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Crash Severity Analysis of Young Adult Motorcyclists: A Comparison of Urban and Rural Local Roadways

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Abstract: In developing nations, motorcycles are a ubiquitous mode of transportation on local road networks, contributing to a substantial frequency of traffic accidents and fatalities. These occurrences exhibit significant discrepancies between urban and rural road environments. Specifically, urban roads exhibit greater traffic density and more robust law enforcement presence compared to their rural counterparts, factors that invariably influence vehicular speeds. Consequently, these variations in speed are associated with the adoption of riskier behaviors by motorists, with a pronounced impact on Young Adult Motorcyclists (YAMs) who demonstrate a heightened propensity for engaging in perilous activities, such as operating a motorcycle while under the influence or executing excessively close maneuvers. This study seeks to examine the factors that influence injury severity among YAM on local roads by contrasting urban and rural roadways, taking into account the different roadway contexts. Data from motorcycle crashes on local roads in Thailand between 2018 and 2020 were analyzed using the Random Parameter Logit Models with Unobserved Heterogeneity in Means and Variances (RPLMV) approach to investigate the relationship between contributing factors and YAM injury severity. The findings revealed several critical insights into the factors influencing the severity of motorcycle accidents, particularly among YAM on local urban roads. It is evident that a confluence of factors, including the absence of a valid driver's license, exceeding designated speed limits, and the involvement of male drivers, significantly elevates the probability of fatal outcomes in these accidents. Our analysis has also unveiled intriguing patterns in nighttime accidents involving motorcycles, where those with functioning vehicle lights and those occurring under the cover of darkness without proper illumination share notable similarities in terms of severity. Furthermore, our research has emphasized that accidents transpiring outside city confines during nighttime hours with adequate lighting exhibit a negligible impact on higher crash severity. The key findings advocate for the development and implementation of targeted policy recommendations and countermeasures to alleviate the severity of accidents involving YAM. This includes a proposition to bolster law enforcement efforts, particularly in regions beyond city borders, and to enforce strict adherence to regulations concerning driver's license verifications. Our study offers a crucial foundation for future research and policy development aimed at improving road safety and reducing the severity of motorcycle accidents, with the ultimate goal of safeguarding the lives of YAM.

Keywords: crash fatality; unobserved heterogeneity in means and variances; random parameters; logit models; developing countries; motorcycle crashes

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Citation: Champahom, T.; Se, C.; Aryuyo, F.; Banyong, C.; Jomnonkwao, S.; Ratanavaraha, V. Crash Severity Analysis of Young Adult Motorcyclists: A Comparison of Urban and Rural Local Roadways. *Appl. Sci.* **2023**, *13*, 11723. https://doi.org/10.3390/app132111723

Academic Editor: Vicente Julian Inglada

Received: 30 September 2023
Revised: 23 October 2023
Accepted: 25 October 2023
Published: 26 October 2023

1. Introduction

Worldwide, there are initiatives and campaigns to improve road access for more vulnerable road users (as stated in Goal 11.2 of the Sustainable Development Goals) [1].

Motorcyclists make up a large portion of vulnerable road users, so motorcycle crashes pose a critical challenge for sustainable development, especially in developing nations (like Thailand, Vietnam, Indonesia, and Malaysia), where motorcycles are widely used [2,3]. Motorcycle crashes often have a heightened risk of fatalities, whether in single-vehicle crashes or crashes with other vehicles [4]. Thailand is among the countries with the highest prevalence of motorcycle use, with at least one motorbike owned by 87% of households in the nation.

Due to the fact that motorcycle accidents on main roads, arterial routes, or highways are associated with high fatality rates [5], comprehensive research has already been conducted on this aspect in Thailand [6]. However, a noteworthy facet of transportation infrastructure that deserves more thorough examination relates to local roads. These roadways witness a significant inflow of motorcycle traffic and, alarmingly, make a substantial contribution to the escalating fatality toll resulting from motorcycle accidents. Notably, between 2015 and 2020, there were a staggering 94,284 reported motorcycle accidents on local roads in Thailand, resulting in 14,495 fatalities [7]. Local roads, typically prioritizing accessibility, often traverse areas like villages and similar communities.

Figure 1 serves as a visual representation of the distribution of motorcycle accidents on local roads in Thailand. Upon closer examination, a disconcerting trend manifests where a significant proportion of these accidents predominantly involve motorcyclists under the age of 30, a demographic commonly classified as Young Adult Motorcycle riders (YAM) [8]. The selection of YAM as the focal point of our study finds its rationale in several key considerations. This age group often exudes a heightened level of self-assurance grounded in their physical attributes, which include exceptional vision and overall physical strength. This sense of self-assuredness, in turn, inclines them toward operating their motorcycles at elevated speeds [3]. Moreover, substantiating our choice further, the research findings of Khan et al. [9] expound upon the correlation between possessing a driver's license and amplified self-confidence, particularly among individuals aged 18 to 19 within the YAM demographic. This boost in self-confidence has been observed to lead to the adoption of aggressive driving behaviors, thereby elevating the susceptibility to accidents and subsequent fatalities. Such increased risks materialize in various forms, notably through close-cutting maneuvers and instances of driving under the influence. Therefore, our emphasis on YAMs in this study not only aligns with the observed trend, but also delves into the nuanced dynamics of this demographic's driving behavior, shedding light on the multifaceted aspects contributing to elevated risks and ultimately emphasizing the urgent need for targeted safety policies and interventions in the context of local road safety in Thailand.

