1. INTRODUCTION

1.1 Background

Road traffic deaths continue to rise steadily, reaching 1.35 million in 2016 as shown in **Figure 1.1**. However, the rate of death relative to the size of the world's population has remained constant. When considered in the context of the increasing global population and rapid motorization that has taken place over the same period, this suggests that existing road safety efforts may have mitigated the situation from getting worse. However, it also indicates that progress in realizing Sustainable Development Goal (SDG) target 3.6 – which calls for a 50% reduction in road traffic deaths by 2020 – remains far from sufficient.

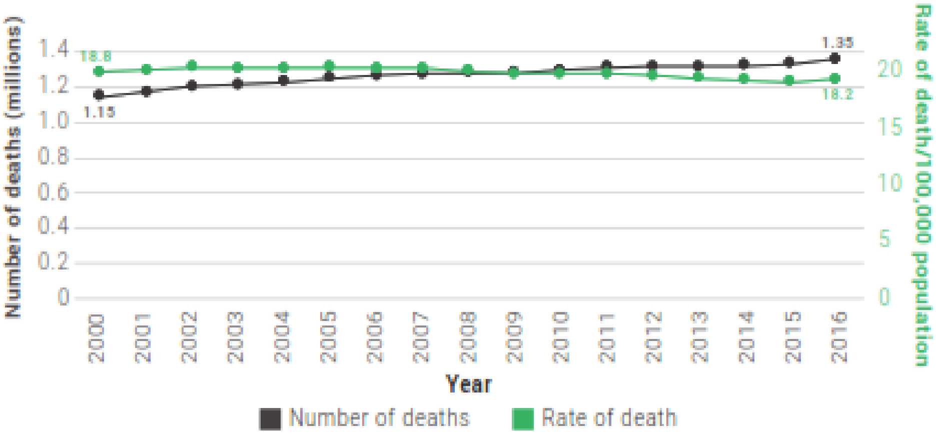
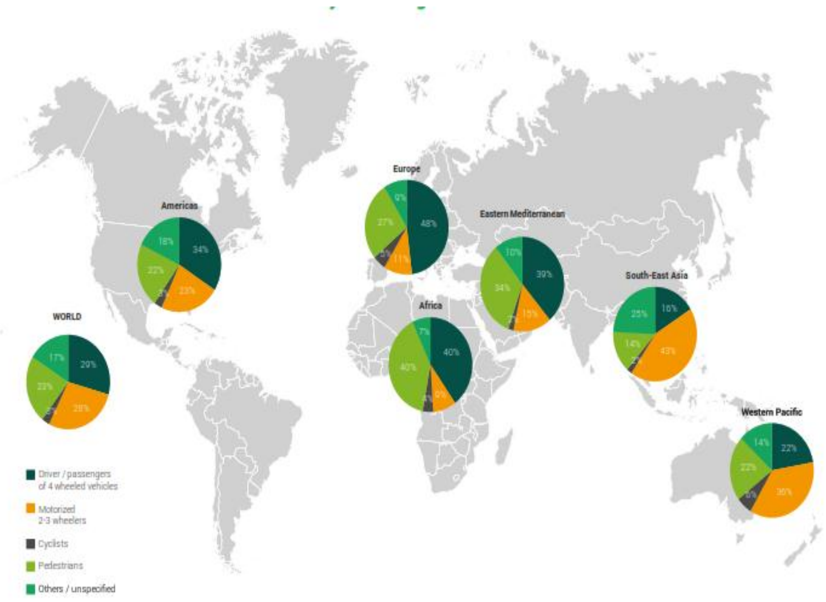


Figure 1.1 Number and rate of traffic death per 100,000 population, 2000-2016 [1]

The variation in rates of death observed across regions and countries also corresponds with differences in the types of road users most affected. As seen in **Figure 1.2**, vulnerable road users – pedestrians, cyclists, and motorcyclists – represent more than half of all global deaths. Pedestrians and cyclists represent 26% of all deaths, while those using motorized two- and three-wheelers comprise another 28%. Car occupants make up 29% of all deaths, and the remaining 17% are unidentified road users. Africa has the highest proportion of pedestrian and cyclist mortalities, with 44% of deaths. In South-East Asia and the Western Pacific, the majority of deaths are among riders of motorized two and three-wheelers, who represent 43% and 36% of all deaths, respectively.



