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FACTORS AFFECTING CRASH SEVERITY ON TWO MAJOR INTERCITY ROADS IN WESTERN SRI LANKA: A RANDOM PARAMETER LOGIT APPROACH

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ABSTRACT

Although Sri Lanka has significant traffic-related fatalities and injuries, only a limited number of studies have focused on the road safety challenge. This study applies the random parameters logit model to police reported crash data to identify the factors contributing to the severity of crashes in Sri Lanka. We find that severe crashes are associated with roadways that are unlit, in rural areas and have traffic controls, dual purpose vehicles, heavy vehicles, head-on and hit pedestrian crashes, drivers who are unlicensed, and casualties who are older (65 years and older) and do not use safety equipment, while minor crashes are associated with rear-end crashes, and female or younger (aged 25 years or younger) casualties. Several engineering, enforcement, and education measures are recommended based on the risk factors identified.

Keywords: *Sri Lanka, crash severity, random parameters logit model*

1. INTRODUCTION

Road crashes are a pressing global issue, claiming about 1.35 million lives annually, with over 90% of these fatalities occurring in low and middle-income countries [1]. In the Asia-Pacific region, the situation is dire, with one person losing their life on the roads every 38 seconds [2]. Sri Lanka, as part of this region, is grappling with a significant toll of traffic-related fatalities and injuries: the country experiences an estimated 38,000 road crashes each year, leading to approximately 3,000 deaths and 8,000 serious injuries. The rapid increase in vehicle ownership and a mix of motorised and non-motorised traffic exacerbates road safety issues, demanding immediate and sustained attention [3].

The social and economic costs of these crashes are staggering. Road crashes account for 1% of Sri Lanka's gross domestic product (GDP) due to the extensive burden on hospital resources and the long-term financial strains on families and the healthcare system [4], [5]. Particularly hard-hit are low-income commuters, who are involved in 70% of road crashes. Among these incidents, motorcycle-pedestrian crashes are especially deadly, contributing to about 40% of pedestrian fatalities [3]. Further, the fatality risk per capita in Sri Lanka was 17.4 in 2019, surpassing neighbouring countries such as India (16.6), Bangladesh (13.6), and Nepal (17.0) [3]. Pedestrian fatality risk in Sri Lanka stands at a shocking 5.0 per 100,000 people, ten times higher than Bhutan (0.5 per 100,000) and more than three times higher than India (1.5 per 100,000). Furthermore, the fatality risk associated with motorised bikes and three-wheelers is the highest in the region [3]. Despite the alarming statistics, road safety in Sri Lanka often takes a back seat to other pressing socio-economic challenges [4], [6]. This lack of priority is a critical oversight, given its substantial impact on public health and economic stability.

The existing literature on road safety is largely concentrated on developed countries [7]–[10]. While some studies address road safety in South-East Asia [11]–[16], only a few have specifically examined road safety in Sri Lanka over the last two decades, particularly in comparison to other parts of the world [5], [6], [17]–[21]. Such a vacuum in traffic crash statistics and analyses has negatively impacted the policy-making process in Sri Lanka, resulting in most road safety issues remaining unresolved [5], [6].

Though few, recent studies provide valuable insights into the various aspects of road safety and traffic accidents in Sri Lanka, they also offer potential solutions and highlight critical areas needing attention. Danthanarayana and Mallikahewa [22] analysed enduring factors contributing to road traffic accidents, emphasising the impact of rapid vehicle growth, road length, and socio-economic conditions. De Silva et al. [23] examined road traffic crashes and the built environment, identifying crash hotspots and stressing the need for infrastructure improvements. Bhalla et al. [4] used multiple data sources to estimate road traffic fatalities and injuries, underscoring the importance of accurate data collection for effective policymaking. Kushan and Chandrasekara [24] classified accident severity on the Colombo-Katunayake expressway, revealing how specific roadway features influence crash outcomes. Jayaratne and Kumarage [17] focused on vulnerable road users, advocating for targeted safety measures for pedestrians, cyclists, and motorcyclists. Jayanetti et al. [21] and Kodithuwakku and Peiris [25] further investigated factors influencing accident severity, while Shajith et al. [26] and Amarasingha [27] specifically addressed risks associated with motorcycle accidents. Liyanage [28] provided a broader perspective on factors affecting road accidents in the Western Province.

