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INTEGRATING USER PSYCHOLOGY IN ROAD TRANSPORT SAFETY: A MODEL FOR LOW AND MIDDLE-INCOME COUNTRIES, BASED ON SRI LANKA

T Kandanaarachchi [a]*, P T R S Sugathadasa [b] and H N Perera [b, c]

[a] Institute of Transport and Logistics Studies, University of Sydney, NSW 2006, Australia

[b] Department of Transport and Logistics Management, Faculty of Engineering, University of Moratuwa, Katubedda 10400, Sri Lanka

[c] Professor H.Y. Ranjit Perera Institute for Applied Research, Nugegoda 10250, Sri Lanka

* Correspondence should be addressed to *thira1992@gmail.com*

ABSTRACT

Low and Middle Income Countries (LMICs) account for 90% of road collisions that occur globally. These collisions account for 17.63 million serious injuries and deaths while costing LMIC economies 1.7 trillion USD amounting to 6.5% of aggregate annual GDP. Though there are a plethora of models on road transport safety, few address the impact of user psychology and the contextual environment in LMICs on road safety.

This paper proposes such a model formulated and developed using existing literature and focus group discussions. The model is composed of three key constituents - behaviour, skills and knowledge, and infrastructure. It further interprets behaviour as an integration of three sub-elements—mindset, circumstances and legal system—pertaining to the incident. The interaction between these constructs constitutes user behaviour in a given circumstance. The research also proposes an implementation guideline to authorities that is instrumental in changing society's perception of transport safety.

Keywords: *Road safety model, road users, collision prevention, skills and knowledge, LMIC, behaviour*

1. INTRODUCTION

As the mobility needs of individual grow exponentially, road transportation becomes an essential provision [1],[2]. Resource and space constraints emerging in recent decades have led to the introduction of many new road transportation concepts. In contemporary solutions, both the industry and researchers have shifted towards Transport Management with existing or slightly higher supply provision [3]. Disrupting technologies have been employed to integrate capabilities, leading to optimum and technology-driven solutions [1],[4]. Safety has become paramount, closely followed in importance by the need to achieve spatial and temporal efficiencies. However, the situation is markedly different in the majority of Lower- and Middle-Income Countries (LMICs) who are still struggling in their journey towards efficient, effective, innovative and futuristic transport solutions amid multifaceted constraints [5],[6].

LMICs together account for around 140 countries and about 82% of the world's population. They often face challenges such as managing their natural resources, reducing pollution, and facing climate change, while being extremely vulnerable to natural disasters. Most LMICs are excessively dependent on export commodities, and are therefore vulnerable to global economic changes. A recent study identified communicable and non-communicable diseases and road traffic collisions as key challenges faced by the healthcare industry in LMICs [7]. Some studies pinpoint road traffic crashes as a major healthcare problem affecting developing countries, given their lack of resources. Different road safety measures have been developed and implemented, but crash rates appear to be increasing [6],[8],[9]. Road collisions have resulted in more than 17.63 million deaths and serious injuries while costing these economies 1.7 trillion USD, which is 6.5% of the GDP of LMICs in 2016[6].

One of the key underlying issues is the lack of emphasis given to the design and planning aspects of infrastructure and networks in LMICs [8]. On top of accidents caused by inappropriate infrastructure, this has resulted in plenty of idle hours spent on the road daily by the workforce: these could have been used either as productive hours or for recreational activity and social interaction. This has a reversible effect on the attitudes of people via creating a competitive mindset where they compete for spatial and temporal efficiencies in fulfilling their transport needs [5],[10]. Another reason for increasing accident rates is that LMICs lack effective policies and strategies that are backed by empirical research: the available data is less reliable, possibly as a result of poor data collection methods and underreporting [9],[11].

This paper aims at providing a conceptual model to address transport safety concerns in LMICs through mechanisms mainly focused on behavioural changes among users

and planners in the road transport sector. The model was developed for the Sri Lankan context based on the inputs captured through interviews and focused group discussions conducted in both industry and academia. It contributes to the practice by introducing a conceptual model for road safety in LMICs while providing fertile ground for future research aimed at enhanced road transport services in LMICs.

The remainder of this paper is organised as follows: the literature review evaluates existing literature prior to proposing the methodology followed in the model development. The paper then discusses the implementation of the model, highlighting the key interventions that need to be made by the respective authorities. It concludes by synthesising the main constructs identified through this study and by indicating future research directions.

2. LITERATURE REVIEW

Road collisions are estimated to cause more than 1.35 million deaths and 50 million injuries each year. Around 90% of these occur in LMICs. Further, these numbers are continuously increasing, retarding the economic growth of those countries while causing suffering, loss and grief [6]. Para-transit services have been identified as a leading factor increasing collisions in LMICs, given the lack of discipline and also owing to profit-seeking, competitive behaviour under which they operate [12],[13].

Three-wheelers, accounting for 15% of the entire vehicle fleet in Sri Lanka and catering to around 6% of the passenger kilometres transported, is one example substantiating the above fact [14]. The awareness of the road users about the contextual environment (weather conditions, speed, traffic conditions, demography etc.) also plays a significant role, where 25% of collisions were found to be caused by issues pertaining to this reason, whereas vehicle defects accounted for 8%. Law enforcement is also weak, due to poor performance of relevant officials, owing mainly due to lack of training [12],[15]. Upon investigating collision data of 40 countries, it has been found that human error was a reason for 95% of collisions, and the sole reason 65% of the time. Errors of perception, psychiatric disorders, deficiency issues, errors in manoeuvring the vehicle and impairment or exhaustion were also recognised as key reasons [16],[17],[18]. Most of these reasons have a considerable influence on the psychological state of the user in a given situation. Hence it is vital to understand the key constructs that affect the road user psychology when developing proactive measures to reduce roadside incidents.

2.1. Road User Behaviour

Road users mainly include drivers and pedestrians. This can be extended to include micro-mobility users such as cyclists, scooters and skateboarders depending on

context [19],[20],[21]. Drivers are considered the main stakeholders or decision-makers in the road because of their comparative speed and mass Šucha [21]. Driver behaviour has been identified as a key aspect that leads to collisions. Van der Wall, et al. [22] has found that fatigue and sleep deprivation as key factors affecting driving behaviour; these could sometimes be worse than the effects of drunk driving. The mood of the driver is a factor that impacts focus and therefore driving safety. It has been noted that when the driver is sad, the response time to hazards is slower, increasing the risk of incidents, when compared to driving with positive and neutral emotions. Evidence shows that emotional arousal or unrest acts similar to negative emotions, which demands mental effort to control the emotions [23],[24],[25]. Thus, irrespective of whether it is positive or negative, a heightened state of emotions tends to distract drivers. Hence, findings indicate a positive mood with mild or no arousal as the best state of mind for driving [23].

Zimasa, et al. [26] conducted a study seeking ways of disengaging the drivers from mind wandering[1] while car-following[2]. The research found that mood valence and arousal have different impacts on driving safety. Negative moods have appeared to cause more dangerous driving whilst mild cognitive loads have resulted in disengaging the drivers from a mood induced mind-wandering state. The cognitive loads were given in the form of questions where the driving-related loads (DRL) resulted in improving the driver's attention while non-driving related loads (NDRL) created no such effect. Further research has been suggested to quantify the amount of load necessary for the disengagement pertaining to different moods.

Tornros and Bolling [27] using the experimental method on both handheld and hands-free mobile devices when driving, found that there was a significant reduction in the performance of drivers due to phone usage. This is due to the increased mental workload resulting from the phone conversation. However, there was a significant drop in speed due to phone usage, and an increasing number of collisions given the low performance on a peripheral detection task (PDT) - a measure of mental workloads – such as driving.

Drivers' failure to follow rules and regulations was also considered a trivial factor that hampers road safety. Lack of knowledge on the impact of behaviour on safety was also identified as a factor leading to collisions [15]. Although road users are aware of the negative impacts of unsafe driving behaviours, such behaviour is still

[1] Mind wandering refers to "a condition in which thoughts do not remain focused on the task at hand but range widely and spontaneously across other topics" and car-following refers to "the incident of how vehicles follow one another on a roadway"

[2] When the driver follows a lead car.

evident. A study in Nigeria analysed the road user type, location, and time of the day of 946 incidents that occurred due to unsafe driving behaviours. Researchers reported that road users had engaged in either one or more unsafe behaviours before the collision. Tailgating and incorrect use of indicators were found to be the most prevalent misconducts while road user type, location and time-of-the-day were statistically associated with such behaviours. Better road infrastructure, effective regulatory enforcement and proper road safety education have been recommended as measures to improve road safety in Nigeria [8].