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1 The distribution of deaths among road user categories is based on data reported by countries. In some countries, this data is not available or is incomplete, which contributes to the large percentage of those identified as 'others' or 'unspecified'.

Figure 1.2 Distribution of deaths by road user type, by WHO Region [1]

Several ways have been proposed to decrease the number of deaths and injuries due to traffic accidents. Out of technical aspects of vehicle's design, enacting and enforcing legislation on critical behavioral risk factors including speed, drink-driving, and failing to use motorcycle helmets, seatbelts, and child restraints are critical components of an integrated strategy to prevent road traffic deaths. As seen in **Figure 1.3**, 123 countries, representing nearly six billion people, have laws that meet best practices for at least one of the five key behavioral risk factors. Since 2014, 22 additional countries have amended their laws on one or more key risk factors to bring them in line with best practices. It covers a potential additional one billion people or 14% of the world's population.

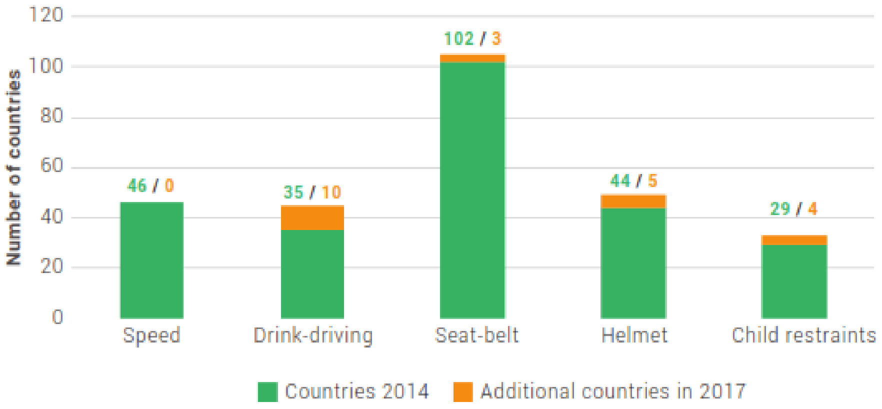

Figure 1.3 Countries with laws meeting best practice on five risk factors, 2014, 2017 [1]

1.1.1 Safe vehicles

Vehicle safety is increasingly critical to the prevention of crashes. It has been shown to contribute to substantial reductions in the number of deaths and serious injuries resulting from road traffic crashes. Features such as electronic stability control and advanced braking are examples of vehicle safety standards that can prevent a crash from occurring or reduce the severity of injuries. However, not all new and used vehicles have to implement internationally recognized safety standards with these potential benefits. Progress with the uptake of the eight priority standards has been minimal since the last review. To date, 40 mainly high-income countries have implemented 7–8 of these standards. Eleven countries apply two to six of the eight priority standards, and 124 apply one or none of the priority standards as seen in **Figure 1.4**. Since the last review, one additional country, India, has been applying the front and side-impact protection standard

