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A Study on Heavy Vehicle Visibility and Crash Analysis Using ANSYS

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ABSTRACT

A pilot study was conducted to evaluate the visibility of heavy truck in Malaysia. A survey, analytical computations, and computer simulations were all part of the investigation scope. The survey was conducted with 40 respondents to investigate the visibility detection of heavy vehicles, which considered lights, light reflective stickers, and the color of canvas used on heavy vehicles. Another concern is the poor speed of heavy vehicles when climbing up hills with heavy loads, which is a hazard since being too slow may produce a more severe rear-end collision damage. Additionally, computer impact analyses were also done by using ANSYS, where many rear-end crashes between a car and a heavy vehicle were analyzed. Hence, a conclusion may be formed that the slower the speed of a heavy vehicle, the higher the impact experienced by the car colliding from behind the heavy vehicle.

Keywords: ANSYS, crash analysis, heavy vehicle visibility

1. INTRODUCTION

There are several fatal road and highway accidents that occur each year. When it comes to Malaysia, this is especially noticeable during festival season and long holidays such as school breaks. There are a variety of factors that contribute to this. These include technical faults resulting from design, assembly, and utilisation that are related to human error as the fundamental cause of the failure. Accidents are frequently caused not just by human unconscious act, such as driving while in a drowsy state or being under the influence of alcohol or drugs, but also by the difficulty of the human to see other vehicles on the road and the improper use of safety features.

Thus, each mode of transportation has its own set of safety characteristics. The safety features in visibility aspect especially are capable of preventing unforeseen events from occurring for example, car accidents in general. In addition to passive safety and active safety features, there are also general safety and environment characteristics, all of which are outlined in the United Nations Safety Regulations. As part of the Transportation (Vehicle) Type Approval (VTA) procedure, Malaysia has translated Article 100 of the United Nations Regulations into the regulations of motor transportation (Construction and Use) 1959, which are implemented through the Gazette 100 of the UN Regulations [1]. Despite the fact that Malaysia has adhered to these laws, there are certain obstinate groups who are willing to compromise and overlook safety aspects in order to obtain benefits for their own interests. Unfortunately, this mindset will have unintended repercussions, including crashes involving not just them but also other road users.

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Even though heavy trucks are not highlighted as a main cause of accidents on the highways and roads, the visibility of heavy trucks is a very important issue that has to be addressed by all road users. Heavy trucks, on the other hand, are well-known for contributing to the greatest percentage of fatal accidents. Improvements in the design and safety factor especially visibility of heavy trucks must be implemented immediately in order to prevent the situation from becoming worse. Furthermore, the rising number of heavy vehicles on Malaysia's roadways is contributing to traffic congestion, particularly during holiday seasons and peak hours. As an additional feature of many roadways, heavy vehicles rising slowly in the left lane as they ascend the slope are a familiar sight as they pass by. As a result of the engine's performance, which also includes the efficiency of its transmission, this is referred to as the powertrain.

As an outcome, the visibility of heavy vehicle will be concentrated on this work, with some of the current safety measures being examined and enhanced as part of the process. One of them is the employment of active safety measures like lights, light reflecting stickers, and canvas, which will be investigated to see whether or not they are suitable to use. Apart from that, the ability of a heavy vehicle to transport goods while ascending a slope was also investigated. The speed at which a heavy vehicle must travel up a slope while carrying a specific weight will be determined and computed in this study. Following that, a simulation will be given to demonstrate how a crash analysis happens with varied velocity and mass of heavy vehicle.

2. HEAVY VEHICLE CRASHES IN MALAYSIA

According to statistics given by [2], the overall number of heavy vehicles in Malaysia is increasing every year. In accordance with data from [3], it appears that the number of accidents involving lorries is increasing year after year. Due to the continued increase in the number of registered heavy vehicles, the number of accidents keeps rising accordingly as well. Heavy vehicles collisions can involve a single mode of transportation (heavy vehicles alone), such as driving off the road or rolling over, as well as colliding with another vehicle. When it comes to heavy vehicle crashes, the most common factors to consider are speed, the mechanical condition of the transportation vehicle, particularly the brakes, the characteristics of the load being transported (including overloading), and the surrounding environment, which can be either dark or bright depending on the weather and time of day. Because the project is concerned with the installation of a warning signal on a heavy truck, it may be used in low-light conditions such as at night, on rainy days, or in any other situation when there is less light. This cognitive ergonomics will play a significant part in communicating to other road users that a large vehicle is on the road and that they should be cautious.

A study has been done by Ackaah, Apuseyine, and Afukaar [4] to investigate the nature and risk variables connected with road traffic accidents that occurred at night in Ghana, as well as to propose appropriate control strategies. The statistics on crashes and injuries from the years 2013 to 2017 were evaluated. The fatality index and fatal crash ratio metrics were used to determine the severity of injuries among those who were involved in traffic accidents. In general, road accidents that occurred at night resulted in more severe injury outcomes than accidents that occurred during daytime hours. The majority of the crashes (67 percent) happened in the early hours of the morning, between the hours of 18:00 and 22:00 hrs. The most significant contributory risk factors connected with night travel are low night vision combined with inadequate visual guidance on the road, both of which are combined. Infrastructure policies must be directed toward the supply of functional street lights in urban areas, as well as road line markers, delineators, and signs for highways and arterial roads.