A study conducted in Iran by Mohaymany, et al. [15] identifying driver characteristics that lead to crashes pointed out that drivers aged 18-28 years were more likely to face crashes due to risk taking, aggressive, and ambitious behaviour. Thus, it suggested enforcement and educational activities targeting the above age group. It further mentioned that drivers with less than two years of experience and with Type-2 licences (a category which permits heavy and large vehicle access) were more responsible than the other drivers who possessed Type-1 licences with relatively high experience.

Another study [28] revealed that 50-60% of the collisions have taken place on two-way, two-lane road segments where drivers tend to overtake others using the opposite lanes. Further, the study found that driver characteristics and geometric design of both the vehicle and infrastructure also played a critical role in the passing decisions of drivers.

Batool and Carsten [29] conducted a study in Pakistan based on the premise that driving behaviour would be mediated by the attitudinal and motivational factors. It suggested a market segmentation approach for drivers based on their attitudes measured through their responses to attitudinal factors. This approach was instrumental in discovering the interactions between attitudes, behaviour, and social demographic factors. Further, it also suggested that a similar mechanism would be effective in implementing safety interventions based on the diverse characteristics of different driver segments.

Timmermans, et al. [30] conducted an exploratory study in the State of Qatar to examine the impact of *Attention Deficit Hyperactivity Disorder* (ADHD) using self-reported inattention and hyperactivity-impulsivity traits on the aberrant driving behaviour. They arrive at a similar recommendation. Young male drivers with hyperactivity-impulsivity traits were found to report more aberrant driving behaviour while inattention traits had an insignificant effect on them. However, inattention traits among young female drivers were identified as the most vital factor behind safety violations. The study has suggested gender-sensitive driving education and training about ADHD traits would reduce the risk of road safety violations.

In Sri Lanka, there were several newspaper articles written by industry experts regarding road traffic collisions although academic literature is scant. They have highlighted poor licence issuing procedures, lack of law enforcement (bribing), the attitude of the drivers to catch-up delays and lost time (last-minute push and rush), the attitude of the people (pedestrians crossing roads at random locations), poor road conditions, type and suitability of the vehicles as the key factors attributable towards transportation safety [31],[32].

Drinking and driving is another factor that has led to the increase of road traffic accidents in developing countries, including Sri Lanka. This is underpinned by a lack of legislative procedures and lack of awareness among the drivers about the allowed percentage of alcohol in the blood[33]. A study conducted by Damsere-Derry, et al. [34], has noted that there was a decrease in drunk driving in developed countries due to increased legislation and random breath testing.

A study conducted by Uzondu, et al. [11] in Nigeria on road crashes stated that traffic directionality, time of the day, road user's age, gender and driving speed as the key determinants behind the severity of a crash. Another study [13] conducted in Northern Ghana [14] on motorcycle driver behaviour and its implications on road traffic violations has posited that background characteristics such as age, occupation and ownership of motorcycles were significantly associated with the wearing of helmets. Change in registration protocols of motorcycles with stringent driving tests, increased frequency of public education programs on road traffic rules and regulations and enforcement of laws through the respective authorities have been recommended for the city Wa in order to reduce the rate of increasing motorcycle crashes and fatalities.

The studies conducted by Zinebi et al. [25],[35] claim to be the first attempts at collating all the variables that control driving behaviour into a single model. Based on a systematic literature review, the first study identified speed, acceleration/declaration and braking as the main variables to define driver behaviour in quantitative studies while position, time range, mileage, and road type being the other factors. After analysing behavioural questionnaires used in the literature via Pareto and ABC analyses, the second study came up with 23 factors; namely, anxiousness, carefulness, anger, bad perception, inattention, overtaking, speed, absent-minded, aggressive braking, aggressive expression, not respecting signs, patience, route planning, sensation seeking, turning, use of vehicle, alcohol consumption, distraction, forgetfulness, lane changing, revenge, slips, and tailgating. Some of the less officially accepted facts mentioned above, such as assertiveness, sensation seeking and competitiveness were found to affect the overtaking behaviour as some drivers would feel victorious when overtaking others and would feel defeated if overtaken by others [36].

Pedestrians can be considered as the most vulnerable type of road users who tend to face roadside collisions. Half of the fatalities in road traffic crashes involve "vulnerable road users" (VRUs) such as pedestrians [6],[37]. A study conducted in Lahore, Pakistan, has noted that 25% of fatalities involved pedestrians. Results have shown that pedestrian behaviour would be safer at pedestrian sites in highly developed commercial areas. Older pedestrians (over 60 years of age) seemed more cautious in their road usage while children were the most exposed group given their weak mental and physical abilities in addition to their limited peripheral vision. It has been suggested to use regression analysis in modelling pedestrians at road crossings and sidewalks to understand accurate behaviour which could be useful in designing safe infrastructure [38]. Increased focus towards elderly pedestrians, use of temporal epidemiology and injury profiles have been considered as critical factors needing to be considered when developing road traffic interventions [37].

The relationship between roadside incident rates and the roadway crash rates has also been highlighted by a study on Washington State highways, in the process of modelling roadway and roadside accident rates. The study was conducted by the Washington State Department of Transportation (WSDOT) to improve the efficiency of safety projects [39]. Combination of Histogram of Gradients (HOG) method and Haar partial detection has been identified as an effective method that can be used to warn drivers about possible collisions with pedestrians [40]. Another study on the importance of considering the "Pedestrian Falls (tripping, slipping and colliding with other objects)" has highlighted that this aspect has not been given adequate attention when investigating the pedestrian collisions. The paper suggested including *pedestrian falls* into the definition of crashes so that the analysis of collision risks would consider pedestrian falling instances. This would pave the way for planners, designers and policymakers paying more attention to pedestrian infrastructure planning[41]. Constant and Lagarde [42] has suggested separating motorised and non-motorised road users, improving the visibility focusing on street lightning and on the promotion of injury prevention mechanisms (wearing a helmet, pedestrian right of way, etc.) as key policy interventions to reduce the fatalities among VRUs.

2.2. Road safety Models

The development of proper models to address road safety concerns needs a thorough understanding of multiple interfaces upon which a particular system is built. A model can be defined as a careful and thoughtful representation of concepts, which would assist their understanding. A model should assist in creating a mental picture which also facilitates questioning, evaluating, and understanding the concepts presented. Models can be visual, mathematical or physical, based on the purpose they are intended to serve [43]. Most of the models which are developed to explain the human

error in technological systems have been designed to evaluate the situation from a retrospective angle without giving adequate attention to prospective mechanisms. Such models add less value unless those provide inputs to road designers in view of collision prevention [44],[45].

Hughes, et al. [45] state that concise descriptions of holistic entities could be called models, frameworks, concepts or other terms. They conducted a study of all safety models and categorised them into seven key types: namely, component models, sequence models, intervention models, mathematical models, process models, safety management models and system models. They also identified each model in terms of its strengths and weaknesses. The model which is presented in this research falls within the category of "system models"; thus, more focus is given to such models when perusing literature.

System models can be used to analyse systems, including effects of countermeasures, influencers, and consequences. Strengths of these models are their holistic nature, consideration of interdependencies among different elements of the models and being supported by a theoretical basis. Often, their weaknesses tend to be complexity, not being able to predict all outcomes, and lack of quantitative basis [45]. If a model is to be calibrated in a purposeful manner, structural, human, political and symbolic aspects must be recognized and addressed systematically [17]. Economic and social factors have been highlighted as essential aspects of a road safety model which have often been omitted or rather briefly considered.