However, it is important to note that most of these studies have limitations. These studies often focus on descriptive statistics or specific elements, such as road conditions or driver behaviour in isolation, without integrating these factors into a cohesive analytical model. For instance, most of the studies are descriptive [6], [29] or use data collected through driver questionnaire surveys [30]–[32]. Many have adopted a segmented approach within the road safety context, focusing mainly on one or few elements, such as motorcycles, three-wheelers, or pedestrians, or focusing only on fatalities [6]. Despite these limitations, these studies provide valuable insights into the multifaceted nature of road safety challenges in Sri Lanka and offer potential solutions, giving hope for the future of road safety in the country. In addition, there is a restricted application of sophisticated statistical methods, such as the random parameters logit model. This model can accommodate unobserved differences and offer a more profound understanding of the root causes of crash severity. The absence of a thorough crash severity analysis also hinders the creation of impactful road safety strategies.

This study aims to fill this gap by applying the random parameters logit model to examine police-reported crashes on two major intercity roads from 2010-2012. The use of advanced statistical techniques, such as the random parameter logit model, can provide deeper insights into the underlying factors contributing to crash severity. This model accounts for unobserved heterogeneity and can offer a more comprehensive analysis by integrating elements such as road conditions, driver behaviour, vehicle types, and other pertinent factors into a cohesive analytical framework.

2. METHODS

2.1. Data

According to the Road Development Authority (RDA), as of 2023, Sri Lanka's road network comprises 12,568 km of "A", "B", and " E" Class roads. For the past half a decade, approximately 35% of the crashes recorded on "A" and "B" Class roads were reported from the Western Province. In this study, we focused on two major intercity roads within the Western Province that had experienced higher traffic-related fatalities and injuries. More specifically, we focused on traffic crashes occurring along A001 from Vilasitha Niwasa (Colombo) to Avissawella and along A004 from Peliyagoda (Colombo) to Ambepussa.

A004 is the longest road in Sri Lanka, stretching 430 km and connecting the western and eastern provinces. According to traffic flow data, bidirectional average daily traffic (ADT) along this road ranges between 8,000 and 63,000 vehicles per day. Road A001, commonly known as the Colombo-Kandy Road, is the first modern road built in Sri Lanka and spans 116 km. This road facilitates traffic between Sri Lanka's Capital Region, the central hills, and the northern and north-central areas, making it one of the busiest and most commercially significant routes. According to the 2011 survey data from the University of Moratuwa [33], traffic volumes on this road are particularly heavy during peak hours, with ADT values reaching up to 86,000 vehicles per day.

Crash data from 2010 to 2012 along these roads were provided by the Sri Lanka Police, who maintain the central crash database. Although the data is somewhat dated and presents a limitation for the study, the restrictions to protect personal information and the lack of readily available crash information make this data valuable. Like police reports in many countries, the database includes details about the time and location of the crash, weather and road surface conditions, type of crash, type of vehicle involved, driver age, and gender, though only a few roadway characteristics are recorded. In Sri Lanka, reporting is only required for crashes resulting in death or injury; making reporting damage-only accidents to the police quite rare. Field police officers also often encourage involved parties to settle damage claims without formally recording these types of crashes, potentially leading to underreporting of crashes.

This study classifies crash severity into two categories: (a) serious crashes, where at least one person is either deceased or hospitalised, and (b) minor crashes, where no one is deceased or hospitalised. The severity of a crash is determined by the most severe injury recorded, and the casualty information in the database typically refers to this individual. Over the three years, 2,954 crashes were reported, with 37.3%

classified as serious and 62.3% as minor. The description and summary statistics for the variables used in this study are provided in Table 1.