Champahom et al. [10] investigated the severity of motorcycle crashes by comparing younger and older motorcyclists. As displayed in Table 1, many studies have not concentrated on local roads and have seldom been conducted in developing countries. Moreover, no research has analyzed crashes based on spatial instability [11]. Thus, it is clear that the following crucial aspects remain unaddressed: the physical features of the roads, traffic volume, and vehicle types used on local roads. Differences between urban and rural roads may exist. Urban rural roads, delineated by municipalities and characterized by the concentration of primary activities in sub-districts and districts, prioritize access to large activity sites such as shopping malls, stores, and government offices. Consequently, urban local roads experience higher traffic density and a greater number of cars. In contrast, rural local roads typically have less traffic. Figure 2 has been constructed to visually represent the stark contrast between two distinct local road settings. In Figure 2a, situated within the confines of an urban area, the roads are conspicuously flanked by parked cars on both sides. This parking arrangement exerts a considerable influence on vehicular speed and introduces a heightened risk of collision. Conversely, as depicted in Figure 2b, the periphery of the city exhibits a markedly different landscape, characterized by sparse vehicular presence and unobstructed roadways, fostering high-speed travel. However, in such locales, when collisions transpire, the potential for severe outcomes, including fatalities, is significantly amplified. Another noteworthy distinction pertains to the presence of activity centers, such as shops and restaurants, within these settings. Here, urban traffic often necessitates halting, potentially leading to rear-end collisions. Although these incidents may result in relatively minor injuries, the risk remains palpable. Meanwhile, rural roadways primarily abut residences, rendering vehicular transportation superfluous and enabling uninterrupted high-speed travel. Additional factors include law enforcement, which is more rigorous in urban areas, exemplified by checkpoints, helmet requirements, and other measures. The differences also extend to engineering approaches; urban roads may receive more funding for pavement construction and safety equipment, which are often more standardized on urban roads than rural roads.

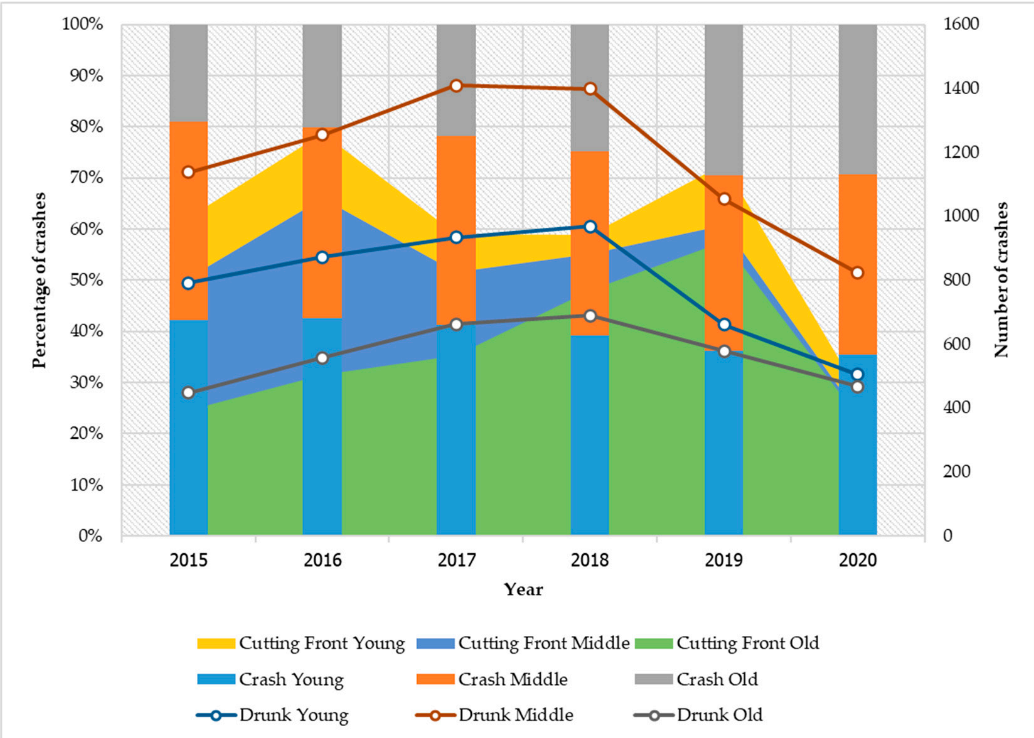


Figure 1. Motorcycle crashes on local roads in Thailand.

Table 1. The studies of crash injury severity of Young Adult Motorcyclists.

Author (Year)	Research Aims	Country	Road Type	Spatial Instability
This study	To identify factors influencing injury severity in young adult motorcyclists on local roadways, comparing urban and rural areas.	Thailand (2018–2020)	Local Road	✓
Champahom et al. [10]	To investigate motorcycle crash severity, comparing young and old riders.	Thailand (2015–2020)	Local Road	-
Islam [8]	To analyze the impact of motorcyclists' age on injury severity, considering three age groups.	Florida (2013–2017)	Not specify	-
Khan et al. [9]	To assess the link between age and severe injuries in young motorcycle riders.	Pakistan (2007–2015)	Not specify	-
Halbersberg and Lerner [12]	To predict fatal motorcycle crashes and identify key contributing factors.	Israeli (2002–2008)	Not specify	-
Hidalgo-Fuentes and Sospedra-Baeza [13]	To analyze motorcycle crashes in Spain based on gender and age.	Spain (2006–2011)	Not specify	-
Isa et al. [3]	To warrant a study to understand overall crash characteristics and associated risk factors.	Malaysia (2006–2008)	Not specify	-

(**a**) (**b**)

Figure 2. Local roadways in urban and rural areas. Source: Google maps. (**a**) Local roadway in an urban area (coordinates: 14.974957769842616, 102.0974113396429), (**b**) Local roadway in a rural area (coordinates: 14.977037204559815, 102.09087001080657).

Studies aiming to identify policies for reducing crash severity primarily employ the Logit Model Analysis method, which differentiates between the alternative outcomes: fatal and non-fatal crashes [14]. Currently, the Logit model has evolved to incorporate a more complex principle of random parameters, an analysis premised on the assumption that various factors may impact differing crash severity levels by examining parameter variance [15]. This is logical, as even though motorcycles may operate in the same area, crash severity levels can vary. The analysis, based on the principle of unobserved heterogeneity in means, seeks to determine how each random parameter variable is influenced by specific factors (factors not analyzed for their effect on crash severity), either increasing or decreasing the mean of the random parameter. Unobserved heterogeneity in variance refers to the identification of factors that may influence the resulting variance [16]. Prior research has demonstrated that a random parameter logit model with unobserved heterogeneity in means and variances analysis is suitable and can offer more in-depth policy insights than other methods [17,18].