Johnson (1980) has pioneered the system aspect models where he initially presented the dynamics of home injuries introducing *Background factors* (person, home, incident susceptibility and incident potential), *Initiating factors* (change in patterns and agent of the incident), *Intermediate factors* (mainly psychological and physiological) and *Immediate factors* (which are leading to an incident). The system approach to the investigation was also presented by Stang [46] as a response to the Chernobyl incident by proposing a human-machine interaction system. He suggested that the functioning of the whole system would depend on the proper quality and interaction among all the sub-components. That study also recognized the possibility of areas that could not be explained or understood without a "system approach" towards an incident. Human integration brings plenty of complex interactions to a system that could not be explained as a sequence. Human failure is one of the key factors which leads to the ultimate failure of a system as per this model [46].

As cited by Williams [47], the Haddon Matrix is a renowned and recognised model for collision analysis, considering the perspective of the host, agent/vehicle, physical environment, and social environment. This approach provides three dimensional perspectives of an incident namely: pre-, during, and post. Further, this can also be

used as a preventive mechanism. Yet, the causation (i.e., conceptualisation of contextual factors with the causal effects) is not captured through the model, making it a more brainstorming tool than a conceptual model or a framework [48].

Actor System Dynamics (ASD) model developed by Burns and Machado [49] depicted an integration in social structures, sociotechnical systems, physical and ecosystem structures, processes, and influencers. It further explains the interrelationships and interconnection among the above-mentioned factors in their combinations leading towards road collisions or incidents. Whitefield [50]suggested a system that could improve the level of safety management within a given context. Drivers who could be considered as "inputs to the system" and, as the "initial element", would lead the way towards avoiding hazards. "Safety management" would be the second element focusing on how safety should be implemented in each context. The third element is "measurement", which considers the output of the above activities. This model focuses more on changing the attitudes and behaviour of persons which would lead towards forming a safety culture.

May, et al. [51]developed a social-ecological model for road safety with four main dimensions, namely road safety, road crashes, road safety enhancement and road safety inhibitors. This also addressed how the environmental factors would affect road safety, studied under those four dimensions. Katsakiori, et al. [52] analysed the types of models which would provide collision investigation mechanisms. Most models were related to causation principles which would analyse reasons for causation, while some other models such as Tree-Analysis would break down each and every activity into a single unit [45].

A systematic literature review has been conducted by Staton, et al. [53] on road traffic injury prevention initiatives. It summarised the 18 most relevant out of a totality of 8,560 articles. Half (9) of these articles focused on legislation. Other focuses have been on public awareness and education (4), enforcement (2), road improvement (1), speed and control measures (1) and multi-faceted intervention (1). Legislation has been identified as the most common intervention which resulted in the best outcomes when combined with strong enforcement initiatives.

The literature further proposes to perform road traffic injury prevention with patient-centred outcomes as a guide to prevent injuries in complex settings. Recently, there has been an increased emphasis placed on improving the integral road network system of a country as a means of preventing road collisions. It encapsulates the fact that the road system should be able to address the limitations of human capabilities and behaviour. "Sustainable safety" in Netherlands and "Vision Zero" in Sweden are two examples that are built upon this view where the road transport system has replaced the driver as the key reason behind road collisions [54].

2.3. Road safety models for LMICs

The models discussed above indicate how the context and the external environment would play a critical role in shaping the driver behaviour leading to collisions. Yet, integrated models, combining both psychological factors, causation relationships and applicability concerns pertaining to developing countries, are limited.

Some studies have been conducted focusing on LMICs pertaining to road safety incidents. A procedural model has been posited [55] which focused on establishing a surveillance system aiming at Road Traffic Injuries (RTI) and supported defining the level of burden, identifying high-risk groups, planning necessary interventions and monitoring the impact. That study was conducted in the emergency departments of five major hospitals in Karachi, Pakistan. It revealed that such models could be established and effectively managed in a developing country context, despite limited resources. Another study was conducted [56] to evaluate the effectiveness of road safety programmes in LMICs which yielded 13 lessons; namely (a) defining the evaluation scope, (b) selecting study sites, (c) maintaining objectivity, (d) developing an impact model, (e) utilising multiple data sources, (f) using multiple analytical techniques, (g) maximising external validity, (h) ensuring an appropriate time frame, (i) importance of flexibility and a stepwise approach, (j) continuous monitoring, (k) providing feedback to implementers and policy-makers, (l) promoting the uptake of evaluation results, and (m) understanding evaluation costs. A study conducted in Nigeria proposed Traffic Conflict Technique (TCT) as an alternative to crash statistics given the quality concerns of existing data. It proposed that TCT could be practically applied in developing countries as a complement to crash data; a method of observation in which near-crash situations would be recorded and used to predict the collision risk and to understand the factors leading to crash situations [11].

However, given the increasing rate of road collisions in LMICs, it is vital to have a more focused approach addressing both environmental and sociological aspects prevailing in such countries. Though several procedural approaches have been developed, as discussed above, a proper model aggregating the behavioural and environmental contexts appears to be a necessity. Such a model would help the authorities to develop preventive mechanisms way before the incidents occur while saving the overwhelming economic and social costs.

3. METHODOLOGY

This study was conducted as qualitative research, using extant literature and focused group discussions; the latter being employed as the primary sources of data. Newspaper articles and published data on road collisions in LMICs were used as secondary sources of data.

3.1. Case of Sri Lanka

After understanding the scope of existing models and the factors that could have led to increasing road accidents in LMICs through the literature survey, several candidate cases were evaluated for the purpose of primary data collection. Sri Lanka was selected as the case study for this research for three main reasons; namely, (i) the country being an LMIC facing an increase of roadside incidents over the last few years, (ii) the convenience of recruiting participants and grasping in-depth knowledge which otherwise would be costly and time-consuming, and (iii) the familiarity of the researchers pertaining to the Sri Lankan context.

Sri Lanka is an Asian country situated in the Indian Ocean in close proximity to the most renowned east-west maritime route, just south of India. It encompasses 65,610 square kilometres with a population of 21.7 million. Sri Lanka is considered as a lower-middle-income-country with a per capita Gross Domestic Product (GDP) of USD 3852 as of 2019 [57],[58] .Yet, over 4.1% of the population in the country lives below poverty line, and the proportion of the employed population with incomes below $1.90 purchasing power parity a day was 0.8% in 2019 [59].

Sri Lanka has a road length covering 12,438 km of A, B and E grade roads. A and B roads stand for national highways; A being those with higher capacities. E stands for Expressways which are tolled. In 2019, Sri Lanka had 7 million vehicles on its roads [60]. Table 1 depicts the distribution of the entire road length in their respective categories.

Table 1: National Highways in Sri Lanka (Class "A", "B" & "E" Roads)

Road Class	**Length (km)**
Class "E" Roads	217.82
Class "A" Roads	4,217.42
Class "AA" Roads	3,720.31
Class "AB" Roads	466.92
Class "AC" Roads	30.19
Class "B" Roads	**8003.17**
Total of "A" & "B" Class Roads in Sri Lanka	12,220.59
Grand Total of National Highways in Sri Lanka ("A", "B' and "E" Class Roads)	**12438.42**

Source: Road Development Authority (2019)

Though the most populous Western Province (with nearly 27% of the population of the country) has higher GDP, and highest road infrastructure per square kilometre [61], the transportation system has not been able to cater to the mobility needs of the people of Western Province to a satisfactory level. A significant share of people's time is spent on roads due to inefficient mechanisms that are put in place vis-à-vis transport management. Lack of emphasis given to public transportation has resulted in increased congestion levels in peak hours which increases day by day [62].

According to the most recent statistics of the Ministry of Transport (MOT) in 2019, there were more than 33,000 traffic collisions in Sri Lanka, accounting for 2,829 deaths and 7,693 critical incidents [63]. Though these are somewhat lower than the numbers reported in 2017 (36,599 accidents, 33,452 recorded injuries, and 3,147 deaths), and in 2011 (40,258 accidents and 2,677 deaths), these statistics indicate that Sri Lanka is facing an intolerable burden of roadside incidents. On average, nine deaths were recorded per day due to road collisions in 2019. Most victims were pedestrians (776) and motorcyclists (1,162); given their vulnerability in the face of a collision.

These statistics are grim and underscore the need to take action to save lives. It is also widely believed by the public that the behaviour of citizens is a crucial part of this puzzle.