Table 1: Summary Statistics

Variable	Description	Distribution (%)
Severity	Severity of Crash	
Minor	Minor crash = 1; otherwise = 0	62.3
Severe	Severe crash = 1; otherwise = 0	37.7
Road	Road where the crash occurred	
A001	A001 = 1; otherwise = 0	61.7
A004	A004 = 1; otherwise = 0	38.3
Rural	Crash occurring in urban or rural locations	
Yes	Rural = 1; otherwise = 0	32.2
No	Urban = 1; otherwise = 0	67.8
Road segment	Location on road where crash occurred	
Intersection	Intersection = 1; otherwise = 0	16.9
Midblock	Mid-block = 1; otherwise = 0	83.1
Lighting	Light condition when the crash occurred	
Adequate	Adequate = 1; otherwise = 0	32.7
Inadequate	Inadequate = 1; otherwise = 0	67.3
Traffic Control	Presence of traffic control at crash location	
Yes	Yes = 1; otherwise = 0	24.4
No	No = 1; otherwise = 0	75.6
Crash type	Type of collision	
Single vehicle	Single vehicle = 1; otherwise = 0	3.9
Rear end	Rear-end = 1; otherwise = 0	15.0
Head-on	Head-on = 1; otherwise = 0	23.7
Hit pedestrian	Hit pedestrian = 1; otherwise = 0	35.9
Hit bicycle	Hit bicycle = 1; otherwise = 0	4.3
Others	Others = 1; otherwise = 0	17.2
Vehicle type	Type of vehicle involved	
Heavy vehicle	Heavy vehicle = 1; otherwise = 0	25.0
Dual purpose	Dual purpose vehicle = 1; otherwise = 0	14.8
Car	Car = 1; otherwise = 0	4.4
2-3 wheelers	2-3 wheelers = 1; otherwise = 0	40.2
Others	Others = 1; otherwise = 0	15.6
Driver age (years)	Age of drivers	
Young ($\leq$25)	Age $\leq$ 25 = 1; otherwise = 0	50.5
Middle-aged (26-64)	Age 26-64 = 1; otherwise = 0	18.2
Older ($\geq$65)	Age $\geq$ 65 = 1; otherwise = 0	29.8
Driver gender	Gender of driver	
Male	Male = 1; otherwise = 0	95.5
Female	Female = 1; otherwise = 0	0.9
Missing	Missing = 1; otherwise = 0	3.5

Variable	Description	Distribution (%)
Driver license	License status of the driver	
Licensed	Licensed = 1; otherwise = 0	36.5
Unlicensed	Unlicensed = 1; otherwise = 0	13.9
Missing	Missing = 1; otherwise = 0	49.6
Casualty gender	Gender of casualty	
Male	Male = 1; otherwise = 0	80.4
Female	Female = 1; otherwise = 0	19.6
Casualty age (years)	Age of casualty	
Younger (≤25)	Age ≤ 25 = 1; otherwise = 0	23.2
Middle-aged (26-64)	Age 26-64 = 1; otherwise = 0	70.2
Older (≥65)	Age ≥ 65 = 1; otherwise = 0	6.6
Safety equipment use	If safety equipment is used by casualty	
No	No = 1; otherwise = 0	1.7
Yes	Yes = 1; otherwise = 0	25.9
Missing	Missing = 1; otherwise = 0	72.4

2.2. Data Analysis

Building on the recent work of Fountas et al. [34], Wang et al. [35], Waseem et al. [36], and Washington et al. [37], we estimated a random parameters logit (RPL) model to identify the significant factors contributing to the injury severity of crashes along these roads in western Sri Lanka. The RPL model, also known as the mixed logit model, provides several advantages over the traditional logit model, especially in capturing individual-specific variations and addressing inherent limitations.