In this regard, this study aims to expand knowledge of crashes involving Young Adult Motorcyclists (YAMs) and identify factors that influence crash severity in order to develop strategies for reducing fatalities. To create specific policy recommendations, it is essential to consider the following two dimensions: (1) the YAM group statistically exhibiting the highest crash rate among drivers and (2) differences existing between local roads, particularly urban and rural roads in terms of law enforcement, traffic volume, and the presence of larger vehicles. The model's results will be presented and used to draw some policy recommendations to decrease motorcycle crash severity for YAMs. Relevant organizations that can implement these recommendations may include the Subdistrict Administrative Organization (responsible for local roads) and road safety agencies such as the Ministry of Public Health, the Traffic Police, and the Ministry of Transport.

2. Literature Review

In this section, we discuss the findings from previous research reviews that highlight factors potentially affecting motorcycle crash severity among young adult motorcyclists (YAMs) and explore the differences between urban and rural roads.

One frequently identified significant factor is the gender of the driver. Many studies have found that male drivers, especially young males, are more prone to crash fatalities than females [13]. Another variable that may play a role is the presence of foreign drivers. In developing countries, a substantial number of tourists are allowed to rent motorcycles. However, their unfamiliarity with local laws, speed limits, and traffic conditions could influence crash severity [7]. An at-fault rider signifies the cause of a crash in such instances. While previous research has investigated this issue, the results have been inconsistent, with most findings deemed insignificant. Islam and Brown [19] argued that if the motorcyclist is at fault, the likelihood of fatality increases. A local address pertains to drivers who are from the same district and are highly familiar with the roads, especially in urban settings, where they are aware of stopping points and intersections. This contrasts with drivers from other areas [10]. Helmet use is a well-established factor that can decrease the risk of death, regardless of a rider's age or location [20]. A crucial consideration for YAMs is possessing a driver's license, which demonstrates that they have undergone training and testing, resulting in the learning of vital skills for preventing and minimizing crash severity [21].

The hypothetical cause of an incident can lead to varying degrees of severity. For instance, using excessive speed directly impacts the force of a collision, consequently increasing the chances of fatality. The differences between urban and rural roads in terms of traffic conditions may influence drivers to drive at higher speeds. While rural roads have less traffic, drivers are more likely to drive faster on urban roads [22]. Another significant factor is suddenly cutting in front of other vehicles. In cases where vehicles are of the same type, the impact may be less severe, particularly on low-speed roads such as urban streets [23].

The physical characteristics of roads often influence driving performance, with crashes frequently occurring on straight roads, especially those outside cities. This can increase the likelihood of fatal motorcycle crashes [24]. Local roads tend to be of a lower standard than highways and may have damaged pavement, which can greatly affect smaller vehicles like motorcycles. This issue might also be connected to familiarity with the route [25]. Environmental factors can significantly impact driving, particularly for less experienced riders like YAMs. Variables, such as riding in the rain, can affect driving behavior. Most motorcyclists tend to drive slowly in the rain and may even stop, resuming their ride once the rain has stopped. As a result, the correlation with severity could be negative [6]. Driving in low visibility conditions, like in dust or fog, is often associated with driving in the rain due to a driver's hesitance to use high speeds [10]. Nighttime driving, which includes crashes with and without lights, can lead to higher severity. Clearer roads at night may encourage higher speeds, while low visibility can make it difficult to see warning signs or parked vehicles on the road shoulder, increasing the risk of severe crashes compared to daytime driving [15].

An in-depth analysis of the literature reveals various factors that have been identified as critical in influencing the severity of injuries sustained in motorcycle accidents. These factors span a wide spectrum, including driver-related characteristics, determinants related to the nature of the crash, attributes of the road infrastructure, and variables associated with the surrounding environment. While the existing body of research provides valuable insights, a significant research gap is evident. Most notably, previous investigations in this domain have predominantly concentrated on motorcycle accidents occurring on arterial routes and major highways. However, there is a clear lack of specific studies that employ a distinct analytical approach to differentiate the causal influences of accidents that transpire on local urban roadways from those that occur on rural roads. This distinction is particularly relevant because it is plausible that the outcomes of motorcycle accidents may significantly diverge within these two distinct contexts. The significant variations between these two road settings in terms of traffic density, road characteristics, and collision scenarios suggest the need for a dedicated investigation to comprehend and delineate the specific factors influencing accident severity in each context. The present research addresses this specific research gap by undertaking a comprehensive examination of motorcycle accidents on local urban roadways and rural roads, contributing to a more nuanced understanding of this critical road safety issue.

3. Method

3.1. Data

This study utilized crash data from Thailand from 2018 to 2020, gathered by the Ministry of Public Health's Department of Disaster Prevention and Mitigation. The data were collected through a network of road safety centers, which include local administrative organizations and public health officers at the district and provincial levels in certain instances. The recorded information encompasses characteristics of those involved in crashes (e.g., gender and age), the injury levels (death or serious injury, etc.), the causes of crashes (e.g., driving at excessive speeds, sudden cutting in front, etc.), and the types of roads where crashes took place (highway, local road, etc.).

3.2. Research Procedure

This study concentrated on motorcycle crashes involving young adults (under 30 years of age) and compared crashes on local roads in urban and rural areas (specified using the municipal area, which includes the central business district of each district and some densely populated sub-districts). The data analysis procedures are illustrated in Figure 3. The process began by filtering data from all road crash types down to local roads. Next, crashes involving motorcycles and riders under 30 years of age were selected. To separate urban and rural areas, a geospatial information system was employed to aid in selection based on the principle of location-based choices. In cases where crashes overlapped with municipalities (within a radius of 1 km), such incidents were classified as urban area crashes. The results of this identification are displayed in Figure 4.

Upon obtaining the data, it was converted into code by setting INJURY as 1 for a fatal motorcycle crash (including fatalities at the scene and after hospitalization) and 0 for other injuries (serious injuries and minor injuries) [26]. All other variables were coded as binary. For example, for gender, 1 represents male and 0 represents female. A description of the variables can be found in Table 2.

