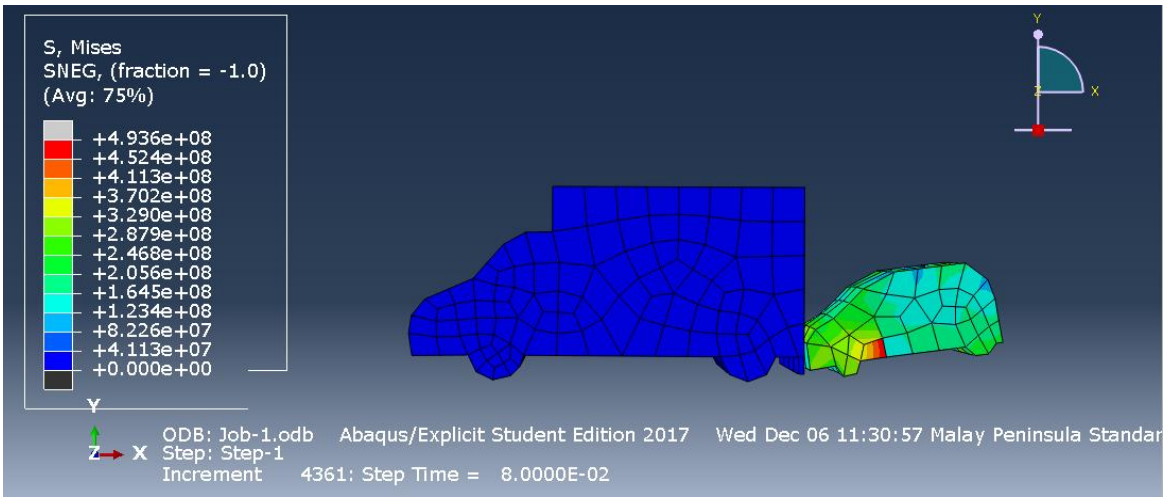

Fig. 6 - The maximum stress at the car front is about 494 MPa. The 26,000 kg truck is moving at 80 km/h

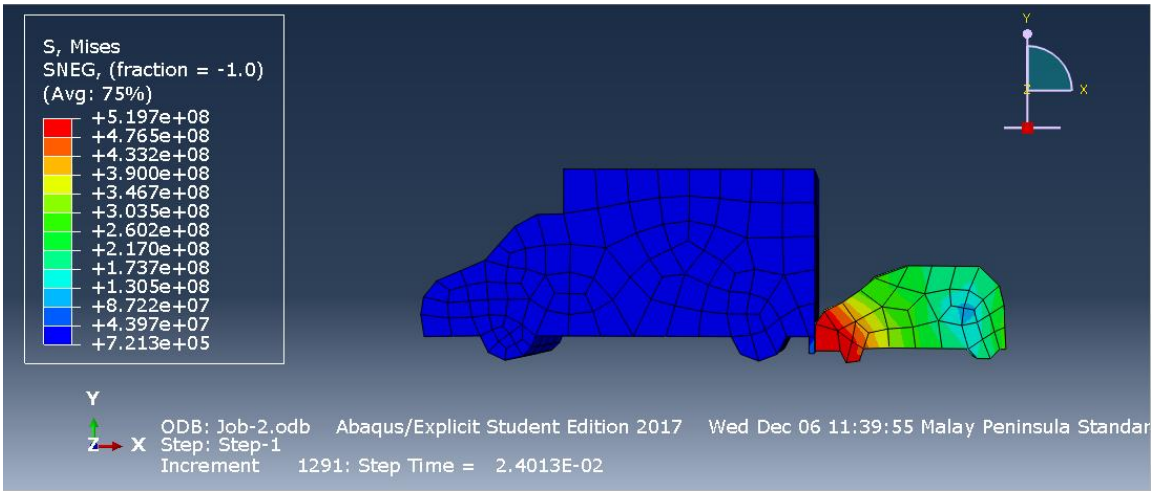

Fig. 7 - The maximum stress is almost 520 MPa. The 26,000 kg truck is moving at 60 km/h