3.2. Study design

The study was designed in two stages. The Stage-I used focused group discussions and the Stage-II involved an expert panel consisting of academia and industry. The focus group discussion had 34 participants who were selected based on convenience sampling, but with a mix of genders, age and education levels. It revolved around key themes, namely, the opinions of the road safety of Sri Lanka and the factors that lead towards collisions, factors that affect the road user behaviour (drivers and pedestrians), and the potential issues in implementing road safety mechanisms in Sri Lanka. The researchers noted down the key points highlighted throughout the discussion.

The expert panel consisted of representatives of academia and industry who were interested in improving road safety. Three academic experts, four industry experts, and two institutional representatives, were thus included. The themes that emerged from the literature review and focus group discussions were evaluated within the panel to understand their interrelationships and their comprehensiveness in explaining the situation in the Sri Lankan context. A particular focus was given to those aspects pertaining to roadside incidents in LMICs that had not been adequately addressed by the existing models.

4. DATA ANALYSIS

The data gathered in Stage-I were analysed using thematic analysis. The notes were examined looking for excerpts which fall under the focus of the study, i.e., the factors that lead to roadside incidents. Table 2 provides a summary of the initial themes developed using the agglomeration of the excerpts.

Table 2: Excerpts and themes developed through the analytical process

Excerpt	Verification from literature	Thematic category	Discussion stage
Lack of road signage, poor design of the transport infrastructure, condition of the road	[31], [32], [42]	Physical context	Focus Group Discussion I
Lack of concern towards safe driving, poor attitudes, lack of focus, unnecessary rush, short-sighted actions	[26], [29], [31], [64], [65]	User context	Focus Group Discussion I
Lack of acknowledgement on safety culture, not adhering to rules, lack of enforcement, bribery and corruption	[6], [31], [32]	Social context	Focus Group Discussion I
Inadequate investigations and monitoring, lack transparency in the licensing process	[9], [11], [32]	Procedural context	Focus Group Discussion II
Attitudes and values, deep-rooted practices through culture, social interactions, opinions and feelings about driving and road safety	[23], [27], [65], [18], [29], [66], [42], [67]	Mindset	Focus Group Discussion I
Without adequate sleep, with medication or under the influence of drugs, Physical and mental unfit conditions, during night-time, At high speed to reach the destination on time, With an overloaded passenger/load capacity, In adverse weather conditions, In unfit vehicles & road infrastructures	[22], [68], [69], [70], [18], [33], [34], [64], [22], [16], [71], [15]	Circumstances	Focus Group Discussion I
Taking timely actions, developing stringent rules and regulations, enforcing the law	[6], [8], [72]	Legal System	Focus Group Discussion II
Manoeuvring a vehicle, detecting a dangerous situation and managing the situation, detecting a technical fault, concentrating on driving, managing the stress on the road, being patient, being calm and not being panic, road space analysis and decision making, crisis management	[16], [69], [26], [30], [24], [64], [15], [18]	Skills and Knowledge	Focus Group Discussion I
Proper road and vehicle infrastructure, adherence to design guidelines, having the right technology	[8], [16], [73]	Infrastructure	Focus Group Discussion II

The excerpts that had close meaning and interpretation were investigated to find the common theme that is emerging through the excerpts. These were validated with the constructs identified in the literature while examining the overlaps and deviations. The deviations were considered as the key points of discussion for Stage-II.

All the constructs identified in Stage-I were documented and presented to the discussion at the focus group, which included the expert panel. Additional themes emerged in Stage-II as stated in Table 2. In Stage-II, "Behaviour" was suggested as the umbrella theme for the mindset, circumstances, and legal system. Expert opinions on the relationship between themes were evaluated during the discussion. This formed the basis for the conceptualisation of the double triangulation model for road safety which integrates user psychology in a detailed manner. Few iterations of the models were developed until the model encapsulates the factors that emerged through the focused group discussion adequately.

5. DISCUSSION ON THE FINDINGS

5.1. Findings

The key factors which resulted in the causation of collisions in Sri Lanka could be summarised as below. These factors are similar to those in a majority of LMICs. The common causes are resource constraints and lack of emphasis placed by regulatory authorities [5],[6],[8]

(i) **Physical context** - This refers to the level of existing physical infrastructure which leads to collisions, such as poor road conditions, lack of additional signage and non-ergonomic designs. This is due to the lack of emphasis placed on the development, implementation and maintenance of such vital infrastructure due to inefficient planning and allocation of available resources [31],[32],[42].

(ii) **User context** – This refers to the mood and attitudes of road users, which lead to different short-sighted actions to satisfy their needs, despite the negative consequences of such acts. Urgency, dominance, unnecessary rush, lack of focus and poor attitudes could be identified as some such acts which appeared frequently in the extant literature and focus group discussions [26],[29],[31],[64],[65].

(iii) **Social context** – Social context refers to the societal conditions which shape the behaviour of persons as a society. Lack of adherence to rules, lack of prominence given to safety, bribery and corruption have become norms in society. Lack of enforcement of rules and regulations owing to inadequate monitoring systems is the key reason behind these developments [6],[31],[32].

(iv) **Procedural context** – Processes and procedures related to road safety are not defined and sequenced in an orderly manner. Lack of mechanisms to report and evaluate the safety incidents have led to poor visibility of the existing statistics in most LMICs [9],[11]. Bribes could play a role, particularly in the areas of renewing and issuing licences and vehicle emission certificates, due to undefined processes. These need to be addressed through the enforcement of law and order [32].

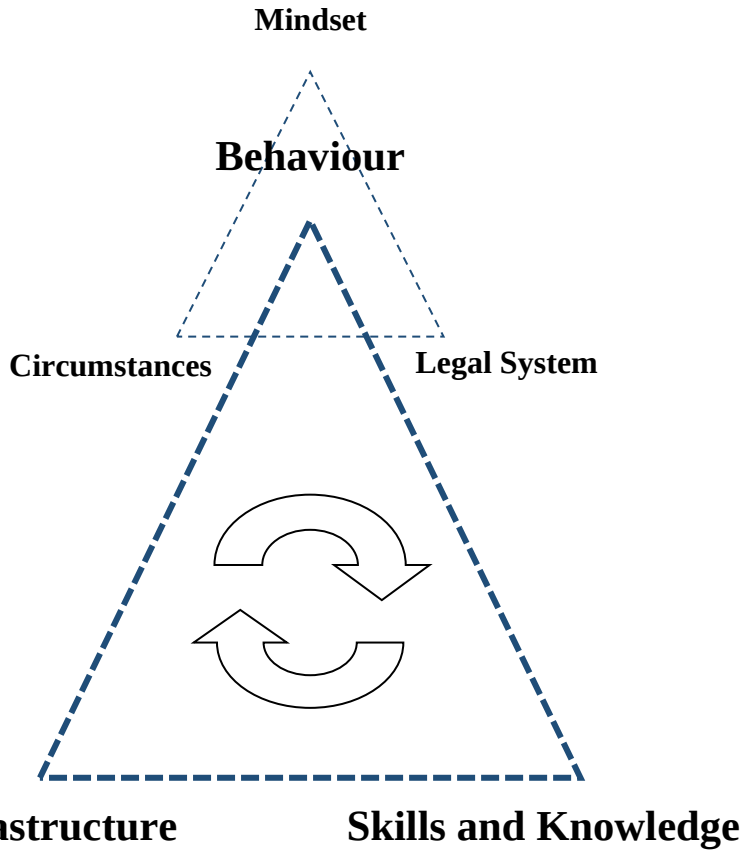

Figure 1: A conceptual model for LMICs integrating user psychology

Figure 1 depicts the model developed to elaborate the interaction of the key themes that emerged to address the above contextual factors. The model consists of two triangulations; thus, called a *double triangulation model*. The first triangle consists of three main dimensions which are Infrastructure, Skills and Knowledge, and Behaviour. The second triangle comprises how the behaviour is impacted. The three key dimensions are the mindset, the circumstances, and the legal system of a particular country. Table 3 compares the proposed model with other models which were identified as key safety models developed based on the systems approach.