Craft in [5] researched on the prevalence of heavy vehicles involving in rear-end collisions with other vehicles that suggested that many accidents occur when another vehicle ramming into the rear-end of a heavy vehicle. Most of such an accident occur in low-light conditions such as at night or stormy conditions. A possible reason is that the drivers of the other vehicle are unable to detect the heavy trucks in front of them in time.

In the following study, the factors that affect truck participation in night time collisions that occur in rural regions is larger than those that occur in urban areas was investigated by Sullivan [6]. Unlike metropolitan areas, rural regions typically have less illumination or insufficient streetlights. This is compounded by the absence of many other cars on the road, which could have provided additional light to road users.

Prior to that, Sullivan and Flannagan [7] investigated the impact of lighting conditions on rear-end collisions involving large trucks, finding that rear-end collisions involving any vehicle were twice as likely to occur at night than during the day. They discovered that deadly rear-end crashes with large trucks were up to nine times more likely to occur in the dark than they would during the day. When there is inadequate light in the surrounding area, road users' ability to see clearly is hindered by the gloomy surroundings.

In addition, Friswell, Williamson and Irvine [8] discovered that heavy trucks and trailers were prone to collisions in the middle of the night to dawn. Their work was to determine the trend in heavy truck crashes in some region in Australia during a four-year period. The study found that large trucks typically begin their journeys on the highways at night in order to evade busy traffic during the day. Unfortunately, the combination of a dark environment with little light and a distracted driver usually end in an accident in the dark road.

Data from fatal crashes involving heavy commercial goods vehicles (HCGVs) in Malaysia [9] revealed that the most prevalent types of crash configurations for HCGVs were head-on collisions (33 percent) and rear impact collisions (28 percent). For rear-end incidents involving heavy commercial goods vehicles (HCGVs), the quantity of light was not important, as the number of accidents that happened during daytime and the different levels of darkness were 51 percent and 49 percent, respectively for the different categories of darkness.

Heavy vehicles, which usually move at a relatively slow pace, present a potentially hazardous in this situation, particularly given the high death rates for drivers of commercial vehicles who are involved in collisions with them, which are a result of the large mass of the heavy vehicles involved in the accident. Although nighttime, dawn, and twilight traffic volumes account for less than a third of the total daily traffic volume, around 40 percent of all road accidents occur during these periods. As a result, it may be inferred that driving at night is at least twice as risky as driving during the day in the context of crashes involving heavy trucks [10].

In Malaysia, there are several hilly expressways where accidents frequently occur, like the state road between Temerloh and Gemas, for instance. Therefore, drivers must have a thorough understanding of the functioning of their heavy machines in order to avoid any unforeseen incidents, such as a large truck being sluggish on a slope due to overloading. According to the presentation by JPJ in [2], the majority of cases of overloading occurred in the more-advanced places in the manufacturing industry and in areas with a high concentration of forestry products and even mining. One such state in Malaysia is the great old state of Pahang. This circumstance will not only make the roads busier, but it also has the potential to result in collisions if the importance of safety precautions is not underscored adequately. Aside from that, the road conditions can deteriorate if heavy vehicles are overloaded and driven across it on a regular basis, as overloading makes the heavy vehicle significantly heavier. Hence, this may result in road damage like potholes that contribute to further road disasters.

Additionally, other hazards can be mitigated by the design of safety features especially on visibility on heavy vehicles, such as the use of on-board warning systems and accident-avoidance technologies, which can increase the stability and control of the vehicle during transit. At the time of a rear-end collision, conspicuity is quite important, especially during the night. It is necessary to equip heavy trucks and their trailers with conspicuity markings, such as retro-reflective markers (RRMs), and to keep the vehicles and trailers in excellent condition in order to increase heavy vehicle visibility. In order to improve the visibility of heavy vehicles to other drivers, especially in poor light or severe weather situations, these markings are applied. They serve to alert other drivers that they are approaching a large truck by reflecting the light from their headlights. According to Morgan [11], it has been shown that the alternate red and white pattern on the back of an HGV signals the presence of a heavy trailer, while at the same time aiding other drivers in determining their distance and rate of approach. Furthermore, Morgan [11] also discovered that retroreflective tape is helpful in increasing the visibility of large vehicles and minimizing side and rear collisions by 29 percent while driving in low visibility or in the dark. The use of retroreflective tape in low-light circumstances decreased the number of fatalities from side and rear contact collisions by 44 percent.