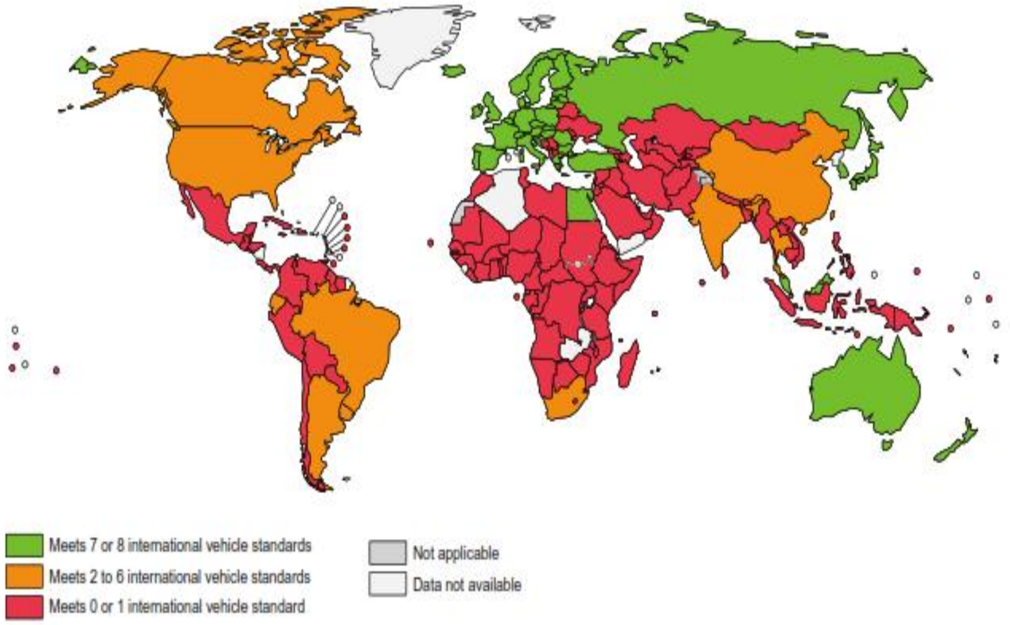

Figure 1.4 Countries applying UN vehicle safety standards [1]

1.1.2 International Vehicle Standards

Standards protecting occupants in front and side-impact crashes (crashworthiness) are poorly implemented. The World Forum's most essential crashworthiness regulations help to protect occupants withstand front and side-impact crashes. During simulated tests, energy absorbed by the crash-test dummy must be below a certain threshold for the car to pass the tests. However, these requirements are poorly implemented globally: 49 countries (27%) apply the UN frontal impact test regulation, and 47 (26%) apply the side impact test regulation. These are predominantly high-income countries.

Crashworthiness is a vehicle safety standard in the event of a collision (impact). Crashworthiness requirements have been standardized by the AAR (Association of American Railroads) and approved by the FRA (Federal Railroad Administration). The safety standards that have been created like airbags, ABS (antilock braking system), EBD (electronic brake force distribution), seatbelt, and crumple zone [2]. A Crumple zone is a part of the vehicle that is deliberately weaker than the other parts. The aim is that the force that arises due to collision is absorbed entirely by that section so the passengers can be safe. One of the part vehicles that include the crumple zone is a crash box. The crash box is the energy absorber which is usually located in the front of the vehicle. The crash box had been designed with various models which can absorb energy.

1.1.3 Previous Researches

Many kinds of research have been conducted in this area. Choiron [3] used numerical analysis to observe the ability of crash box with the tapered wall thickness. The results showed that increasing the angle of tapered thickness will increase the absorbed energy under impact loading from the frontal direction. Liu [4] studied the effect of different crash box types to absorb energy during a collision. Through his study, a square shape pipe is recommended to be used as the main structure. Hussain [5] investigated the effect of triggers attached to the crash box to absorb energy during a collision. He used three types of triggers, and he found that the fillet trigger can absorb more energy collision than edge slot trigger or even a combination of fillet and solt edge trigger. Khusairi [6] investigated the effects of origami patterns on crash boxes to absorb energy collision in the vehicle. He found that the origami pattern can reduce impact force at the first impact and has stable characteristics and predictable collapse mode. Balaji [7] investigated the effect of grove and notch given to crash box under quasi-static loading. The result showed that the application of both groove and notch could increase the absorption of energy. Dirgantara [8] investigated the characteristics of a crash box with a hole. His study showed that the peak crushing force decreases while the mean crushing force is relatively constant. In more advanced research, Marshdatti [9] investigated the crashworthiness of the S-Shaped structure under axial impact loading.