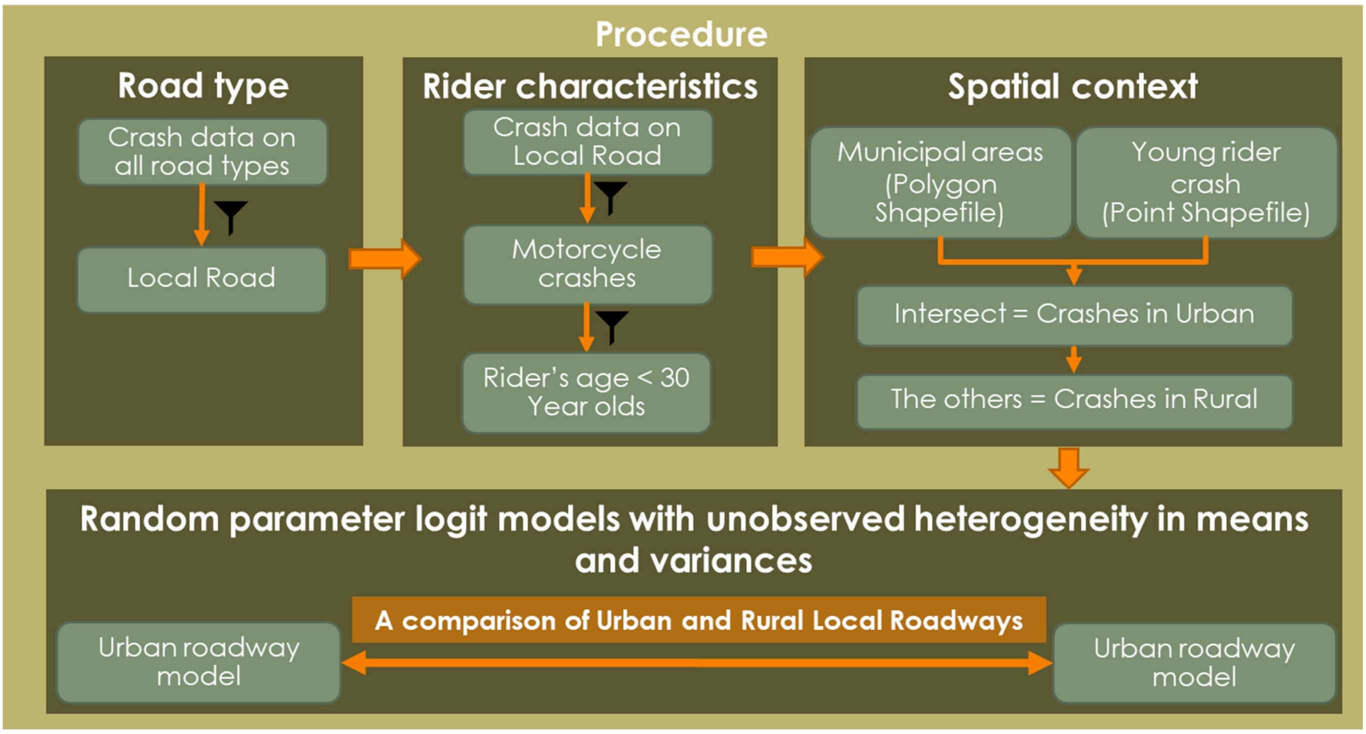
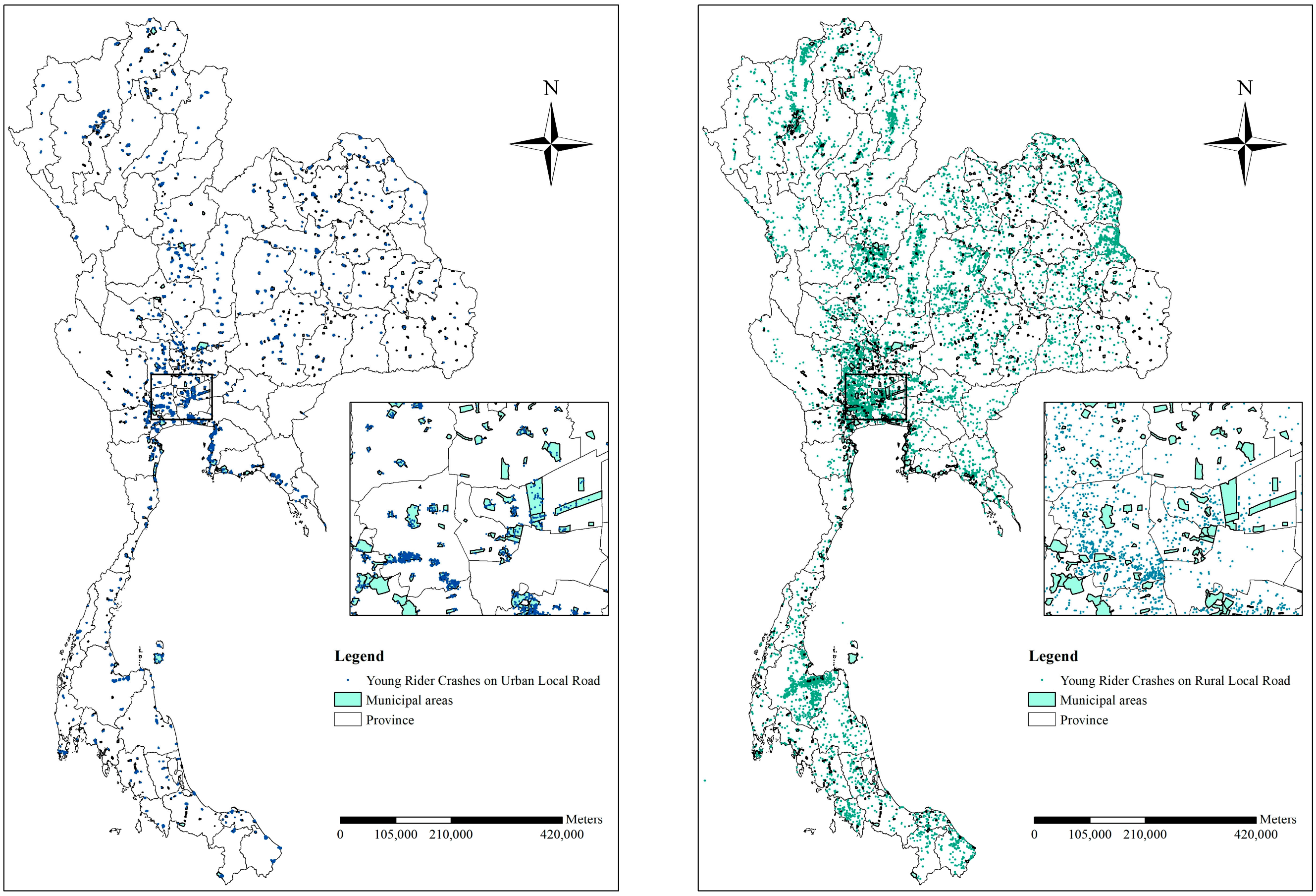


Figure 3. Research procedure. Y Indicates the data filtering.



