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# DEVELOPING A CONCEPTUAL ROAD SAFETY FRAMEWORK TO CONSTRUCT ROAD SAFETY REGRESSION OUTCOME

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# ABSTRACT

Road safety and accident occurrences face some of the most difficult sustainability challenges in transportation industries. In order to secure its continued social license or its level of acceptance or approval to operate, the industry must response to these challenges by engaging its many different stakeholders to address their sustainability concerns. To achieve this conceptual road safety framework consisting of seven factors determining exposure to risk (resulting from travel behaviour), risk (injury risk and crash risk), task, driver, vehicle, hazard and road condition was constructed. It was from the framework that the model was developed to construct a road safety road safety outcome based on multiple regression analysis, the number of road deaths that occurred in the case study country Malaysia for the period of (1995-2010) was plotted as the depended variable against data for the seven chosen factors (independent variables) for the same period of study and a regression equation (significant at 95 percent confidence interval,  $R^2 = 0.812$  of the form:  $D = 2231.481+2.224X_1 - 160X_2 + 0.0201X_3 + 5.166X_4 + 13.939X_5 - 16.890X_6 - 0.747X_7$  was developed as a guide for the stake holders in the transportation industries as a measure of safety performance.

Keywords: Road safety, traffic accident, framework, risk, factors.

#### **1. INTRODUCTION**

According to world health report of 2013, road traffic injuries cause 1.3 million deaths and 20-50 million injuries each year around the world, most of these injuries lead to lifelong disability including brain and spinal cord injury. Road traffic injuries are the leading cause of death among young people aged 15-29.

Unless serious action is taken, road traffic deaths are expected to increase by 67% by 2020 and become the fifth lead cause of death for all by 2030. If this happens, road traffic crashes will cause an estimated 1.9 million deaths each year by 2020 and 2.4 million deaths by 2030. [1].

Most countries invest in building and improving their road infrastructure systems. Transportation improves quality of life by giving people access to important things such as employment, education and health services. However, safety measures must go hand in hand with road infrastructure development or transportation can come at a high price [2].

More than 90% of road traffic deaths occur in low and middle-income countries (LMICs), the number of deaths in these countries is projected to rise more than anywhere else in the world in the near future [3]. Several studies have been researched on road safety these have largely focused on European and Asian countries [4], [5], [6]. Further research has already been undertaken regarding risk factors related to road crashes and casualties [7], [8]. Some of these risk factors (covering humanvehicle-road-environmental-regulation interactions) are sometimes generally related to road user's behaviour (e.g. alcohol, speeding, and distractions), vehicle (e.g. defects) and the road environment [9], [10]. As reported by [4] on SafetyNet project as it provided a further methodological basis for the Safety Performance Indicator's development. Based upon the potential of different road safety areas for increasing road safety as well as on the experiences and data available, [11], [12] seven problem areas were designated as central to road safety activities in Europe. They are: (1) alcohol and drug-use; (2) speeds; (3) protective systems; (4) daytime running lights; (5) vehicles (passive safety); (6) roads and (7) trauma management. For each one of these areas, safety index were developed and using the data provided by national representatives of the European countries. An evaluation of the relative magnitudes of the crash problems contributed by younger and older drivers indicates that younger-driver problems vastly exceed older-driver problems [12].

(Yu zhang and Kaber, 2013) [13] carried out an empirical assessment of driver motivation and emotional states in perceived safety margins under varied driving condition and concluded that adaptable warnings based on emotional state is necessary in vehicle to assist drivers.

This paper introduces a conceptual framework for road safety as applied to commercial buses, most of the major problems of road safety research are that most of it does not have strong theoretical bases which make it difficult to design suitable studies and interpret findings [15]. In order to explain the framework and its usefulness, the question is how vehicle safety is affected by the triplet variables of human, vehicle and road (HVR) characteristics [16].

# 2. A CONCEPTUAL ROAD SAFETY FRAMEWORK

A conceptual framework or model is an abstraction or simplification of reality so as to help better understand the reality the real world systems, facilitate communication and integrate knowledge across disciplines [17]. These framework are best served by models with a limited numbers of factors such as the investigation of



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road safety issues through a microsimulation model built by [5], [18].



Figure-1. A conceptual road safety framework.