Unlike the traditional logit model, which assumes parameter homogeneity across all observations and adheres to the independence from irrelevant alternatives (IIA) assumption, the RPL model allows parameters to vary across observations, thus capturing unobserved heterogeneity in individual preferences [38]. This flexibility enables the RPL model to reflect real-world decision-making processes better and provide more accurate predictions [39]. Additionally, the RPL model relaxes the IIA assumption, making it more suitable for complex scenarios with unrestricted substitution patterns [38],[40]. It employs simulation-based maximum likelihood estimation methods, such as Halton draws, to efficiently estimate model parameters, thereby enhancing the robustness and reliability of the analysis [39],[40]. Empirical studies have demonstrated the RPL model's effectiveness in various fields, including transportation safety and market research, highlighting its superior capacity to accommodate variations in preferences and other influencing factors [38]–[40]. As a result, the RPL model is a highly versatile and accurate tool in discrete choice modelling, offering strong reassurance of its robustness and reliability.

Building on these strengths, our study employs the RPL model to investigate crash severity. As presented in Washington et al. [37] and Milton et al. [41], the severity function defining an individual crash n belonging to the severity type i is model by.

$$\mathrm{Y_{in}} = \beta_\mathrm{i}\mathrm{X_{in}} + \varepsilon_\mathrm{in} \text{ --(1)}$$

Where, Y_{in} is the injury severity function for estimating the crash severity category I (severe crash, minor crash) for the nth observation. β_i is a vector of estimable parameter for discrete outcome i, which may vary across observations, X_{in} is a vector of explanatory variables that determine discrete outcomes for observation n, and ε_{in} is the error term which is assumed to be generalised extreme value distributed [37]. To arrive at the random parameter logit model, random parameters are introduced with $f(\beta_i/\vartheta)$, where ϑ is the density function of β_i with ϑ referring to a vector of parameters of that density function (mean and variance), and all other terms are as previously defined. The resulting outcome probabilities are given by [37], [41].

$$\mathrm{P_n}(\mathrm{i}/\vartheta) = \int \frac{e^{\beta_\mathrm{i}\mathrm{X_{in}}}}{\sum_{\forall \mathrm{I}} e^{\beta_\mathrm{i}\mathrm{X_{in}}}} \mathrm{f}(\beta_\mathrm{i}/\vartheta)\mathrm{d}\beta_\mathrm{i} \text{ ---(2)}$$

Here $P_n(i/\vartheta)$ is the probability of crash severity outcome *i* for a certain crash *n* and *I* is a set of possible injury severity categories is that conditional on $f(\beta_i/\vartheta)$. To enable the estimation of the random-parameters logit model, β_i would capture the crash-specific variances of the impact of the explanatory variables on crash injury severity probabilities, based on the density function $f(\beta_i/\vartheta)$ enabling the computation of β_i. Random logit probabilities are then a weighted average for different values of β_i across crashes, where some elements of the parameter vector β_i are fixed and some may be random. Then a simulation-based maximum likelihood approach is employed to estimate the random parameter logit model using Halton draws as found in many previous studies [36],[37],[41],[42]. Two widely used distributions, normal and uniform are initially investigated to select the random parameters density functional forms. The normal distribution was found to have the better statistical fit and thus retained in the final analysis. The selection of normal distribution is consistent with the previous similar studies [36],[43],[44].

In our application of the RPL model, we make several key assumptions that align with the model's strengths in handling unobserved heterogeneity. First, we assume that the coefficients β_i vary randomly across observations, which allows us to capture individual-specific differences in crash severity outcomes. This is particularly important in crash data, where unobserved factors such as driver behaviour or road conditions may significantly influence the results.

Second, by relaxing the independence from irrelevant alternatives (IIA) assumption, the RPL model accommodates the possibility of correlated unobserved factors affecting multiple severity outcomes. This is crucial for modelling complex scenarios where different crash outcomes are not independent of one another.

Finally, the use of simulation-based estimation methods, such as Halton draws, enhances the robustness of our parameter estimates by efficiently approximating the likelihood function. This approach ensures our model is statistically reliable and practically applicable to crash severity analysis. The statistical software used for the analysis was NLOGIT Version 5.0.

3. RESULTS AND DISCUSSION

The estimation results are reported in Table 2. As shown, the coefficients for the intercept and two explanatory variables (intersection and rural) are identified as random, with statistically significant standard deviations.