(**a**) (**b**)

Figure 4. Crash Locations (**a**) young rider crashes on local urban roads, (**b**) young rider crashes on local rural roads.

Table 2. Variable description.

Variable	Description	Urban Roadways		Rural Roadways	
		Mean	**S.D.**	**Mean**	**S.D.**
INJURY	1 if fatal injury, 0 otherwise	0.170	0.376	0.126	0.331
GENDER	1 if male young adult motorcyclist (yam), 0 if female yam	0.716	0.451	0.720	0.449
FOREIGN	1 if foreigner, 0 if Thai	0.027	0.162	0.025	0.155
AT_FAULT	1 if is at-fault, 0 otherwise	0.752	0.432	0.796	0.403
LOCAL_ADDRESS	1 if local address same crash scenes, 0 otherwise	0.621	0.485	0.727	0.446
HELMET	1 if wearing helmet, 0 otherwise	0.502	0.500	0.412	0.492
DRUNK	1 if under influence of alcohol, 0 otherwise	0.094	0.292	0.133	0.339
UNLICENSE	1 if unlicensed rider, 0 license rider	0.045	0.207	0.049	0.215
EXCESS_SPEED_LIMIT	1 if exceeding the speed limit, 0 otherwise	0.266	0.442	0.242	0.428
VIOLATION	1 if involved traffic sign/signal/wrong direction violation, 0 otherwise	0.013	0.115	0.006	0.078
ILLEGAL_OVERTAKING	1 if illegal/improper overtaking, 0 otherwise	0.009	0.094	0.006	0.078
MOBILE_USE	1 if using mobile phone, 0 otherwise	0.003	0.050	0.006	0.077
ASLEEP	1 if fallen asleep/fatigue, 0 otherwise	0.002	0.048	0.003	0.059
CUTTING_FRONT	1 if hitting vehicles cutting in front; 0 otherwise	0.169	0.375	0.131	0.338
CURVE	1 if horizontal curve, 0 straight road	0.089	0.285	0.163	0.370

Table 2. *Cont.*

Variable	Description	Urban Roadways		Rural Roadways	
		Mean	**S.D.**	**Mean**	**S.D.**
ROUGH	1 if rough road surface, 0 good road surface	0.013	0.112	0.032	0.177
RAINING	1 if under rainy weather, 0 otherwise	0.028	0.164	0.031	0.174
SMOKE_DUST_FOG	1 if under dust/foggy weather, 0 otherwise	0.018	0.135	0.034	0.182
WET	1 if wet road surface, 0 otherwise	0.037	0.190	0.037	0.189
AFTERNOON	1 if 12:01 a.m.–4:00 p.m., 0 otherwise	0.223	0.416	0.254	0.435
MORNING	1 if 8:01 a.m.–12:00 a.m., 0 otherwise	0.129	0.335	0.147	0.354
NIGHT_LIGHT	1 if nighttime and lit road, 0 otherwise	0.313	0.464	0.174	0.379
DARK	1 if nighttime and unlit road, 0 otherwise	0.130	0.336	0.225	0.417

Note: The frequency of motor vehicle accidents involving young riders, stratified by roadway type, demonstrates a pronounced contrast between urban and rural environments. Specifically, the data reveals that there were 5950 reported instances of young rider crashes on urban roadways and 11,863 reported instances on rural roadways. Moreover, when examining the temporal dynamics of these incidents, it is apparent that the annual frequency of such accidents experienced fluctuations over the course of three consecutive years. In 2018, there were 7537 reported accidents involving young riders, which decreased to 6169 in 2019 and further decreased to 4053 in 2020. It is worth noting that the 2020 dataset encompasses the influence of the COVID-19 lockdown measures, which may have contributed to the observed decline in accident rates.

3.3. Parameter Estimation

To investigate the factors affecting the severity of injuries in YAM motorcycle crashes, this study utilized the random parameter logit model with heterogeneity in means and variances. This model allows for multiple levels of unobserved heterogeneity by enabling the coefficients of the parameters to vary across each crash and interactions between the crash-level factors and the unobserved characteristics (i.e., the distribution of random parameters). Unlike the standard logit model, this approach takes into account the varying effects of unobserved factors on injury severity in different crashes. The modeling process began by defining a function that determines the severity of injury in YAM motorcycle crashes, as follows [27]:

$$S_{jm} = \beta_j X_{jm} + \varepsilon_{jm}, \tag{1}$$

where S_{jm} denotes severity function of YAM sustaining injury severity j-level in motorcycle crash m, β_j denotes vectors of estimable parameters, X_{jm} represents vectors of various crash-level factors that affect the injury severity of the motorcyclist (e.g., wearing a helmet, exceeding speed limit, crashing on an unlit road, etc.), and ε_{jm} represents an error term. The probability function of the YAM crash m sustaining injury severity j in the random parameter estimation, can be written as [28]:

$$P_m(j) = \int \frac{EXP(\beta_j\, X_{jm})}{\sum_{\forall j} EXP(\beta_j\, X_{jm})} f(\beta|\rho) d\beta, \tag{2}$$

where $P_m(j)$ is the probability of a YAM crash m sustaining the injury severity j. $f(\beta|\rho)$ represents the density function of β, and ρ denotes a vector of parameters describing the density function (mean and variance), and all other terms are previously defined. To allow for heterogeneity in means and variances, let β_{jm} be a vector of estimable parameters that vary across crash, which can be written as [28]:

$$\beta_{jm} = \beta_j + \Theta_{jm} Z_{jm} + \sigma_{jm} EXP(\omega_{jm} W_{jm}) \nu_{jm}, \tag{3}$$

where β_j denotes the mean of the random parameter vector, Z_{jm} is a vector of explanatory variables capturing heterogeneity in the mean β_j, Θ_{jm} represents a vector of corresponding estimable parameters, W_{jm} represents vector of explanatory variables capturing heterogeneity in the standard deviation σ_{jm}, and ν_{jm} is the disturbance term [29]. The models were run using Nlogit 6 and a random draw of Halton = 1000, which is considered reasonable and consistent with empirical data, according to previous studies [11]. The selection of the best model was based on how closely it approximated the empirical data, using the ρ^2 value as follows [18]:

$$\rho^2 = 1 - \frac{LL(\beta)}{LL(0)} \tag{4}$$

where $LL(\beta)$ represents the log-likelihood of the model at convergence after estimating its parameters, while $LL(0)$ is the log-likelihood of the model with only a constant parameter estimated [30]. The selection of the appropriate value of ρ^2 does not have a fixed value, but a value greater than 0.1 is generally considered acceptable for the road crash model, according to previous studies [17]. Moreover, the average Marginal Effect (ME) was utilized to assess the impact of factors on crash severity. This value represents how modifying a single variable (such as changing from male to female) would affect the probability of a YAM motorcycle crash resulting in death on local roads [28].

3.4. Different Road Context Test

Typically, studies on crash injury severity use two types of likelihood ratio tests to assess instability or differences between sub-models. Namely, a global test that includes all sub-models and a pairwise comparison of sub-models [31]. For the global test, the likelihood ratio test can be written as follows:

$$\chi^2 = -2[LL(\beta_{Urban\ and\ Rural}) - LL(\beta_{Urban}) - LL(\beta_{Rural})] \tag{5}$$

where $\beta_{Urban\ and\ Rural}$ represents the log-likelihood at the convergence of the model that utilized all of the available data (in this study, this includes motorcycle crashes on local roads involving riders under 30 years old, but on different road types: Urban refers to urban local roads, and Rural refers to rural local roads). β_{Urban} is the log-likelihood at the convergence of the model using crash data from urban roadways, while β_{Rural} is the log-likelihood at the convergence of the model using crash data from rural roadways. The degree of freedom (df) represents the number of estimated parameters in each model. The null hypothesis states that parameter estimates from both models are transferable or identical, implying that there is no need to separate the models. As shown in Table 3, the analysis results indicated that χ^2 = 131.87 and df = 18 produce a 99.99% confidence level with a p-value less than 0.01 to reject the null hypothesis. This demonstrates that crash data from local urban roads and local rural roads should be analyzed in separate models [32]. Furthermore, the study also conducts a pairwise test to directly compare parameter estimates between urban and rural models, which can be defined using the following equation [28]:

$$\chi^2 = -2[LL(\beta_{m2m1}) - LL(\beta_{m1})] \tag{6}$$

where $LL(\beta_{m2m1})$ is the log-likelihood at the convergence of the model that used the converged and statistically significant parameters estimated from the m_2 model to analyze dataset of m_1. $LL(\beta_{m1})$ is the log-likelihood at the convergence of the model using the same m_1 subgroup of data with the same variables as is the case for $LL(\beta_{m2m1})$ but their parameters (regardless of their statistical significance) are no longer restricted to the converged parameters of subgroup m_2 [17]. Table 4 shows the results of the pairwise test between urban and rural models. Specifically, using equation m_1 = rural and m_{21} = urban, the test yields a 99% confidence level with a p-value of < 0.01 to reject the null hypothesis. Although the reverse of this test (i.e., m_1 = urban and m_{21} = rural) produces a relatively lower confidence level (70%), the findings from the pairwise test still provide strong evidence with a high confidence level to dismiss the null hypothesis that the effects of parameter estimates from both urban and rural models are transferable.

Table 3. Like hood ratio Test (Global Test).

	LL(B) Rural	LL(B) Urban	LL(B) Total	χ^2
	−4006.86425	−2431.00996	−6503.81093	131.87344
Degree of Freedom	19	15	16	18

Note: p-value < 0.000 (Level of Confident => 99.99%).

Table 4. Like hood ratio Test (Pairwise Test).

m_1 = Rural	m_{21} = Urban	χ^2	*Df*	*p*-Value	Level of Confident
−4006.86425	−4023.35934	32.99018	15	0.00470858	99.53%
m_1 = Urban	**m_{21} = Rural**	χ^2	***Df***	***p*-Value**	**Level of Confident**
−2431.00996	−2441.8613	21.70268	19	0.29930232	70.07%

4. Results

4.1. Descriptive Statistics

Table 2 displays the descriptive statistics of crashes on both urban and rural roads. In the preliminary analysis of the injury variable, crashes involving YAM drivers on urban roads showed a mortality rate of 17%, while those on rural roads accounted for 12.6% of fatal crashes. One of the notable differences was the higher number of night crashes on lit roads in urban areas (mean = 0.313), compared to the suburbs with a mean of only 0.174, suggesting that urban roads have more well-lit zones. In contrast, the dark variable, which represents crashes occurring in unlit areas, was more prevalent in rural areas. Regarding helmet usage, the rate was 50.2% in urban areas, while it was only 41.2% in rural areas.

4.2. Parameter Estimation Results

The results for parameter estimation are displayed in Table 5 for the urban crash model and Table 6 for the rural road model. Comparing the goodness of fit to the Fixed Parameter Logit model (FPL) and the Random Parameter Logit Model with Unobserved Heterogeneity in Means and Variances (RPLMV) for urban roads, the McFadden ρ^2 for FPL and RPLMV were 0.1013 and 0.1046, respectively. Meanwhile, for crash models on rural roads, the values were 0.1021 and 0.1063, respectively. The McFadden ρ^2 of RPLMV was greater for both models, indicating its better suitability.