Table 3: Comparison of the major system models proposed for transport safety in literature

Model	Factors considered	Areas of applicability	Characteristics and limitations (if any)
Haddon Matrix (1975)	Host, agent/vehicle, physical environment, and social environment	Collision prevention	Provides both pre-during-post dimensional viewpoints of the incidents, causation or conceptualisation with the causal effect is not captured through the model
Actor System Dynamics (ASD)	Integration in social structures, sociotechnical systems, physical and ecosystem structures, processes, and influencers	Collision prevention	States interrelationships and interconnection of the above factors in combination lead towards road collisions or any incidents
Whitefield (2009)	Inputs, safety management and outputs	Road Safety	Inculcating a safety culture
May et al. (2010)	Road safety, road crashes, road safety enhancement and road safety inhibitors	Road safety	Inclusion of preventive actions based on identified reasons
Double Triangulation model (The model proposed in this paper)	Behaviour (mindset, circumstances, legal system), skills and knowledge, infrastructure	Road safety	Improved emphasis placed on behavioural aspect and contextual factors Applicable in the context of LMICs

5.1.1. Behaviour

This explains driver behaviour (whist driving and parking) and behaviour of road stakeholders such as pedestrians and the general public. Behaviour is highly influenced by the mindset of the drivers and other road stakeholders, circumstances as well as degree of strictness of the enforcement of the law. Plenty of studies emphasise "behaviour" as a key aspect in ensuring road safety [8],[24],[26],[29],[64],[65],[74]. These are explained in detail as follows.

(i) Mindset – This can be explained as to how the mind of a driver/pedestrian works in a particular context. This is influenced by a combination of attitudes, values, upbringing, and other deep-rooted subconscious thought patterns as well as the strictness of the legal system [23],[27],[65]. Values are moral principles, ethics, or standards of behaviour on the road. Values are directly

influenced by family, friends, culture, religion, and social interactions. Attitudes are a settled way of thinking and feeling which also play a critical role in road user behaviour. These are opinions or feelings about certain subject matters such as road safety, speed driving, drunk driving, driving without physical fitness etc. [18],[29],[66]. Attitudes are influenced by values. Mindset can be enhanced to a desirable level using tools such as training programs, workshops, on the job training as well as rewards and punishments [42],[67].

(ii) **Circumstances –** This can be explained as facts or conditions connected to a situation, event or action that are unavoidable, or avoidable only with reasonable efforts [18],[75]. Such factors are listed below; among which, the first three factors are related to the condition of the driver and other factors are related to the environment, context, vehicles and road infrastructure.

- Without adequate sleep [22],[68],[69],[70]
- With medication or under the influence of drugs [18],[33],[34]
- Physical and mental unfit conditions [64]
- During night-time [22]
- At high speed to reach the destination on time [15],[68]
- With an overloaded passenger/load capacity [14],[70]
- In adverse weather conditions [70],[71]
- In unfit vehicles & road infrastructures[16],[71]

It is advisable to avoid the circumstances, where possible, by proactive planning and organising. However, in an unavoidable circumstance, the situation should be managed diligently.

(iii) **Legal System –** This should be timely, practical and adequately enforceable. Strict measures should be promptly taken [29]. Where possible technology should be used to detect and fine road traffic violations in order to overcome the loopholes in physical controls [6],[8],[72].

5.1.2. Infrastructure

Infrastructure is two-fold. Road infrastructure and the infrastructure related to vehicles. Road infrastructure should be designed, constructed, and maintained considering user safety as an aspect of paramount importance. Design codes and guidelines should be addressed accurately. Construction needs high-quality construction materials, the right technology, and processes as well as close supervision. Maintenance of roads should be given high priority and prompt action [8]. This includes pavements, curves, traffic signals, illumination and all the other

road infrastructures [16],[73]. Vehicles are suggested to be designed and manufactured with adequate safety measures, which need frequent maintenance to ensure the roadworthiness of vehicles.

5.1.3. Skills and Knowledge

Driver skills are suggested to be tested using proper mechanisms to ensure that they are ready for safe and competent driving [8],[13],[64]. This includes, but is not limited to, the skills of,

- Manoeuvring a vehicle [16]
- Detecting a dangerous situation and managing the situation [69]
- Detecting a technical fault
- Concentrating on driving [26],[30]
- Managing the stress on the road [24],[64]
- Being patient [15],[18]
- Being calm and not being panic
- Road space analysis and decision making [41]
- Crisis management

5.2. Method of implementation

Method of implementation was one of the key areas that emerged in the Stage-II, although this was not related to the constructs included within the model. It was evident in Stage-II that the approach towards implementation of the model is vital for its success, and also for a smooth propagation of the safety culture in LMICs, regardless of the level of superiority of a given model. Hence, it is recommended that respective authorities in LMICs should pursue the six steps suggested below in the process of implementing the proposed model.

(a) Make road accident prevention a main health and safety goal of LMICs:

Road collision prevention has not been given prominence in a majority of LMICs. Yet, the number of fatalities demands immediate attention by the responsible parties towards necessary actions [6]. Each year, 1.35 million people lose their lives on roads, which is almost similar to the deaths recorded due to the COVID-19 pandemic throughout the world in the year 2020. A major reason behind the low fatality rates of road collisions in developed countries is the increased emphasis placed on the road safety culture. Sweden's vision zero is an example of robust systems introduced based on the acceptance of the fragile nature of human behaviour to reduce collisions. This is supported by the stringent rules and regulations which demand 100% compliance by people. This

has reduced Sweden's road fatality rates from seven people to less than three people per 100,000 [54],[73]. In order to observe the expected behaviour from people, the top-level authorities should recognise the importance of road safety in the first place. This should be included as key health and safety goal each year which can be tracked and reported continuously.

(b) Provide necessary resource allocations:

In order to enforce the aspects in the model, governments need to make some investments without which the implementation would not be successful. Transport infrastructure such as proper roads and signposts should be developed and maintained as per the safety standards. Additionally, investments need to be allocated for technologies such as violation detection through CCTV cameras [73],[76]. Furthermore, effectively trained human resources are required for the smooth and efficient operation of enforcement services.

(c) Have adequate controls and comprehensive tests to examine mindset, skills and knowledge:

In the present context, the skills and knowledge of many citizens in LMICs in the domain of road safety is minimal. This is due to the poor quality of training and awareness programmes provided to road users, such as drivers, pedestrians, etc. Strict control should be implemented in the training institutions to ensure that the training they provide is up to the expected standards. Specifically, the process of issuing and renewing driving licences should be made more stringent to avoid the risk of producing, through the process, a weak and harmful driver. This can be done through improved testing and monitoring embedded in the process, together with responsible officials. Separate training should also be provided to those officials involved in such critical tasks to ensure the quality of outputs. These standards could be benchmarked with the existing schemes adopted by developed countries which show low roadside fatalities and collision/incident rates. The mindset of the people should be framed in such a manner that they understand the impact of violations on the community. Gender and age group responses should also be taken into consideration when formulating controls that are proven, through past research, to have variations [65],[75],[77].

(d) Continuously develop and update the mechanisms focused on improving mindset, skills and knowledge:

The process of disseminating and updating knowledge should be continuous. The importance of each user's activity should be encapsulated in the minds of the users such that they take their initiatives to improve their conduct concerning

road safety [66]. Research studies have found out that focused programs aimed at the improvement of attitudes and behaviour of drivers could be conducted in addition to any policy level interventions [29],[30]. This will not be achieved unless all prior steps are taken in an appropriate manner. Authorities issuing licenses should ensure that the renewal process includes considerations such as proper mindset, skills and knowledge.

(e) Develop new policies, procedures and legal systems in line with the proposed model:

Government and the respective authorities should work towards implementing new policies aimed at developing infrastructure as well as skills and knowledge related aspects. Policies that improve existing infrastructure and controls would directly impact the behaviour of the people [72]. While introducing and implementing policies towards road safety, it is also important to have stringent legal systems and enforcement systems to complement stringent policies [34]. Many LMICs lack strong legal systems and have loopholes in law enforcement [6]. In addition, processes should be designed to capture and report incidents in an accurate manner, which leads to improved visibility and may assist in monitoring safety performance. Apart from user negligence, institutional issues [9] also constitute a significant key factor behind underreporting, which could be reduced through proper enforcement of policies and procedures. Immediate attention to alleviating this problem is critical to saving lives.