The estimated mean effect of rural roads is positive and significant ($M = 0.1777$; $p = 0.015$), with a relatively large and significant standard deviation ($S.D. = 1.702$; $p < 0.001$). This suggests that, on average, crashes occurring on rural roads are more severe than those on urban roads. These findings are consistent with previous studies [45]–[51].

Senasinghe [19] highlighted that the lack of traffic control devices, non-graded curves, and undivided traffic streams contribute to increased crash severity on A001 and A004 roads. In Sri Lanka, victims of crashes are often transported to hospitals by three-wheelers or other available private vehicles. This delay and reliance on untrained individuals for initial medical care can exacerbate the severity of injuries [19]. This issue is particularly pronounced in rural areas and is not limited to roads A001 and A004 but is a widespread problem nationwide.

Additionally, the same study [19] suggested that the lack of logistical support and financial resources, such as the absence of speed cameras and inadequate seatbelt enforcement, may encourage unsafe driving behaviours, leading to more severe crashes in rural areas. However, the effect observed in this study is highly variable. Specifically, 45.8% of the observations show a negative effect or lower severity, indicating that while rural roads tend to have more severe crashes on average, there is considerable variability in the severity of crashes across different observations.

Table 2: Estimation Results

Model Fit Statistics		
Number of observations (N): 2954		
Log-likelihood function: -1863.05		
Restricted log-likelihood: -1867.13575		
Chi-squared (3 d.f.): 8.59826		
Akaike Information Criterion (AIC): 3765.7ns (N): 2954		
Variable	**Coefficient**	**Standard Error**
Rural		
Yes	0.1778**	0.073
S.D. (Yes)	1.7022***	0.115
Intersection		
Yes	-0.1009	0.087
S.D. (Yes)	1.0713***	0.126
Lighting		
Inadequate	-0.1257*	0.065
Traffic Control		
Yes	0.2086***	0.069
Road		
A001	-0.3318***	0.064
Vehicle Type		
Heavy	0.4482***	0.072
Dual Purpose	0.2531***	0.088
Crash Type		
Head On	0.3608***	0.088
Rear End	-0.2210 **	0.103
Hit Pedestrian	0.4119***	0.082
Driver License		
Unlicensed	0.3579***	0.086
Casualty Gender		
Female	-0.2879***	0.079
Casualty Age		
Younger	-0.2214***	0.074
Older	0.4806***	0.121
Casualty Protective Equipment		
None	0.4136*	0.227
Constant	-0.6875***	0.088
S.D.	0.1603***	0.043

Note: *, ** & *** denote statistically significant at 90%, 95% & 99% levels.

Interestingly, the mean estimated coefficient for intersections is relatively small and not statistically significant (M = -0.1009; p = 0.245), while the estimated standard deviation is statistically significant (S.D. = 1.071; $p < 0.001$). This result contrasts with previous studies that found crashes at intersections to be less severe [45], [52], [53]. In our study, the effect of intersections versus non-intersections is significant, but the direction of the effect is nearly balanced between positive and negative.

In Sri Lanka, roads are characterised by a diverse mix of traffic, including a higher prevalence of heavy vehicles and vulnerable road users such as three-wheelers and motorbikes. This traffic diversity adds complexity to managing intersection safety. Additionally, the presence of numerous unsignalised intersections creates hotspots for potential conflicts, such as issues related to turning movements, traffic control violations, failure to yield the right-of-way, misjudging the speed of approaching vehicles, and limited sight lines. These factors collectively contribute to the increased severity of crashes at intersections [19].

Moreover, this study finds that compared to locations without traffic control, crashes at locations with traffic control tend to be more severe (M = 0.2084; p = 0.003). This result aligns with findings from some previous studies [8], [19], [54], [55-57]. Senasinghe [19] found that 43% of crashes occurring at controlled intersections on road A001 in Sri Lanka involved pedestrians, with 54% of these crashes resulting in severe or fatal injuries. This was followed by 20% head-on and 12% rear-end collisions. Crashes on road A001 were primarily caused by factors like those discussed under intersection results. Additionally, unpredictable pedestrian movements, such as jaywalking, are common in Sri Lanka. Impatient driver behaviour due to slow-moving traffic, including tailgating and sudden lane changes, might also contribute to increased crash severity at controlled locations compared to uncontrolled ones on road A001.