According to Babic and Fiolic [12], the retro-reflective rear marker plates, which are installed in addition to rear lights, are designed to make the heavy trucks more visible to other drivers. Apart from that, according to research by the Amirudin *et al*. [13] from the Malaysian Institute of Road Safety Research (MIROS), 69 percent of respondents agreed that the present usage of RRMs in Malaysia is neither innovative or effective. Consequently, 99 percent of road users agreed that effective RRMs are necessary for heavy trucks and also agreed with the statement that 'the brighter the RRMs, the safer the vehicle for use by heavy vehicles. Although the application of RRM at the back of heavy road transportation is now a law in Malaysia, there are still many instances where the covering tarps cover the reflective stickers, effectively making them useless. Hence, further investigation is needed to solve that such as determining acceptable load covering tarp colors and stricter implementation of the RRM law.

Based on the study in [14], in four different types of roadways, a total of 7168 commercial vehicles were seen driving around in them during a period of the study. The majority of them (almost 50%) were gathered on secondary routes. Light lorries with two axles accounted for almost one-third of the samples, whereas big lorries with two axles accounted for 16 percent. Results show that in general, most heavy vehicles (4.39 percent–98.61 percent) travelled at excessive speeds and did not adhere to the stated speed limits on various types of road hierarchies. The lower the posted speed limit, the greater the proportion of noncompliance rates, which implies that the percentage of compliance increases when the stated speed limit is raised, and vice versa. Those smaller-sized business vehicles (as opposed to larger-sized commercial vehicles) were more likely to travel in the fast lane (28 percent – 57 percent). Hence, the speed at which a heavy vehicle can climb a slope while carrying a specific weight, as well as the speed at which it can travel safely on roads or highways, must be investigated. This can ensure that the pace of heavy trucks is maintained and that they do not cause inconvenience to other road users by going too slowly or too quickly.

3. RESEARCH METHODS

This study included the distribution of a questionnaire focusing on the visibility of heavy vehicle and computer simulations. Following that, the output is examined in order to generate some solutions to the challenges. A survey was undertaken to obtain respondents' opinions on the visibility of heavy vehicles in Malaysia. This survey included about the use of light, the placement of a light reflection sticker, and the color of the canvas used to cover heavy vehicles. The respondents ranged in age, profession, and gender.

3.1 Survey on Heavy Vehicle Visibility

The survey set in Table 1 consists of six questions with yes or no answers to get opinions among road users on the matter. The survey focuses on the factors that contribute to the visibility and heavy vehicle accidents especially on the issue of safety features. Forty respondents participated in the survey, and the data were analyzed using multivariate correspondence analysis from the perspective of road users in Malaysia. One of the pictures included in the survey is shown in Figure 1.

Table 1 Survey Questions on Heavy Vehicle Visibility

Q1	The presence of safety features on heavy trucks is an essential factor in preventing accidents from occurring?	Answer: Yes or No
Q2	If heavy trucks are appropriately equipped with safety elements such as lights, light-reflecting stickers, and canvas, other road users will be able to see them clearly?	
Q3	In most cases, the extra lighting (side and rear) on large vehicles is insufficient to be seen in low-light conditions such as rain, fog, or at night?	
Q4	The look of the light reflection sticker is essential because it serves as an additional lighting source to the existing light on a heavy vehicle?	
Q5	The use of green or dark canvas is not recommended for large trucks, especially at night because dark colors limit the visibility of other road users and cause accidents?	
Q6	Is it feasible for other road users to view this light reflection sticker clearly?	

Figure 1. Two truck moving side by side on a highway. Here one is visible, while the other is not.

In practice, the survey was conducted online using Google Forms, and the participants were all Malaysian drivers and road users. In general, the age of road users is categorized into three groups: I. 25-44 years old, II. 45-54 years old, III. 55 years old and above. As illustrated in Figure 2, there are significant reasons that indicate the importance of adding safety features on heavy trucks as preventing accidents from occurring. The majority of respondents agreed that safety features such as lights, light-reflecting stickers, and canvas if used properly can help other road users see heavy vehicles clearly especially at night or during inclement weather. This short study can summarize the hazards by heavy vehicles to other road user as shown in Table 2.