The YAM crash model on urban roads revealed the following three random parameters: crashes involving foreign riders, those involving local drivers, and those resulting from exceeding the speed limit. Two pairs of variables with unobserved heterogeneity in means were FOREIGN: RAINING and EXCESS_SPEED_LIMIT: RAINING. For unobserved heterogeneity in variance, crashes on wet roads increased the variance of two variables, LOCAL_ADDRESS and EXCESS_SPEED_LIMIT. The predominant fixed parameter, UNLICENSE, had a positive direction, indicating that unlicensed YAMs had a higher chance of experiencing crashes resulting in fatality.

The YAM crash model on rural roads identified three random parameters: crashes on curves, crashes during rainy weather, and crashes occurring in the daytime. Unobserved heterogeneity in means comprised four pairs: RAINING: HELMET; RAINING: NIGHT_LIGHT; MORNING: ILLEGAL_OVERTAKING; and MORNING: NIGHT_LIGHT. Unobserved heterogeneity in variances consisted of two pairs, and traffic violations affected the variance of CURVE and MORNING. The predominant fixed parameter, EXCESS_SPEED_LIMIT, was positively significant, suggesting that when YAM crashes occur due to exceeding the speed limit, the chance of a fatal crash increases.

Table 5. Model result of urban roadways.

Variable	Urban Roadway				Distribution of Random Parameter
	FPL		RPLMV		
	Coefficient	**t-Stat**	**Coefficient**	**t-Stat**	
Constant	−3.523 **	−11.26	−2.945 **	−11.27	
GENDER	0.603 **	6.49	0.518 **	7.06	
AT_FAULT	−0.302 **	−3.71	−0.268 **	−4.09	
HELMET	−0.138 *	−1.80	−0.075	−1.24	
DRUNK	−0.617 **	−4.57	−0.578 **	−5.34	
UNLICENSE	1.621 **	5.69	1.554 **	6.55	
VIOLATION	0.410	1.43	0.378	1.61	
ILLEGAL_OVERTAKING	0.063	0.17	0.064	0.21	
MOBILE_USE	−0.758	−0.72	−0.686	−0.83	
ASLEEP	0.043	0.06	0.023 **	0.04	
CUTTING_FRONT	−0.787 **	−6.32	−0.737 **	−7.18	
CURVE	0.157	1.28	0.128	1.29	
ROUGH	−0.309	−0.75	−0.325	−0.94	
SMOKE_DUST_FOG	−1.160 **	−3.06	−1.027 **	−3.51	
AFTERNOON	−0.614 **	−5.12	−0.553 **	−5.77	
MORNING	−0.512 **	−3.67	−0.441 **	−4.05	
NIGHT_LIGHT	0.179 *	1.82	0.156 **	2.00	
DARK	0.454 **	3.83	0.393 **	4.14	
FOREIGN	0.421 **	2.05	−0.356	−1.27	
S.D. of FOREIGN			2.726 **	6.31	55.2% Below Zero
LOCAL_ADDRESS	0.015	0.19	−0.245 **	−3.80	
S.D. of LOCAL_ADDRESS			1.215 **	19.42	58.0% Below zero
EXCESS_SPEED_LIMIT	1.078 **	13.94	0.690 **	10.44	
S.D. of EXCESS_SPEED_LIMIT			1.493 **	16.89	32.1% Below zero
Unobserved Heterogeneity in means					
FOREIGN: RAINING			1.672 **	1.99	
EXCESS_SPEED_LIMIT: RAINING			−1.124 *	−1.92	
Unobserved Heterogeneity in variances					
LOCAL_ADDRESS: WET			−3.175 **	−14.32	
EXCESS_SPEED_LIMIT: WET			−1.925 **	−4.97	
Model statics					
LL(β)	−2439.899		−2431.010		
LL(0)	−2714.900		−2714.900		
McFadden ρ^2	0.1013		0.1046		

Table 5. *Cont.*

Variable	Urban Roadway				Distribution of Random Parameter
	FPL		RPLMV		
	Coefficient	t-Stat	Coefficient	t-Stat	
Model comparison via Likelihood Ratio Test					
Degree of Freedom			7		
$\chi^2 = -2(LL(\beta)_{\text{model A}} - LL(\beta)_{\text{model B}})$			17.778		
Confidence level			98.7%		
Superior model			RPLMV		

Note: FPL denotes the fixed parameter logit model, RPLMV denotes the random parameter logit model with unobserved heterogeneity in means and variances. LL(0) denote Log-likelihood at convergence model, LL(β) log-likelihood of the model with parameter estimation. ** *p*-value < 0.05, * *p*-value < 0.1.

Table 6. Model result of rural roadways.

Variable	Urban Roadway				Distribution of Random Parameter
	FPL		RPLMV		
	Coefficient	t-Stat	Coefficient	t-Stat	
Constant	−3.173 **	−15.01	−2.294 **	−15.09	
GENDER	0.592 **	7.76	0.457 **	8.07	
FOREIGN	0.175	0.98	0.147	1.11	
AT_FAULT	−0.457 **	−6.76	−0.361 **	−7.21	
LOCAL_ADDRESS	−0.263 **	−4.12	−0.191 **	−4.04	
DRUNK	−0.577 **	−5.81	−0.413 **	−5.70	
UNLICENSE	1.069 **	5.81	0.788 **	5.87	
EXCESS_SPEED_LIMIT	1.307 **	21.91	0.985 **	22.37	
MOBILE_USE	−1.300 *	−1.80	−0.935 *	−1.77	
ASLEEP	−0.330	−0.61	−0.294	−0.77	
CUTTING_FRONT	−0.475 **	−4.60	−0.381 **	−4.98	
ROUGH	−0.366 *	−1.88	−0.278 *	−1.91	
SMOKE_DUST_FOG	−0.430 **	−2.45	−0.324 **	−2.56	
WET	0.003	0.01	0.035	0.18	
AFTERNOON	−0.384 **	−4.81	−0.290 **	−4.92	
DARK	0.389 **	5.41	0.277 **	5.19	
CURVE	0.077	0.99	−0.255 **	−3.00	
S.D. of CURVE			1.236 **	13.90	58.2% Below Zero
RAINING	−0.264	−0.90	−3.004 **	−4.72	
S.D. of RAINING			4.189 **	7.01	76.3% Below Zero
MORNING	−0.349 **	−3.65	−0.812 **	−6.77	
S.D. of MORNING			1.553 **	13.35	70.0% Below Zero