Crashes on unlit roads are also likely to be more severe (M = 0.1257; p = 0.052). Poor lighting conditions reduce driver visibility and the perceptibility of road surroundings, causing drivers to be unaware of hazards until the last moment before a collision. This limited reaction time hinders their ability to take evasive action. This finding is consistent with results from previous studies [53], [58]–[61].

Regarding vehicle characteristics, two types of vehicles have statistically significant effects. As expected, heavy vehicle crashes tend to result in more severe outcomes (M = 0.4482; $p < 0.001$). Another significant category is dual-purpose vehicles, designed or adapted to carry passengers and goods. Although this category has seldom been studied in previous crash analyses, it is separately categorised in Sri Lanka due to its substantial presence in the vehicle population. Crashes involving dual-purpose vehicles are often more severe because these vehicles are typically larger than average passenger cars. Additionally, Senasinghe [19] found that the severity of injuries associated with heavy and dual-purpose vehicles on roads A001 and A004 was primarily due to head-on and pedestrian collisions.

Regarding collision types, three categories have statistically significant effects, as shown in Table 2. First, head-on collisions are associated with higher severity. This finding aligns with results from previous studies [53], [62]–[69]. Second, rear-end collisions are associated with lower severity, which is also consistent with previous studies [53]. Third, vehicle-pedestrian collisions are linked to higher severity, in line with findings from prior research [10], [62].

In terms of driver characteristics, the study finds that crashes involving unlicensed drivers are associated with greater severity. While unlicensed drivers have been found to be linked to an increased likelihood or frequency of crashes in several studies [67], [68], few have specifically examined the severity of crashes involving unlicensed drivers [19], [69]–[71]. This study demonstrates that compared to licensed drivers, unlicensed drivers (those without a valid license) are associated with higher crash severity ($M = 0.3579$; $p < 0.001$). This result is expected, as unlicensed drivers either lack adequate driving knowledge and skill, having failed their driving tests, or have had their licenses suspended or revoked, indicating they are higher-risk drivers. Additionally, Senasinghe [19] highlighted that driving without a valid license for the vehicle type has historically been a significant issue in Sri Lanka, particularly among operators of lorries, buses, motorcycles, and three-wheelers. The same study also found that the likelihood of being involved in a fatal crash increased by 204% for individuals driving without a valid license compared to those with a proper driver's license on road A004.

Intriguingly, several other driver characteristics, such as age, gender, driving experience, and alcohol impairment, are found to be statistically insignificant in this study. The t-statistics for each of these variables are all below 1.65, and their p-values exceed 0.10 in the full model. The chi-square statistic for the difference between the full and restricted models is $\chi^2 = 6.29$, with a p-value of 0.28. This suggests that these additional driver-related variables are not statistically significant and that their insignificance is not an artefact of multicollinearity [72]. These findings contrast with results from most previous studies [8], [19], [52], [53].

In the sample size distribution, the percentage of female drivers is only 0.9%. Consequently, it is evident that female drivers are not significant in the model. This low representation further supports the finding that gender, among other characteristics, does not have a significant effect on crash severity in this study.

In terms of casualty characteristics, this study finds that age, gender, and the use of protective equipment (such as seatbelts, helmets, and safety vests) significantly affect crash severity.

First, female casualties are associated with lower crash severity. This result is consistent with the expectation that females generally take fewer risks, aligning with findings from previous studies [10], [73–78].