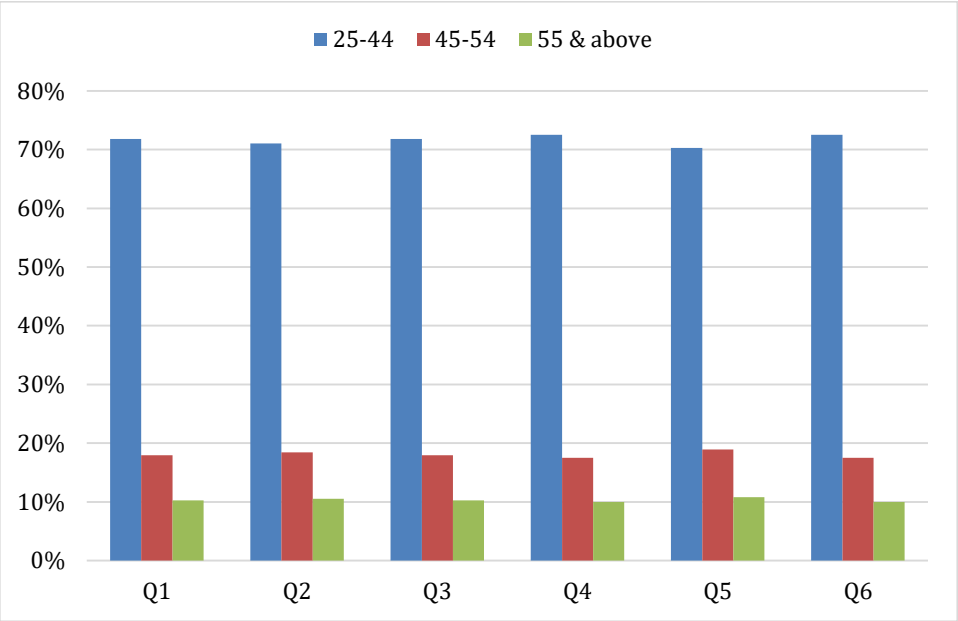

Figure 2. Percentage of road users (based on the range of ages) agreed with the survey questions.

Table 2 Factors of Road Accidents Involving Heavy Trucks

Vehicle	Safety Features	Factor	Causes
Heavy truck	Vehicle speed limit Light reflection sticker	Insufficient speed Poor visibility	Heavy, overload rain, fog, dark day

3.2 Calculation on Performance of Heavy Vehicle

The performance of heavy vehicles to carry loads when climbing the hill were analyzed by taking the VOLVO FM 420, FMX 440 and FH 520 Series. The formula below will determine the speed required to climb a hill with a specific load. When a car travels at its maximum velocity (v) on a level road, all of the engine's power (P) is needed to overcome the resistive force (f). Thus, P is the power output of the engine and F is the power dissipated by the resistive forces, F_D and F_F. Here, A is the frontal area while μ is the coefficient of road friction. Hence, the resulting equations are shown in Equations (1) through (4) based on the free-body diagram (FBD) in Figure 3.

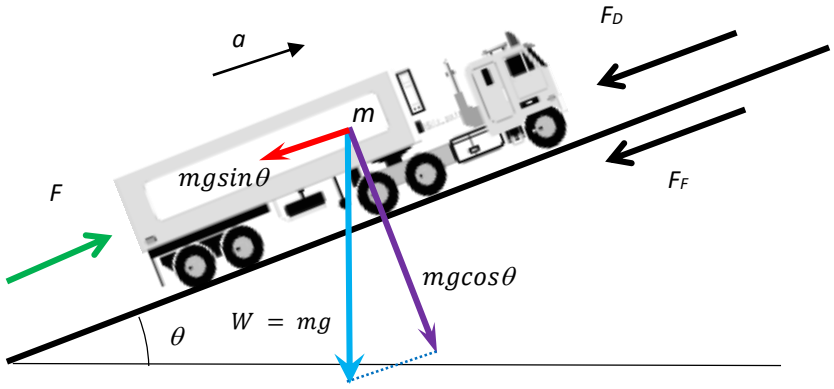

Figure 3. The FBD for a tanker climbing up a slope.

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

When a vehicle with a weight (W) is going up an incline with an angle of inclination of with respect to the horizontal (θ), it is exposed to the extra force $F' = W \sin \theta$ due to gravity, which tends to slow its progress.
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 specifications of heavy trucks that were utilized in this calculation were derived from the data from Volvo Trucks Malaysia [15]. Although, some Volvo models could slowly haul up to 325 tons of load, however, most states in the USA would limit this capacity to 80,000 pounds or about 36,000 kg only [16].

3.3 Crash Analysis

This final section presents the simulation of safe speeds for heavy vehicles using ANSYS, a computer-aided engineering (CAE) product. The simulation will be horizontal and there will be few variations in the interaction of speed between car and heavy vehicle. SOLIDWORKS is required to sketch car and truck. Any solid product requires a basic sketch. Create a new part and choose a template. After the user interface appears, select the Sketch icon on the left side of the Command Manager. This will allow you to draw simple forms like lines, circles, and rectangles. For new users, the Line command is the most basic. To start sketching, choose Line. To add dimensions, pick the Smart Dimension command from the Command Manager, next to the Sketch icon. The car's dimensions are based on Perodua Axia, while the heavy truck's measurements are

approximately based on a Volvo truck, as shown in Figures 4 and 5. The part drawings for the car and the heavy truck were made using the rough outer dimensions.

Once done with the sketching process in SOLIDWORKS, the analyst would apply Extruded Boss/Base, then apply shell for car only. Next, the Explicit Dynamics model was created in the ANSYS workbench with the imported SOLIDWORKS geometry. Once this is completed, the mass for the car was set to be 850 kg and the truck 25000 kg. Following that, a body interaction was added and the meshing process initiated. The velocity value for the car was set at 120 km/h and 40 km/h for the truck. The process was repeated several times with various parameters for the truck while the car's mass and velocity stayed constant. The truck parameters are as shown below in Table 3 have been completed.