In most cases the amount of road safety problems in a country can be observed by the large number of accidents, large number of casualties, high cost [19], [3]. There are a large number of studies and research in road safety in which attempt has been made to formulate a theory or model that can explain why accidents happen. [20], [21] developed a generalized multiple layer data envelopment analysis model for hierarchical structure assessment and they used the model to formulate a road safety index. Griffin *et al.* (2010) [22] uses information network modeling to investigate accident causation through this information network an accident causation model was predicted, while [23] worked on distracted driver thereby uses mechanisms and measurement to build a model on accident as a result of driver's distraction.

## 2.1. Various indicators

#### 2.1.1. Road situation

Figure-2 shows the relationship between various contributed factors that measures both road safety situation and traffic accident occurrences, road situations especially road design attributes, namely road alignment, grade and curvature, section type, traffic-way type, the number of lanes, and speed limit are significantly associated with accident occurrence [2], [24]. Two-way traffic and multilane roads increase the probability of higher accident severity [25]. Relatively to one-way roads, two-ways roads are 54.5%-82.7% more likely to result in severe nonincapacitating injuries and 21.4%-22.6% more likely to result in incapacitating injuries. According to [26] accidents that occur in multi-lane roads are more likely to be significantly associated with severe non-incapacitating injuries (7.3%), incapacitating injuries (4.5%), and fatalities (0.9%). Road curvature is positively associated with increased accident severity. The occurrence of bus accidents on straight sections greatly reduces the probability of light injuries (-15.1%), severe non incapacitating injuries (-60.4%), incapacitating injuries (-31.0%), and deaths (-5.1%) [27]. Road sections at level grade are positively associated with increased accident severity level, while slopes are related to less severe accidents. In fact, accidents that occur at level grade are more likely to result in light injury (19.8%), severe non-incapacitating injury (16.8%), incapacitating injury (20.4%), and death (3.7%).

#### 2.1.2. Vehicle

In most of the commercial bus design there is no standardization or uniformity in these designs most of the design of cabin and driving seats are not done scientifically or ergonomically. The result of this is driver's fatigue which can cause distractions and can affect the driver psychologically by affecting his/her mood of driving and behavioural attitude which can again cause distraction and impaired decision making while driving. [28] Stated that in some private transport companies they overload their bus as much as twice their legitimate capacity which also can create accidents by overturning and rolling back the vehicle on slopes that can consequently result into accident. The following items in a vehicle were identified to assist bus driver in accident mitigation 1. Better vehicle interior design to reduce fatigue and distractions. 2. Vehicle connected with the speed regulator will assist the driver against over speeding. 3. Vehicle connected with forward collision warning will prevent accident. 4. Old and aged vehicle on the highway is risk since it can break down and cause accident thereby. 5. Installation of curve speed warning may be essential to prevent vehicle somersaulting.

## 2.1.3. Driver

The driver at all times in the period of driving uses a set of control tasks, this task can be intuitive or responses to certain traffic conditions, to drive safely the driver should be able to understand his/her surrounding and react accordingly. To do this his/her physical as well as psychological senses and action systems should be always alert and well-coordinated since in most times distraction and fatigue disrupts the driver's coordination and lead to errors in judging driving and environment which can be considered to be a serious reason for road



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traffic accidents. According to [29],[30] different types of distraction can lead to different driving errors or performance degradation like longitudinal, lateral controls, situation awareness and unfavorable response to certain risky road traffic conditions. Some of the items on side of drivers considered to promote road safety include 1. Given attention to road advertisement signs while driving can caused distraction, 2. As a driver wearing of seat belt provide safety, 3. Receiving call while driving can create distraction and cause accident, 4. Habitual speeding can cause accident, 5. Driving with the influence of alcohol/drug is bad and dangerous, 6. Drowsiness and fatigue of the driver can cause accident, 7. Acute psychological stress of the driver can cause accident; 8. Habitual disregard of traffic regulations can cause accident

## 2.1.4. Task

The driving task is everything it takes to operate a motor vehicle; the three skills of the driving task are 1. Physical-coordination with the vehicle, 2. Social interaction with other road users and 3. Mental skills which is the most important aspect that include understanding the motor vehicle, perception based on stored knowledge, understanding traffic laws, judging time/space relationships and concentration on task [31]. According to the analysis of professional truck drivers' task as basis for an EQF compatible profile (2011) [31]. Driving task resulted into nine categories of tasks which are, 1. Handling the vehicle on the road driving, 2. Handling the vehicle in the yard, 3. Dealing with customer or passengers, 4. Dealing with supervisors, colleagues, and other groups, 5. Administration/administrative tasks, 6. Plan a trip, 7. Maintenance activities on vehicles and vehicle combinations, 8. Healthy lifestyle, 9. Key qualifications like personal skills such as reading, writing and calculating and technical and occupational skills.