Second, when comparing different age groups, younger casualties (< 26 years old) are associated with lower severity ($M = -0.2214$; $p = 0.003$), while older casualties (> 65 years old) experience higher severity ($M = 0.4806$; $p < 0.001$) compared to middle-aged casualties (26-64 years old). These results are consistent with expected physiological differences and findings from previous studies [8], [61], [79]–[82]. The influence of prescribed medications may also contribute to these outcomes. In Sri Lanka, high tax rates and low wages often make it difficult for individuals aged 18 to 25 to own vehicles, which may explain why younger individuals experience less severe crashes. Conversely, the lack of a proper re-evaluation process for elderly drivers' fitness to drive could explain the increased crash severity among older drivers [19].

Third, the non-use of protective equipment is associated with higher severity ($M = 0.4136$; $p = 0.069$). This finding is expected, as protective equipment generally reduces injury severity, aligning with previous studies' results [81], [83].

It's crucial to understand that the explanatory variables used in estimating the model are all dummy variables. This means that the estimated coefficients can be directly compared, as the Odds Ratio (OR) is $OR = \exp(\beta)$ and is monotonic. The relative magnitude of the estimated coefficients reveals the urgency of the road safety issues. The most significant factors are the age of the casualty (>65), the involvement of heavy vehicles, pedestrian crashes, the use of protective equipment by the casualty, and head-on collisions. Figure 1 provides a visual representation of the urban and rural sections of roads A001 and A004, underscoring the pressing need to address the safety issues discussed in Table 2.

To address the significant factors identified, we propose several targeted mitigation strategies, starting with the age of the casualty (>65). These strategies are of utmost importance as elderly road users face increased crash severity due to age-related declines in physical and cognitive abilities, such as slower perception, longer reaction times, difficulties in judging speed and distance, and the effects of prescribed medications. Additionally, Sri Lanka currently needs an effective process for re-evaluating the driving fitness of older individuals.

Implementing a comprehensive driver fitness evaluation program is not just crucial, it's a necessity. Moreover, a nationwide policy should be established to cater to the needs of the ageing population and address the challenges of elderly drivers when designing, constructing, and upgrading roads [84]. For example, older pedestrians often need more time to crossroads safely. Therefore, extending pedestrian crossing intervals in areas with a high density of older pedestrians is essential. Additional measures, such as installing pedestrian refuges, increasing crossing times, and reducing speed limits at these locations, can significantly enhance safety and support the ageing community.

Another critical issue is the non-use of essential protective equipment. While Sri Lanka has laws requiring seatbelt and helmet use, the fines for violations are relatively low compared to the risks associated with not using these safety measures. According to an article published in the Sunday Observer (29 October 2017), the maximum fine for not wearing a helmet is about USD4 and approximately USD25 for not wearing a seatbelt. This underscores the urgent need for a review of traffic fines and extensive media coverage to effectively address the issue. However, raising fines could disproportionately impact lower and middle-income populations, so any changes should be carefully considered and studied before implementation.

Additionally, Sri Lanka currently lacks a child restraint law [19], which should be introduced promptly. Furthermore, three-wheelers, a major mode of transport in Sri Lanka, often lack protective features such as seat belts, putting passengers at significant risk. This gap in safety regulations should be addressed urgently [4], [19].

Driving without a valid license for the vehicle type driven is another long-standing issue in Sri Lanka, especially among drivers of dual-purpose vehicles, heavy vehicles, motorcycles, and three-wheelers. Sri Lanka's British-style licensing system requires minimal driver education and relies primarily on a driving test to assess skills and knowledge. Many novice drivers opt for uncertified training from friends or family rather than formal education [19]. To address this, it's crucial to implement a Graduated Drivers Licensing (GDL) system and a comprehensive screening process to evaluate the adequacy of driver training. In the short term, introducing a rigorous license-checking program, increasing penalties, and launching media campaigns to raise awareness could help mitigate the problem.

Offering incentives, such as reduced insurance premiums or tax benefits for completing certified driver training programs, could further encourage proper training and certification. Partnering with private driving schools to ensure high instructional standards and regularly updating their curricula to reflect the latest road safety practices can standardise training and enhance overall driver competence. By adopting these measures, Sri Lanka can improve driver skills, reduce unlicensed driving, and boost road safety.