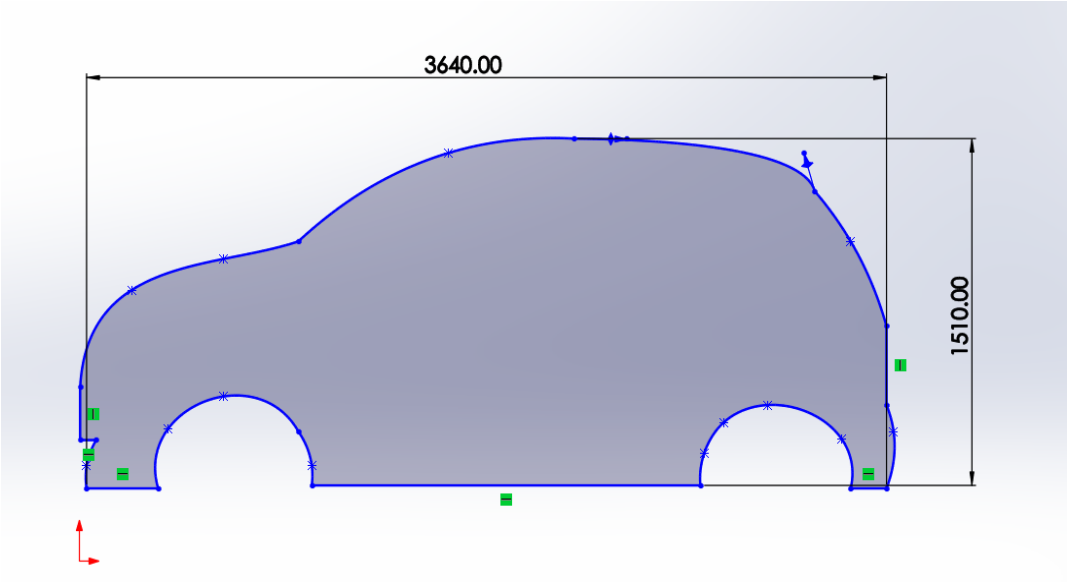

Figure 4. SOLIDWORKS drawing of a car with dimensions in millimeters.

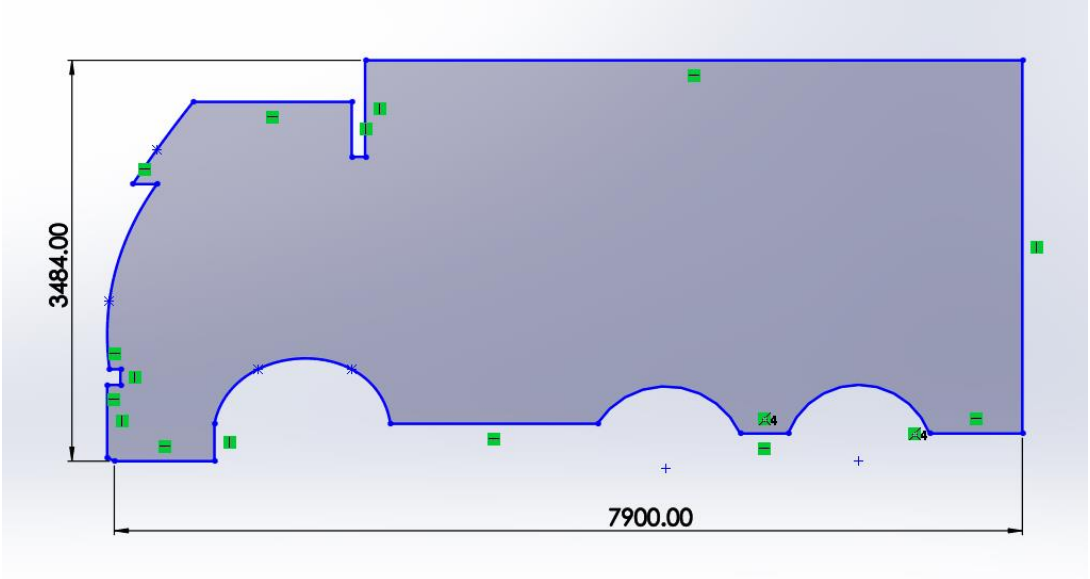

Figure 5. SOLIDWORKS drawing of a heavy vehicle in millimeters.

Table 3 Parameters for the Truck

Mass, kg	**25000**			**31000**			**200000**		
Velocity, km/h	-40	-60	-80	-40	-60	-80	-40	-60	-80

4. RESULTS AND DISCUSSION

The results of the survey on heavy vehicle visibility and safety speed calculation will be presented. Then there will be more discussion to support and strengthen the study's conclusions. The survey analysis, safety speed calculation, and simulation are the three parts of the results.