(f) Implement a legal system with adequate and prompt fines:

Heavy fines can be identified as one of the key reasons behind the improved rates of compliance recorded in developed countries. The government of Sri Lanka increased the fines for road offences in February 2019 with the intention of reducing the growing number of road collisions. This initiative failed during its implementation due to lack of enforcement and policing, combined with the increased rate of bribery that came as a by-product of this move [78],[79]. With the five-fold increase of fines, some offenders and police officers opted to bribery to evade those high fines. This is partly due to the highly bureaucratic system in operation pertaining to settling fines which require an offender to visit the police station and the nearest post office multiple times. Fines would be more effective if technologies such as video surveillance could be integrated; this fact is much evident when investigating the mechanisms in developed countries [73]. Moreover, simplification of the fine settlement processes and the legal procedures (as an example refers to Figure 2 for the current process in Sri Lanka), is warranted and must be established without fail to ensure road safety is effectively enforced.

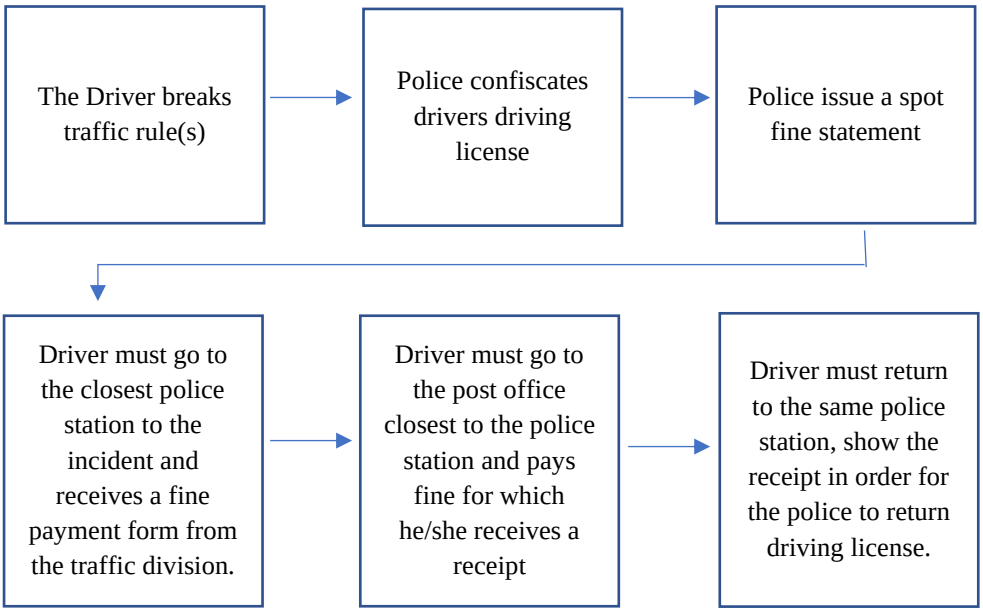

Figure 2. Existing fine settlement process

6. CONCLUSION

Road safety in LMICs is at a critical stage as 90% of the collisions which happen in the world occur in LMICs. A plethora of models are available in the literature which were developed to address the causes of road collisions. Yet, it is necessary to develop a model considering both behavioural and contextual parameters of LMICs that would address their concerns more specifically. The model proposed in this paper is characterised as a system model according to Hughes's classification [46]. It aims to understand different interrelationships between causal and contextual factors that leads to an incident and to facilitate systematic improvements towards road safety.

Contextual environment and sociological aspects prevailing in the LMICs should be considered when formulating a conceptual framework aimed at achieving safer roads [8],[45],[66],[80]. The authors of this paper have studied the specifics prevalent in Sri Lanka both through focus group discussions and literature upon which the base for the proposed model was developed. The researchers' personal experience in the Sri Lankan context was instrumental in conceptualising the phenomenon. This paper has proposed a *double triangulation model* which aims to address the above gap; the first triangle consists of *behaviour, infrastructure, skills and knowledge,* whereas the second triangle consists of parameters that influence the behaviour that include *mindset, circumstances* and the *legal system.* We see a cyclical iteration between the

dimension of the first triangle which is impacted heavily by the behaviour which is again triangulated through the mindset, circumstances and legal system Hence, this model has integrated the key constructs that affect the psychological state of the users which are seldom found on road safety models while necessitating the emphasis that needs to be placed on the contextual environment in LMICs. The reduction of traffic collisions can be achieved by addressing the behaviour while improving the infrastructure and skill related aspects. Further, an approach to implementing this model in LMICs are provided in brief, elucidating the key focus areas and necessary actions. Authorities are requested to refer to the proposed model in their approach towards addressing the road safety strategies in both present and the future.

Further research could be conducted on ways and methodologies which can validate the constructs of this model. Additionally, a detailed implementation mechanism could be proposed defining the stakeholder responsibilities and the amount of resources required to proceed with the implementation.

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REFERENCES

[1] A. Vij, "Understanding Consumer Demand for New Transport Technologies and Services, and Implications for the Future of Mobility," Springer International Publishing, 2020, pp. 91-107.

[2] Y. Z. Wong, D. A. Hensher, and C. Mulley, "Mobility as a service (MaaS): Charting a future context," *Transportation Research Part A: Policy and Practice*, vol. 131, pp. 5-19, 2020, doi: 10.1016/j.tra.2019.09.030.

[3] A. Polydoropoulou, I. Pagoni, A. Tsirimpa, A. Roumboutsos, M. Kamargianni, and I. Tsouros, "Prototype business models for Mobility-as-a-Service," *Transportation Research Part A: Policy and Practice*, vol. 131, pp. 149-162, 2020, doi: 10.1016/j.tra.2019.09.035.

[4] P. Franco, R. Johnston, and E. McCormick, "Demand responsive transport: Generation of activity patterns from mobile phone network data to support the operation of new mobility services," *Transportation Research Part A: Policy and Practice*, vol. 131, pp. 244-266, 2020, doi: 10.1016/j.tra.2019.09.038.

[5] A. F. Rahman and F. N. Rahman, "Complexities of Road Safety Interventions in Low and Middle Income Countries (LMICs) posed a major challenge in achieving Decade Goal- Lessons for the next span," *Journal of Injury and Violence Research,* vol. 11, no. 2, 2019, doi: 10.5249/jivr.v11i2.1362.

[6] World Bank, "Guide for Road Safety Opportunities and Challenge-Low and Middle income country profiles," Washinton DC, 2020.

[7] A. Haileamlak, "The Triple Challenges of Low and Middle-Income Countries," *Ethiop J Health Sci,* vol. 28, no. 1, pp. 1-2, Jan 2018, doi: 10.4314/ejhs.v28i1.1.

[8] C. Uzondu, S. Jamson, and F. Lai, "Investigating unsafe behaviours in traffic conflict situations: An observational study in Nigeria," *Journal of Traffic and Transportation Engineering (English Edition),* vol. 6, no. 5, pp. 482-492, 2019, doi: 10.1016/j.jtte.2018.06.002.

[9] M. W. Younis *et al.*, "Pattern of underreporting of Road Traffic Injuries (RTIs): An investigation of missing burden of RTIs in Pakistan," *Journal of Transport & Health,* vol. 14, 2019, doi: 10.1016/j.jth.2019.100575.

[10] A. Bener, F. M. Abu-Zidan, A. K. Benisali, A. A. Al-Mulla, and K. S. Jadaan, "Strategy to improve road safety in developing countries," *Saudi medical journal,* vol. July 2003, 2003.

[11] C. Uzondu, S. Jamson, and F. Lai, "Exploratory study involving observation of traffic behaviour and conflicts in Nigeria using the Traffic Conflict Technique," *Safety Science,* vol. 110, pp. 273-284, 2018, doi: 10.1016/j.ssci.2018.08.029.

[12] J. D. Jacobs and I. Sayer, "Road Accidents in Developing Countries," *Accident Analysis and Prevention,* vol. 15, no. 5, 1983, doi: https://doi.org/10.1016/0001-4575(83)90013-1.