This final project is actually a part of the initial project that will be done in the Mechanical Engineering Department of Universitas Andalas to study the crashworthiness behaviors in vehicles. The first work was started by Bramindo [10], which discussed the effectiveness of variation of the trigger's shape to absorb energy due to the given load. In that time, the selected triggers are in U and V shape, which can be seen in **Figure 1.5.**

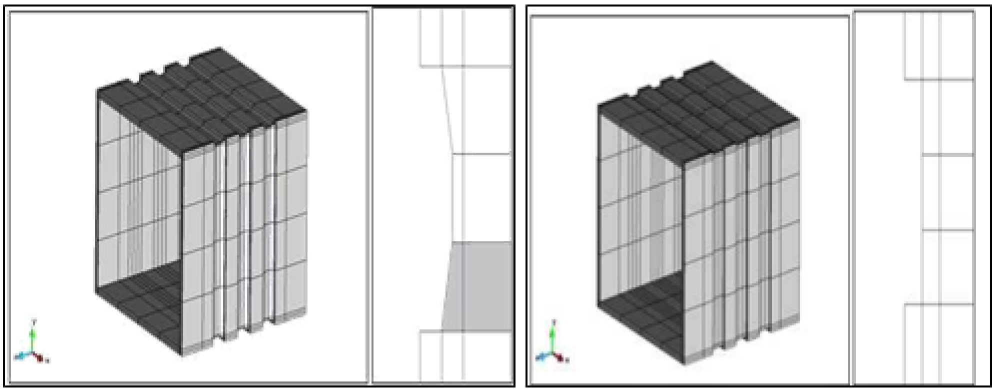
(a) (b)

Figure 1.5 The shaped of triggers are (a) V trigger (b) U trigger [10]

In that work, the crash box is modelled by solid elements only due to the limited ability of the in-house finite element software. Consequently, the resulted models cannot be made as close as possible to the actual model. Based on that work, the critical point showed that the introduced trigger could absorb energy due to the given loading for both types of trigger. However, in the term of deformation patterns that occur in the crash box during loading, the number of folds due to loading is relatively small. Mainly this situation is strongly related to the form of triggers involved in the numerical calculation. Therefore, this study is still needed to improve, especially in terms of modelling of triggers.

1.2 Problem Formulation

The problems from the previous work can be detailly written as follows:

1. In the previous work, the crushed box was modelled by solid elements only due to a limited condition given by the used software at that time. Therefore, the process of modelling was very hard in some parts of the numerical model.
2. The models of triggers were applied in the thickness of the pipe only. In some parts, the thickness of the pipe was treated in the form of U or V shapes. Therefore, the deformation pattern of the pipe was quite different from the desired form.
3. Due to the limited ability of the software, the previously given load is in the type of quasi-static loading only. Therefore, it was quite hard to judge the effect of the velocity of collision form the results.

This proposal is a continuation of the previous work. Several modifications from the previous models are given as follows:

1. The crash box will be modelled by a package of commercial software of MSC Dytran. Therefore the crash box can be modelled as closes as possible with the real model.
2. The model of various triggers is created separately with similar thickness to the main pipe. Several forms of triggers will be introduced with the purpose to increase the number of folds when plastic deformation occurs.
3. Using a package software of MSC Dytran, the effect of different velocities of the loading collision can be determined.
4. Another modification is to use the S-beam model as the main structure. The S-beam structure is considered able to increase the absorbed energy under impact loading, although instability problems are possible to arise.

1.3 Objectives

The objectives of this the final project are as stated as follow:

1. To determine the maximum force and absorbed energy from the straight pipe attached by several triggers due to loading.
2. To determine the maximum force and absorbed energy from the S-beam pipe attached by several triggers due to loading.
3. To determine the effect of the velocity of loading to the maximum force and absorbed energy of the models.

1.4 Outcome

The design crash box from this final project can be used to prevent casualties when a vehicle collision occurs.

1.5 Problem Scope

The limitation of problems in this final project is that there are no energy losses during impact and material is used elastoplastic material.

1.6 Report Outline

This final project consists of five chapters. The first chapter describes the background, problem formulation, purpose, outcome, problem scope, and report outline. The second chapter provides an overview of the literature that becomes a reference in this final project. The third chapter describes the research methodology. The fourth chapter contains results and discussion. The last chapter is the conclusion of the final project.