4.1 Survey on Visibility of Heavy Vehicle

The study on heavy truck visibility was evaluated by considering the human factor, with an emphasis on cognitive ergonomics in terms of perception in order to communicate with other road users. The survey is completed online using Google Forms, with a total of 40 respondents. The purpose of the survey was to get opinions from Malaysian respondents on the subject. To be more specific, the survey will look into heavy truck visibility in terms of lights, light reflection stickers, and the color of canvas used on heavy vehicles. Using these safety features in low-light conditions, such as at night, or in bad weather, such as wet, hazy, or cloudy days, is critical in order to avoid any unexpected incidents. A survey found that most respondents believe that safety features in visibility for heavy vehicles are essential to minimize accidents. They also agreed that other road users will be able to see heavy vehicles clearly if safety measures like lights, light reflecting stickers, and canvas are used properly.

4.2 Light Reflective Sticker Recommendation

Light reflection stickers are one of the visibility elements that should be highlighted in any redesign or recommended alteration. This is because light reflection stickers, can be used as an extra source of light in addition to the lamp on heavy vehicles [17]. Although the lights on heavy vehicles are insufficient, light reflection stickers can be utilized to help illuminate the heavy vehicles if they are used correctly. The work in [17] showed that red and yellow reflective stickers in the rear of the trailers and trucks can be better seen in all weather conditions, while 10 cm stickers can be detected faster than 5 cm ones. The updated laws in Malaysia as indicated in [18] suggest that the stickers are now larger and still be made of retroreflective sheeting, but the honeycomb pattern could be studied further in Malaysian environment, as with other light reflective sticker designs. Another color combination of red and white can also be considered as it is also commonly used in the United States.

Therefore, light reflection stickers are one of the safety characteristics in visibility that should be emphasized in any redesign or update that is recommended. Light reflection stickers can be an extra source of lights apart from the lamp on heavy vehicles. The design concept will be bigger and the material usage is still retroreflective sheeting but need to be standardized with honeycomb pattern as same as other sort of light reflective stickers.

4.3 Speed Analysis

Following that, because the heavy vehicle is travelling up an incline, it is subjected to increased force, and the new power balance equation (2) is written, with sin theta equal to 1/20 or about 2.86° from the horizon. If rated load is desired, then the results tabulated in Table 4 show a maximum speed for the Volvo FM 420 series being 68 km/h, the achieved speed for the Volvo

FMX 440 series being 62 km/h, while the calculated speed for the Volvo FH 520 series being 14 km/h. The acquired speed can guide the driver, who may need to travel faster to pass the slope smoothly. The MACK Anthem is a popular semi-truck model in the USA, included here as a reference. Other road users will be able to continue more smoothly up the slope without heavy vehicles trapped at the top, reducing congestion. Before delivering heavy vehicles, the manufacturer must disclose data regarding the specific speed to pass the slope.

The desired 80 km/h speed can be maintained for the three heavily-loaded trucks to ascend the hill, but this affects the maximum loads being hauled as calculated at the bottom of Table 4. The resulting loads can serve as a guidance for the driver, who may need to maintain a comfortable highway speed in order to pass the slope smoothly. Other road users will be able to proceed more conveniently up the hill without the presence of heavy vehicles stranded at the top of the hill, and the usual traffic congestion created by stalled heavy vehicles will be minimized. Consequently, this can also help to reduce rear-end collisions between heavy vehicles and other vehicles.

Table 4 The Theoretical Speed Attained for Heavy Vehicles

HILL	2.86	DEGREES	5%	GRADE
Model	**VOLVO**	**VOLVO**	**VOLVO**	**MACK**
Variant	**FM 420**	**FMX 440**	**FH 520**	**Anthem**
Assumed number of wheels	18	18	30	18
Gross Combine Weight, kg	25,000	31,000	200,000	36,000
Max power, kW	420	460	540	376
Max torque, Nm	2100	2275	2500	2522
Traveling speed, km/h	**68**	**62**	**14**	**44**
Height (m)	3.152	3.138	3.509	2.86
Width (m)	2.534	2.534	2.495	2.41
Estimated area (m^2)	7.19	7.16	7.88	6.20
Estimated drag, FD (N)	1105.93	915.29	51.38	399.58
Calculated Max Mass, kg	24,823	30,360	191,368	35,828
Traveling speed, km/h	80	80	80	80
Calculated Max Mass, kg	20,324	22,460	30,933	18,259

4.4 Braking Distance

When a car traveling fast on a highway and suddenly the driver sees a truck ahead, he or she could steer to change lane if that is possible. However, should there no space to change lane, then the driver must hit the brake to slow down or may be even stop completely. The reaction time can be linked to physiology and psychology of the driver as shown in many work such as [19]. Meanwhile, guidelines in [20] shows the expected braking distances as a function of the car speed. Here, one should appreciate the importance of detecting the sluggish or even static heavy vehicles on the road. In addition, the braking distances of a passenger vehicle can also be verified through experiments as shown by Koylu and Tural in [21]. Figure 6 depicts a car colliding with the rear-end of a haulage truck, probably because of not being able to brake in time [22].