[13] F. Dapilah, B. Y. Guba, and E. Owusu-Sekyere, "Motorcyclist characteristics and traffic behaviour in urban Northern Ghana: Implications for road traffic accidents," *Journal of Transport & Health,* vol. 4, pp. 237-245, 2017, doi: 10.1016/j.jth.2016.03.001.

[14] A. S. Kumarage, M. Bandara, and D. Munasinghe, "Analysis of the economic and social parameters of the Three-Wheeler Taxi service in Sri Lanka," *Research in Transportation Economics,* vol. 29, no. 1, pp. 395-400, 2010, doi: 10.1016/j.retrec.2010.07.050.

[15] A. S. Mohaymany, A. T. Kashani, and A. Ranjbari, "Identifying driver characteristics influencing overtaking crashes," *Traffic Inj Prev*, vol. 11, no. 4, pp. 411-6, Aug 2010, doi: 10.1080/15389588.2010.485283.

[16] M. Bin Islam and K. Kanitpong, "Identification of Factors in Road Accidents through in-Depth Accident Analysis," *IATSS Research*, vol. 32, no. 2, pp. 58-67, 2008, doi: 10.1016/s0386-1112(14)60209-0.

[17] A. R. Hale and J. Hoveden, "Management and culture: the third age of safety. A review of approaches to organizational aspects of safety, health and environment," in *Occupational Injury: Risk, Prevention And Intervention*, A. N. Feyer and A. Williamson Eds.: Taylor & Francis, London., 1998, ch. 11.

[18] R. Mayou, "Psychiatric aspects of road traffic accidents," *International Review of Psychiatry*, vol. 4, no. 1, pp. 45-54, 2009, doi: 10.3109/09540269209066301.

[19] P. Haddington and M. Rauniomaa, "Interaction Between Road Users," *Space and Culture*, vol. 17, no. 2, pp. 176-190, 2013, doi: 10.1177/1206331213508498.

[20] R. Mayou and B. Bryant, "Consequences of road traffic accidents for different types of road users," *Injury*, vol. 34, no. 3, pp. 197-202, 2003, doi: 10.1016/s0020-1383(02)00285-1.

[21] M. Šucha, "Road users' strategies and communication: driver-pedestrian interaction," presented at the Transport Research Arena (TRA) 5th Conference, Paris , France, 2014.

[22] H. E. C. Van der Wall *et al.*, "Using machine learning techniques to characterize sleep-deprived driving behavior," *Traffic Inj Prev*, pp. 1-6, May 7 2021, doi: 10.1080/15389588.2021.1914837.

[23] T. Zimasa, S. Jamson, and B. Henson, "Are happy drivers safer drivers? Evidence from hazard response times and eye tracking data," *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 46, pp. 14-23, 2017, doi: 10.1016/j.trf.2016.12.005.

[24] K. Zinbei, N. Souissi, and K. Tikito, "Driver Behavior Analysis Methods: Applications oriented study," presented at the 3rd International Conference on Big Data, Cloud and Applications - BDCA'18, Morocco, 2018.

[25] K. Zinebi, N. Souissi, and K. Tikito, "Selecting Qualitative Features of Driver Behavior via Pareto Analysis," *International Journal of Modern Education and Computer Science*, v.10(10), 2018, pp. 1-10, doi: 10.5815/ijmecs.2018.10.01.

[26] T. Zimasa, S. Jamson, and B. Henson, "The influence of driver's mood on car following and glance behaviour: Using cognitive load as an intervention," *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 66, pp. 87-100, 2019, doi: 10.1016/j.trf.2019.08.019.

[27] J. Tornros and A. Bolling, "Mobile phone use – effects of conversation on mental workload and driving speed in rural and urban environments," *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 9, no. 4, 2006.

[28] H. Farah, S. Bekhor, A. Polus, and T. Toledo, "A passing gap acceptance model for two-lane rural highways," *Transportmetrica,* vol. 5, no. 3, pp. 159-172, 2009, doi: 10.1080/18128600902721899.

[29] Z. Batool and O. Carsten, "Attitudinal segmentation of drivers in Pakistan: The potential for effective road safety campaigns," *Accid Anal Prev,* vol. 114, pp. 48-54, May 2018, doi: 10.1016/j.aap.2017.05.027.

[30] C. Timmermans, W. Alhajyaseen, A. Soliman, T. Brijs, K. Bedair, and V. Ross, "Effect of ADHD traits in young drivers on self-reported deviant driving behaviours: An exploratory study in the Arab gulf region," *Journal of Transport & Health,* vol. 17, 2020, doi: 10.1016/j.jth.2020.100857.

[31] J. Edirisinghe, "Riya Anathuruwalata hethu saha piliyam," in *Maubima*, ed. Colombo, 2014.

[32] S. Vithanage, "Mahapare Minimarana Thrasthavadiyo," in *Rivira*, ed. Colombo, 2012.

[33] Y. Oyono *et al.*, "Roadside surveys of drinking and driving in Cameroon," *Traffic Inj Prev,* pp. 1-6, May 20 2021, doi: 10.1080/15389588.2021.1922682.

[34] J. Damsere-Derry, G. Palk, and M. King, "Prevalence of alcohol-impaired driving and riding in northern Ghana," *Traffic Inj Prev,* vol. 17, no. 3, pp. 226-32, 2016, doi: 10.1080/15389588.2015.1066499.

[35] K. Zinebi, N. Souissi, and K. Tikito, "Driver Behavior Quantitative Models: Identification and Classification of Variables," in *International Symposium on Networks, Computers and Communications (ISNCC 2017,* Marrakech, Morocco, 2017: IEEE, doi: 10.1109/ISNCC.2017.8071987.

[36] H. Bar-Gera and D. Shinar, "The tendency of drivers to pass other vehicles," *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 8, no. 6, pp. 429-439, 2005, doi: 10.1016/j.trf.2005.06.001.

[37] S. C. Kim *et al.*, "Comparison of epidemiology and injury profile between vulnerable road users and motor vehicle occupants in road traffic fatalities," *Traffic Inj Prev*, vol. 20, no. 6, pp. 581-587, 2019, doi: 10.1080/15389588.2018.1539840.

[38] K. S. Minhas, Z. Batool, B. Z. Malik, I. Sanaullah, and T. A. Akbar, "Pedestrian environment and behaviour in Lahore, Pakistan," *Journal of Transport & Health*, vol. 7, pp. 181-189, 2017, doi: 10.1016/j.jth.2017.08.013.

[39] S. Chayanan, M. Nebergall, V. Shankar, N. Juvva, and Y. Ouyang, "Interaction between the roadway and roadside - An econometric analysis of design and environmental factors affecting segment accident rates," Washington State Transportation Center (TRAC), University of Washington, Seattle, Washington, 2003.

[40] M. E. Mihcioglu and A. Z. Alkar, "Improving pedestrian safety using combined HOG and Haar partial detection in mobile systems," *Traffic Inj Prev*, vol. 20, no. 6, pp. 619-623, 2019, doi: 10.1080/15389588.2019.1624731.

[41] R. Methorst *et al.*, "'Pedestrian falls' as necessary addition to the current definition of traffic crashes for improved public health policies," *Journal of Transport & Health*, vol. 6, pp. 10-12, 2017, doi: 10.1016/j.jth.2017.02.005.

[42] A. Constant and E. Lagarde, "Protecting vulnerable road users from injury," *PLoS Med*, vol. 7, no. 3, p. e1000228, Mar 30 2010, doi: 10.1371/journal.pmed.1000228.

[43] U. Kjellen, *Prevention of Accidents through Experience Feedback*. Taylor and Francis Group, 2000.

[44] A. R. Hale, J. Stoop, and J. Hommels, "Human error models as predictors of accident scenarios for designers in road transport systems," *Ergonomics*, vol. 33, no. 10-11, pp. 1377-1387, 1990, doi: 10.1080/00140139008925339.

[45] B. P. Hughes, S. Newstead, A. Anund, C. C. Shu, and T. Falkmer, "A review of models relevant to road safety," *Accid Anal Prev*, vol. 74, pp. 250-70, Jan 2015, doi: 10.1016/j.aap.2014.06.003.

[46] E. Stang, "Chernobyl - System Accident or Human Error," *Radiation Protection Dosimetry*, vol. 68, No 3/4, pp. 197-201, 1996.