A001 Road **A004 Road**


(a) Makola Road Junction - Kiribathgoda


(b) Baseline Junction - Kirulapone


(c) University of Kelaniya- Kiribathgoda


(d) Nugegoda junction


(e) Ragama Road Junction - Kadawatha


(f) Flyover Colombo End - Nugegoda


(g) Miriswatta Junction


(h) Gamsaba Junction


(i) Chandrajothi Maha Viyalaya - Yakkala


(j) Gammana Road Junction - Maharagama

Figure 1: Images of road segments from A001 and A004

Source: Google Maps Street View (Year 2012)

On roads A001 and A004, head-on crashes are the most fatal and severe type of collision. Despite the increased risk of head-on collisions when using opposing traffic lanes, as shown in Figure 1 (d), (f), and (h), commuters have adapted to use opposing lane space and division markings. The most effective long-term solution to this issue is to convert these roads into divided roads by installing median barriers or elevated centre medians. This would provide a clear separation between opposing traffic streams, significantly reducing the risk of head-on collisions and improving road safety.

Aside from head-on collisions, the two other types of crashes found to be more severe were hit pedestrian and heavy vehicle crashes. To mitigate vehicle-pedestrian crashes, appropriate sidewalks and roadside barriers should be installed along these roads, and safe pedestrian crossings should be established. Additionally, reducing the speed limit in areas with high concentrations of pedestrians can help alleviate the severity of crashes involving heavy vehicles. Regular license checks on heavy vehicle drivers, coupled with educational initiatives about safety issues specific to heavy vehicles, such as greater stopping distances and blind spots, are also crucial.

To further enhance pedestrian safety, it is essential to establish safe pedestrian crossings, such as overpasses, underpasses, and well-marked crosswalks with traffic signals, on busy roads like A001 and A004. Implementing strategies to reduce jaywalking, including public awareness campaigns that educate pedestrians about the dangers of crossing roads in non-designated areas, should also be a priority.

4. CONCLUSIONS

Sri Lanka, a lower-middle-income country in South Asia, faces a significant burden of traffic-related fatalities and injuries. Despite reports indicating efforts since the 1980s [85],[86], road safety issues have been relatively neglected. This study conducted an empirical analysis to identify the significant factors contributing to the severity of crashes on two major intercity roads in western Sri Lanka. Due to its unique racial, religious, economic, and political background, several novel and intriguing findings emerged, some of which contradict previous studies. For example, contrary to established research, we found that several common driver characteristics such as age, driving experience, and alcohol impairment were statistically non-significant.

Our analysis revealed that severe crashes are associated with factors such as unlit roadways, rural areas, traffic control issues, dual-purpose or heavy vehicles, head-on and pedestrian collisions, unlicensed drivers, and casualties who are older (65 years and above), and do not use safety equipment. In contrast, minor crashes are more commonly associated with rear-end collisions and involve female or younger (aged 25 years or less) casualties. Previous studies on crash severity have rarely examined variables such as dual-purpose vehicles and unlicensed drivers. This study is also among the few that consider the influence of casualty characteristics on crash severity within an econometric model. However, due to the limited data available, the findings are suggestive but constrained, based solely on the A001 and A004 road segments. Future research should aim to conduct a comprehensive all-island road crash analysis using an updated dataset when available.

Based on these findings, we recommend several measures to improve road safety. Transport departments and road safety agencies should prioritise enhancing street lighting along these roads, particularly in rural sections. Better separation of pedestrian traffic from motorised traffic, especially heavy and dual-purpose vehicles, is crucial. Installing median barriers can prevent head-on collisions along these roads. Pedestrian protection can be improved by providing walkways, crossings, and roadside barriers.

In addition to these engineering measures, traffic law enforcement should be intensified, focusing on curbing unlicensed driving and ensuring the use of protective equipment, such as seatbelts, helmets, and safety vests. Educational campaigns should target unlicensed drivers, promote the use of safety equipment, and address the specific needs of younger and older road users and pedestrians. By implementing these recommendations, Sri Lanka can make significant strides in reducing the severity and frequency of traffic-related injuries and fatalities in the future.

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