Figure 6. A public domain picture of a dangerous rear-end collision with a stationary truck [22].

4.5 Simulation Analysis

Finite element modeling (FEM) is a popular engineering tool since 1960s. In a car crash, the model must be treated as non-linear system. Many crashworthiness simulations were done using the computer such as by Praveen and Sandeep-Kumar [23], Sahu and Shuman [24], as well as Babu and Suresh [25]. In this work, the crash analysis between heavy vehicles and car is separated into three section which are crash analysis for mass of 25000 kg, 31000 kg, and 200000 kg. These masses are from previous model which are Volvo FM420, FMX440 and FH520 Series. The speed and mass of the car are maintained with 120 km/h and 850 kg, respectively. Figures 7 through 9 show the result of simulation done using ANSYS. Because of the limited amount of space available for reporting, these data are only for the 25,000 kg Volvo truck. More results have been tabulated in Table 3. According to these findings, it is consistent with rational thinking that when the truck's speed decreases, the resulting stress in the car from the rear collision increases as well. The damage will also get more severe as the truck moves at a low velocity as a result.

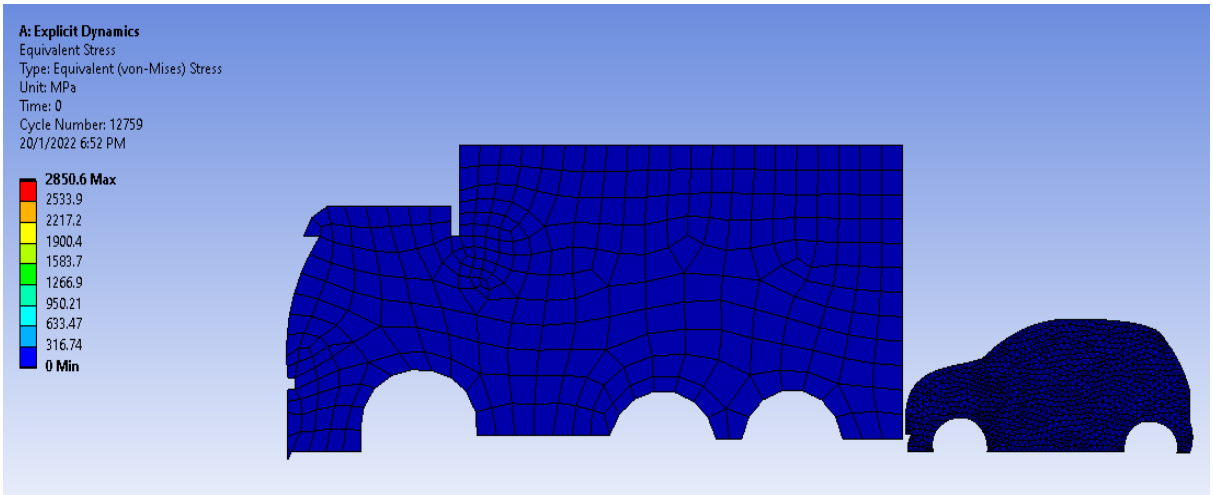

Figure 7. The maximum stress at the car front is 2850.60 MPa. The 25,000 kg truck is moving at 40 km/h.

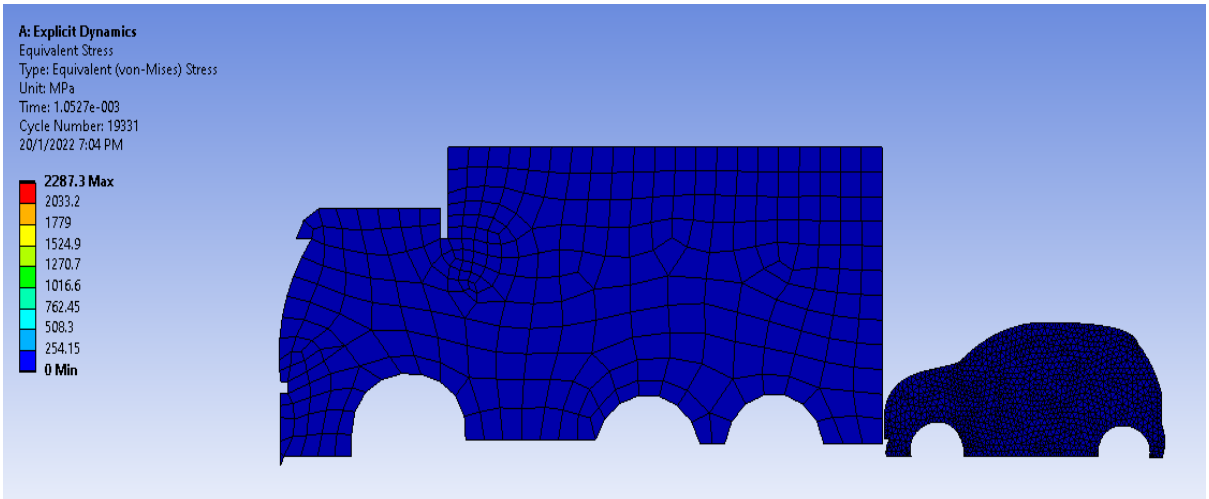

Figure 8. The maximum stress is almost 2287.30 MPa. The 25,000 kg truck is moving at 60 km/h.