#### 2.1.5. Hazards

A hazard can be any possible source of danger on or near the road that could lead to a crash, and it can come from any source or direction[32]. It could be a child chasing a ball unto the road, parked car door opening, vehicle merging into your lane or stopping suddenly in front of you, slippery road after rain [33]. According to the department of transport and main roads says a driver gain experience they develop skills in scanning the road ahead and around them and they become better at recognizing that a potentially dangerous situation is developing. This early detection gives them more time to make a decision about the hazard and respond to it adequately. The following can be source of hazard identification 1. Identifying hazards when driving through business areas, 2. Identifying hazards when driving through roadworks, 3. Identifying hazards when driving through school zones, 4. Identifying hazards when sharing the road with other road users, 5. Identifying hazards when driving through suburban streets, 6. Identifying hazards when driving as night is approaching.

## 2.1.6. Risk

Risk perception is the subjective judgment that people make about the characteristics and severity of a risk especially for young novice drivers are at a significantly higher risk of having a fatal vehicle crash than experienced drivers [34]. According to reference [26] one of the main causes is that novice drivers lack risk perception skills, they have not developed the ability to efficiently perceive or predict risks while driving. [32] Some of the items used in the survey includes, 1. Overconfident in driving is a powerful source of bias in the perception of risk, 2. Subjective perception of risk plays an important role in driver safety, 3.over speeding is an involvement in risk behaviour, 4. Fixate more on stationary object is a risk behaviour, 5. Inexperience driver lack attentional control in traffic jam during safety. 6. Young and novice driver perceive lower level of risk in specific maneuvers, 7. Novice driver adopt less efficient information gathering strategies.

## 2.2. Theories

Here in this section it is appropriate to explain how the elements in the framework interact in terms of theories and concept: crash and injury risk theory, travel behaviour theory and exposure risk theory.

## 2.2.1. Crash and Injury risk theory.

Human factors play a vital role in crash and injury risk as a result of different task, hazard and risk that the driver faces in driving. Theories from physics such as elementary mechanics [30] have been used to explain injury risk i.e., the severity of injuries incurred in a crash which stated that the injury severity score provides a measure of injury severity to the occupant since vehicles moving on the road network carry a high amount of kinetic energy. Crash energy may be release when there is a failure of hazard control mechanisms such as barriers. [31] in road traffic it is the kinetic energy produced by the movement of people and vehicles that is a potential crash energy, the mass different is essential in a situation when motor vehicles and road users collide energy may then be exchange between road users, vehicles and infrastructures, crashes may then be fatal when forces transferred to victims exceed their biomechanical limits which depends on age, health status, stature and some other factors. In reference [17], it is true that vehicle moving on the road network carry a high amount of kinetic energy, the kinetic energy of the respective vehicles is related to the mass and the speed of the vehicle in the form of:  $k = \frac{1}{2} x m x v^2$ where k is kinetic energy of the object, m is mass of the object,  $v^2$  is the velocity of the object.

## 2.2.2. Travel behaviour theory

This theory help to explain the link between road and vehicle, [33] explained that motorways have the lowest risk on injury accidents compared to other types of roads because of the separation between vehicle movements according to their speed. Reference [32] shows that the rate of injury accidents per million vehicle



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kilometers of travel on highways is about 25% of the average for all the public roads. Road surface conditions, poor road surface, defects in road design and maintenance contribute to an increase in the risk of road accident, also new vehicles tend to have more safety and protection features, such as air bags, anti - brake system (ABS). There is relation between vehicle age and risk of a car crash, it is equally known that poor vehicle maintenance and technical conditions can also contribute to accidents. Travel behaviour theories explain the decision to travel which can be determine by type of road and vehicle condition.