[47] A. F. Williams, "The Haddon Matrix - its contribution to injury prevention and control," presented at the Injury Prevention: Road safety, 1995.

[48] P. Albertsson, U. Bjornstig, and T. Falkmar, "The Haddon matrix, a tool for investigating severe bus and coach crashes," *International Journal of Disaster Medicine*, vol. Volume 1, 2003, no. 2, 2009.

[49] T. R. Burns and N. I. D. J. Machado, "TECHNOLOGY, COMPLEXITY, AND RISK, Part I: Social systems analysis of risky socio-technical systems and the likelihood of accidents," *Sociologia, Problemas e Práticas*, vol. September, 2009, 2009.

[50] D. Whitefield, "Is That A Gap In Your Safety Culture—A Discussion Paper on Leading Safety Excellence," presented at the Asia Pacific Health, Safety, Security and Environment Conference, 4-6 August, Jakarta, Indonesia, 2009.

[51] M. May, P. Tranter, and J. U. A. Warn, Canberra., "Towards a Holistic Framework for Road Safety," *Journal of Transport Geography*, vol. 16, pp. 395-405, 2008.

[52] P. Katsakiori, G. Sakellaropoulos, and E. Manatakis, "Towards an evaluation of accident investigation method in terms of their alignment with accident causation models," *Safety Science*, vol. 47, pp. 1007-1015, 2009.

[53] C. Staton *et al.*, "Road Traffic Injury Prevention Initiatives: A Systematic Review and Metasummary of Effectiveness in Low and Middle Income Countries," *PLoS One*, vol. 11, no. 1, p. e0144971, 2016, doi: 10.1371/journal.pone.0144971.

[54] M. P. Hagenzieker, J. J. F. Commandeur, and F. D. Bijleveld, "The history of road safety research: A quantitative approach," *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 25, pp. 150-162, 2014, doi: 10.1016/j.trf.2013.10.004.

[55] J. A. Razzak, M. S. Shamim, A. Mehmood, S. A. Hussain, M. S. Ali, and R. Jooma, "A successful model of road traffic injury surveillance in a developing country: process and lessons learnt," *BMC Public Health 2012*, vol. 12:357, 2012.

[56] A. A. Hyder, K. A. Allen, D. H. Peters, A. Chandran, and D. Bishai, "Large-scale road safety programmes in low- and middle-income countries: an opportunity to generate evidence," *Glob Public Health*, vol. 8, no. 5, pp. 504-18, 2013, doi: 10.1080/17441692.2013.769613.

[57] Central Bank of Sri Lanka, "Economic and Social Statistics of Sri Lanka - 2019," 2019.

[58] World Bank. "The state or quality of being clear or bright; brightness; conspicuousness." https://www.worldbank.org/en/country/srilanka/overview#1 (accessed 12th March, 2022).

[59] Asian Development Bank. "Poverty Data SriLanka." https://www.adb.org/countries/sri-lanka/poverty (accessed 18th Nov, 2020).

[60] Road Development Authority - Sri Lanka. "National Highways (Class A, B & E Roads)." http://www.rda.gov.lk/source/rda_roads.htm (accessed 17th October, 2020).

[61] S. Perera, H. N. Perera, and K. Perera, "Topological Structure of the Road Traffic Network in the Western Regional Megapolis, Sri Lanka," presented at the 2018 Moratuwa Engineering Research Conference (MERCon), University of Moratuwa, 2018.

[62] A. S. Kumarage, "Why-Transport-in-Sri-Lanka-Continues-to-Go-from-Bad-to-Worse," *Sri Lanka Journal of Economic Research,* vol. Volume 5(1) November 2017, 2017.

[63] Department of Census and Statistics. [Online] Available: http://www.statistics.gov.lk/

[64] J. Engstrom, E. Johansson, and J. Ostlund, "Effects of visual and cognitive load in real and simulated motorway driving," *Transportation Research Part F : Traffic Psychology and Behaviour,* vol. 8, no. 2, pp. 97-120, 2005, doi: https://doi.org/10.1016/j.trf.2005.04.012.

[65] P. Ulleberg, "Personality subtypes of young drivers. Relationship to risk-taking preferences, accident involvement, and response to a traffic safety campaign," *Transportation Research Part F : Traffic Psychology and Behaviour,* vol. 4, no. 4, pp. 279-297, 2001, doi: https://doi.org/10.1016/S1369-8478(01)00029-8.

[66] S. M. Pampel, S. L. Jamson, D. L. Hibberd, and Y. Barnard, "Old habits die hard? The fragility of eco-driving mental models and why green driving behaviour is difficult to sustain," *Transportation Research Part F: Traffic Psychology and Behaviour,* vol. 57, pp. 139-150, 2018, doi: 10.1016/j.trf.2018.01.005.

[67] S. Koppel, A. N. Stephens, K. L. Young, P. Hua, R. Chambers, and C. Hassed, "What is the relationship between self-reported aberrant driving behaviours, mindfulness, and self-reported crashes and infringements?," *Traffic Inj Prev,* vol. 19, no. 5, pp. 480-487, Jul 4 2018, doi: 10.1080/15389588.2018.1440083.

[68] N. Merat, A. H. Jamson, F. C. H. Lai, M. Daly, and O. M. J. Carsten, "Transition to manual: Driver behaviour when resuming control from a highly automated vehicle," *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 27, pp. 274-282, 2014, doi: 10.1016/j.trf.2014.09.005.

[69] G. Underwood, D. Crundall, and P. Chapman, "Driving Simulator validation with hazard perception," *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 14, no. 6, pp. 435-446, 2011, doi: https://doi.org/10.1016/j.trf.2011.04.008.

[70] Z. Batool and A. Yasir, "The Influence of Sleep Quality, Safety Culture and Cabin Ergonomics on Work-Related Stress and Burnout of Bus Drivers in Lahore," *Journal of Transport & Health*, vol. 9, pp. S24-S25, 2018, doi: 10.1016/j.jth.2018.05.081.

[71] Y. Huvarinen, E. Svatkova, E. Oleshchenko, and S. Pushchina, "Road Safety Audit," *Transportation Research Procedia*, vol. 20, pp. 236-241, 2017, doi: 10.1016/j.trpro.2017.01.061.

[72] S. Porter and J. Wettig, "Policy issues on the control of major accident hazards and the new Seveso II directive," *Journal of Hazardous Materials*, vol. 43, 1999.

[73] Transport Accident Commission-Victoria. "Vision Zero and Swedens Approach towards Road safety." https://www.towardszero.vic.gov.au/ (accessed 18th November, 2020).

[74] M. A. Nees, K. Herwig, L. Quigley, and J. Zhang, "Relationships among driving styles, desire for control, illusion of control, and self-reported driving behaviors," *Traffic Inj Prev*, pp. 1-6, May 7 2021, doi: 10.1080/15389588.2021.1909728.

[75] E. M. Dias, "Theory of planned behaviour and pedestrians' intentions to violate traffic regulations," *Transportation Research Part F : Traffic Psychology and Behaviour*, vol. 5, no. 3, pp. 169-175, 2002.

[76] (2018). *High-Level Meeting on Development cooperation in middle-income countries*.

[77] F. Wegman, H.-Y. Berg, I. Cameron, C. Thompson, S. Siegrist, and W. Weijermars, "Evidence-based and data-driven road safety management," *IATSS Research*, vol. 39, no. 1, pp. 19-25, 2015, doi: 10.1016/j.iatssr.2015.04.001.

[78] B. Cooke, "Police Harassment in Sri Lanka: Fines, Bribes and Batons." [Online]. Available: https://groundviews.org/2019/06/11/police-harassment-in-sri-lanka-fines-bribes-and-batons/

[79] T. Cushing, "Notoriously Corrupt Sri Lanka Police Force Arrests Citizens For Pretending To Bribe A Cardboard Cutout Cop." [Online]. Available: https://www.techdirt.com/articles/20190104/20595041335/notoriously-corrupt-sri-lanka-police-force-arrests-citizens-pretending-to-bribe-cardboard-cutout-cop.shtml

[80] C. Ghee, D. Silcock, G. Jacobs, and A. Astrop, "Socio-economic aspects of road accidents in developing countries," *Geography*, 1997.