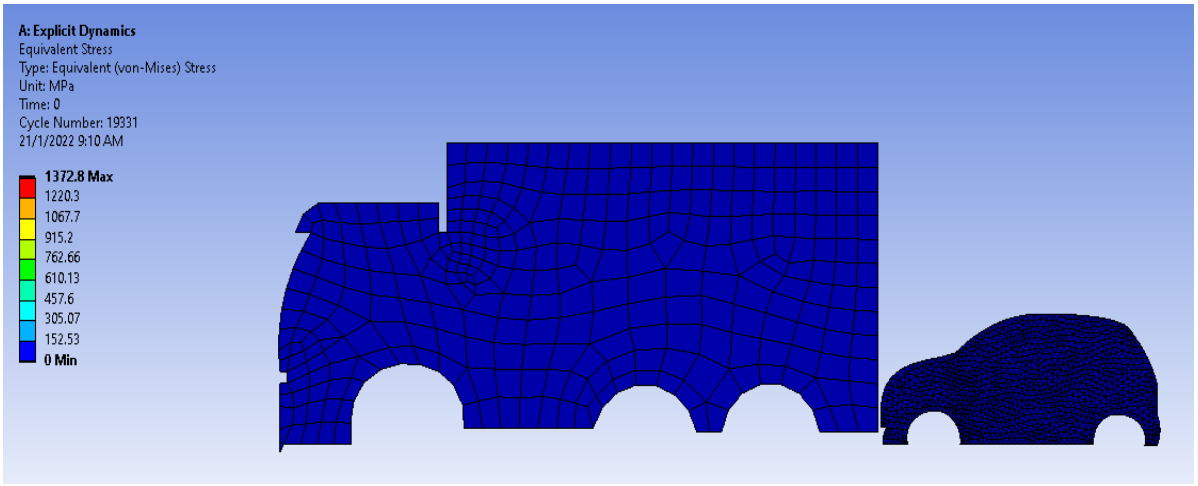

Figure 9. The maximum stress is 1372.80 MPa. The 25,000 kg truck is moving at 80 km/h.

The different of velocity gives the different of impact between car and heavy vehicle. The results are obtained from the crash analysis in ANSYS by following the steps in methodology. Maximum stress value developed for 25000 kg in 40 km/h which is 2850.60 MPa. The stress value increases as the velocity of heavy vehicle decreases as can be seen in Table 5.

Table 5 Results Data from The Simulations

Truck Velocity (km/h)	Equivalent (von Mises) Stress (MPa)		
	25000 kg	**31000 kg**	**200000 kg**
40	2850.60	2849.80	2840.30
60	2287.30	2291.70	2315.40
80	1372.80	1371.80	1371.30

It can be concluded that the slower the vehicle's speed, the greater the amount of stress it will be under and the worse its condition will become. Aside from that, the condition of the car at the time of the final crash becomes more smashed up as the speed of the vehicle decreases. Nevertheless, the study of such crashes should emphasize the displacement to show the severity of the damage from the collision as shown in the work of Hickey and Xiao [26]. An online calculator could predict the amount of crumple experienced by a passenger vehicle based on the speed prior to collision [27].

5. CONCLUSION AND RECOMMENDATIONS

The survey concluded that correct use of lights, light reflecting stickers, and canvas tarp will allow other road users to see heavy vehicles clearly. The majority of respondents believed that visibility for heavy trucks is a significant factor in decreasing the probability of an accident occurring. However, there are still many shortcomings with the implementation of safety features in terms of visibility in Malaysia, such as insufficient additional light (side and back) on heavy vehicles, the appearance of light reflection stickers being in poor condition, and the use of green or dark canvas for heavy vehicles, which is not recommended at night due to the fact that dark colors reduce the detection to others on the road.

The simulation of the crash analysis between cars and heavy vehicles with varying parameters such as mass and velocity has also been carried out using ANSYS/CAE Dynamic Explicit software. The viewpoint on accident among car and heavy vehicle can be seen. The lower the velocity the greater the stress endured by the car as well as its situation get much worse.

Overall, the brief visibility study of heavy vehicles in Malaysia is successfully achieved where these can provide an additional information of visibility to other road users, making heavy vehicles visible to them, as well as additional information about safety to heavy vehicle drivers, allowing them to maintain their safety speeds and avoid accidents.

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