#### 2.2.3. Exposure risk theory

Exposure is an important dimension in road traffic that refers to the amount of travel in which accidents may occur. [40] Stated that the more we travel on roads, the higher the probability of an accident to occur. Many studies show that there is correlation between vehicle traffic volume and the total number of accidents even as traffic volume (mobility) is one of key issues, which is needed to promote the sustainability of transport in any nation. The framework represent a relationship between exposure and risk that shows an arrow from risk to exposure, this combined together measure the level of safety of the road that traffic accident (Traffic Accident Model) and the categorical crash severity measure (Road Safety Measure).

#### **3. THE MODEL**

#### 3.1. Model-1: road safety index

A multiple linear regression model was used to analyse the effect that safety measure had on individual identified factors in the model. The resulting model allowed identification of the safety factors in the independed variables that predicted the traffic accident and from their established the road safety index.

$$D = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5$$
(1)

Where:  $X_1 =$  Driver's factors  $X_2 =$  Vehicle factors  $X_3 =$  Road factors

 $X_4$  = Driving Task  $X_5$  = Hazard/ Risk perception D = Road safety outcome Equation (1) above can be expressed in the form:

This can also be written as

$$K = D/X_1^{B} + X_2^{B} + X_3^{B} + X_4^{B} + X_5^{B}$$
(3)

Where K is known as the Road Safety Index

Based on equation (3) the road safety of each of the study commercial bus company was expressed as a function of the five selected indicators in the model. Countries were then ranked on the basis of this index with lower 'K' value indicating a better road safety performance (i.e., lower death ratio with regard to the indicators considered) and a higher 'K' value indicative of a worse road safety performance (i.e., higher death rates with regard to the indicators used).

# 4. FRAMEWORK PERFORMANCE RESULT

Road Safety Index based on Multiple Regression Analysis The number of road deaths that occurred in the case study country Malaysia for the period of (1995-2010) was plotted as the depended variable against data for the seven chosen factors (independent variables) for the same period of study using multiple regression analysis and a regression equation (significant at 95 percent confidence interval,  $R^2 = 0.812$ ) of the form stated below.

Substitute standardized coefficients into equation 1

 $D = 2231.481 + 2.224X_1 - 160X_2 + 0.0201X_3 + 5.166X_4 + 13.939X_5 - 16.890X_6 - 0.747X_7$ (4)

Where:  $X_1$  = vehicle Registered,  $X_2$  = Road Length,  $X_3$  = Vehicle Owners,  $X_4$  = personal Risk  $X_5$  = Traffic Risk,  $X_6$  = Task,  $X_7$  = Hazard.

This can also be written as

$$2.224X_1 - 160X_2 + 0.0201X_3 + 5.166X_4 + 13.939X_5 - 16.890X_6 - 0.747X_7 + 2231.481.$$
(5)

D

Where K is constant also known as 'Road Safety Index'

Based on equation (5), the number of deaths in each of the years was expressed as a function of the seven factors or indicators and a road safety index produced for Malaysia. Other countries of the world can also ranked based on this index with a lower 'K' value indicating a better road safety performance (i.e., lower death ratio with regards to the indicators considered) and a higher 'K' value indicating a worse road safety performance (i.e., a higher death rates with regards to the indicators or factors considered).

#### 5. DISCUSSIONS

This paper presented a conceptual road safety framework consisting of seven factors determining exposure to risk (resulting from travel behaviour), risk (injury risk and crash risk). It was from the framework that the model was developed to construct a road safety index. The concept and the scope of road safety problem using



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Malaysian accident data from 1995 to 2010 through Malaysian accident database was briefly presented through the model. It aimed to show a problems and summary of the road safety situation across different regions of the country. This made it clear that road safety is a serious problem everywhere and it concerns every country alike. The major steps and various approaches used in the construction of safety index is as well very important so as to have a reliable and good result this starts from getting the best indicators to be added together in the model, then normalising or standardising the factors follow by weighting the variables and combining the chosen indicators into the model using different approaches and finally using multiple regression to develop the safety index. It is better to conclude that the road safety development in a country is not only measured by the parameters just given, it is more effective where there are a large number of factors involved in the model. In addition, a simple active model of road safety was developed to justify the various approach used for the framework and for easy validation in the context of the interaction between the combined factors used in the framework.

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