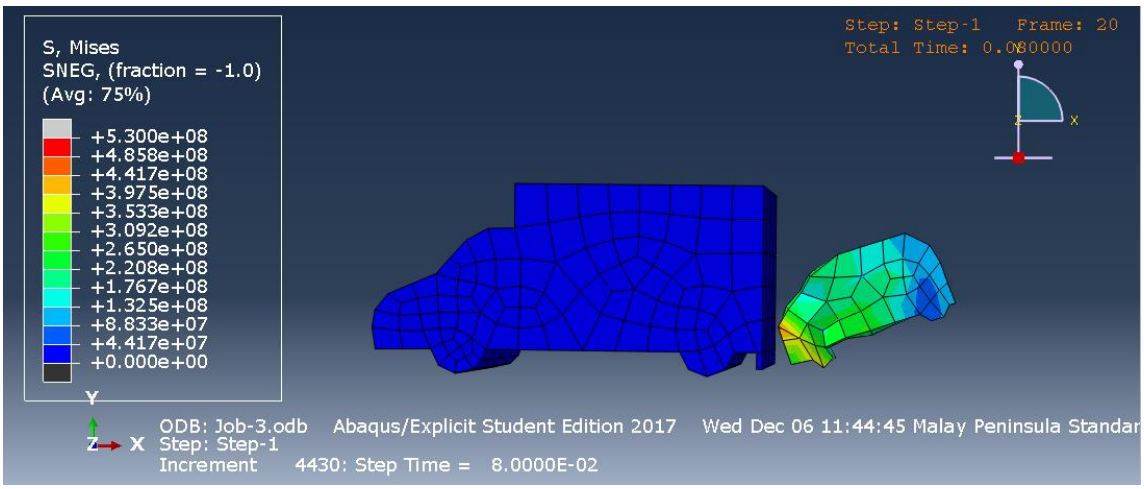

Fig. 8 - The maximum stress is 530 MPa. The 26,000 kg truck is moving at 40 km/h

Further check with MatWeb found that a 1020 cold-rolled steel like this could have an ultimate tensile strength of about 420 MPa [19]. Hence, in all situations, the small car was going to wreck catastrophically since the maximum stresses produced was significantly beyond the strength. In a related study, Ikpe, Owunna & Satope [20] studied the side impact of the B-pillar of a car that resulted in a maximum Von Mises stress of around 673 MPa in the improved design. Thus, it can be stated as the slower the speed of the truck, the higher the stress faced by the car bumper, its damage becomes worse. Apart from that, the crumple of car at the final crash becomes more severe as the velocity of the truck decreases. Hence, it can be stated as the heavier the vehicle, the slower it is moving and the more dangerous it can be to other road users. If this simulation is occurring in real life, it is likely that the passengers in the car become casualties or suffer really bad injuries. Consequently, a recent study has looked into various aspects of the drivers like age, gender, and fatigue level in order to lower the risk of rear-end crashes that may cause injury and fatality [21].

5. Conclusions and Suggestions

This study found that the regulation for reflective stickers in Malaysia has been enhanced to make larger vehicles more visible, through the regulation amendment in 2019. The new law set a minimum width of 150 mm for a reflective sticker tape with 45° yellow and red stripes. There are configurations to apply the sticker according to commercial vehicle types. Our suggestion is to add the white honeycomb pattern, subject to further study. However, this pattern is already practically available in the market.

Then, the second objective was achieved by analyzing the performance of heavy vehicles to carry loads when climbing steeper roads. It found that the allowable load mass is largely more than what the engine can deliver in order to achieve safe speed. Hence, rather than solely depend on the number of axles and wheels, this study showed that the engine capacity is also important should it wants to maintain a certain safe speed.

Consequently, a loaded trailer truck needs to maintain a minimum speed of 60 km/h even going up a hill since it is least damaging to rear-end collision with a light car. The slower the truck travels on a highway, the higher the impact

would become with a speeding vehicles from the rear. Therefore, the chances for passenger survival would diminish significantly.

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