Table 6. *Cont.*

Variable	Urban Roadway				Distribution of Random Parameter
	FPL		RPLMV		
	Coefficient	t-Stat	Coefficient	t-Stat	
Unobserved heterogeneity in means					
RAINING: HELMET			1.105 **	2.57	
RAINING: NIGHT_LIGHT			−1.294 **	−1.98	
MORNING: ILLEGAL_OVERTAKING			1.170 **	1.96	
MORNING: NIGHT_LIGHT			1.592 **	2.31	
Unobserved heterogeneity in variances					
CURVE: VIOLATION			0.914 *	1.7	
MORNING: VIOLATION			−35.802 **	−79.83	
Model statics					
LL(β)	−4025.653		−4006.864		
LL(0)	−4483.470		−4483.470		
McFadden ρ^2	0.1021		0.1063		
Model comparison via likelihood ratio test					
Degrees of Freedom			9		
$\chi^2 = -2(LL(\beta)_{\text{model A}} - LL(\beta)_{\text{model B}})$			37.578		
Confidence level			99.99%		
Superior model			RPLMV		

Note: FPL denotes fixed parameter logit model, RPLMV denotes the random parameter logit model with unobserved heterogeneity in means and variances. LL (0) denotes the Log-likelihood of the convergence model, LL(β) log-likelihood of the model with parameter estimation. ** *p*-value < 0.05, * *p*-value < 0.1.

5. Discussion

Table 7 and Figure 5 display the Marginal Effect (ME) used to compare the severity of crashes involving Young Adult Motorcyclists (YAM) on urban and rural local roads.

Table 7. Marginal effects.

	Urban Roadway				Rural Roadway			
Variable	Effect	t-Stat	95% CI		Effect	t-Stat	95% CI	
GENDER	0.0708	7.66	0.0527	0.0889	0.0558	8.74	0.0433	0.0684
FOREIGN								
AT_FAULT	−0.0405	3.98	−0.0605	−0.0205	−0.0499	6.86	−0.0641	−0.0356
LOCAL_ADDRESS	**−0.0362**	3.78	−0.0550	−0.0174	−0.0254	3.94	−0.0381	−0.0128
HELMET								
DRUNK	−0.0740	6.20	−0.0974	−0.0506	−0.0491	6.30	−0.0644	−0.0338
UNLICENSE	0.1475	11.8	0.1230	0.1720	0.0823	7.56	0.0610	0.1037
EXCESS_SPEED_LIMIT	**0.1100**	9.77	0.0879	0.1321	0.1486	20.52	0.1344	0.1627
VIOLATION								
ILLEGAL_OVERTAKING								
MOBILE_USE					−0.0914	2.52	−0.1626	−0.0202
ASLEEP								

Table 7. *Cont.*

	Urban Roadway				Rural Roadway			
Variable	**Effect**	**t-Stat**	**95% CI**		**Effect**	**t-Stat**	**95% CI**	
CUTTING_FRONT	−0.0933	8.67	−0.1143	−0.0722	−0.0456	5.49	−0.0618	−0.0293
CURVE					**−0.0315**	3.20	−0.0508	−0.0122
ROUGH					−0.0335	2.08	−0.0650	−0.0019
RAINING					**−0.1626**	20.45	−0.1782	−0.1470
SMOKE_DUST_FOG	−0.1120	5.05	−0.1555	−0.0685	−0.0385	2.82	−0.0653	−0.0117
WET								
AFTERNOON	−0.0739	6.41	−0.0965	−0.0513	−0.0362	5.14	−0.0500	−0.0224
MORNING	−0.0587	4.49	−0.0843	−0.0331	**−0.0883**	8.67	−0.1083	−0.0684
NIGHT_LIGHT	0.0231	1.97	0.0001	0.0460				
DARK	0.0617	3.87	0.0305	0.0930	0.0376	5.00	0.0229	0.0524

Note: Bold text denotes the random parameter.

Gender analysis of YAMs revealed that males were more likely to die than females in both road areas, a finding consistent with numerous studies. Yan et al. [11] argued that males exhibited more aggressive driving behaviors than females, especially among YAMs. Considering the ME loadings, the urban roads showed higher values. Male YAMs were more likely to die in urban crashes than in rural crashes (ME Urban = 0.0708 (t-stat = 7.66), ME Rural = 0.0558 (t-stat = 8.74)). In the present study, we present a demographic analysis of driver's licenses categorized by gender as of 31 May 2020. The driver's licenses under scrutiny encompass three distinct categories for motorcycle operation, motorcycle (temporary), motorcycle (five years), and motorcycle (life). The data reveals that the male population possesses a total of 8,691,794 licenses, while the female population holds 4,547,454 licenses within the specified categories [33]. The variable representing crashes with foreign drivers was not significant in either model, though it emerged as a random parameter (Figure 6a). YAM crashes with at-fault riders were less likely to result in fatalities (ME Urban = −0.0405 (t-stat = 3.98), ME Rural = −0.0499 (t-stat = 6.86)). At-fault riders in this context also refer to single crashes, which typically do not involve different-sized vehicles, leading to a lower chance of death. Wang [20] confirmed this effect, finding that motorcycle crashes with other vehicle types caused more fatalities than single crashes. Supplementary data pertaining to the aggregate count of registered vehicles in Thailand as of 31 December 2022, elucidate that the distribution of these vehicles consists of 22,137,636 motorcycles, accounting for 52.66% of the total, followed by 11,334,873 passenger cars designed to accommodate no more than seven passengers, representing 26.99% of the total, and 7,085,910 personal cars, constituting 16.86% of the overall vehicular population [34]. Local drivers were less likely to die in both urban and rural road crashes (ME Urban = −0.0362, ME Rural = −0.0254). It is clear that familiarity with routes allows for caution at dangerous points and an understanding of local behaviors [35]. LOCAL_ADDRESS emerged as a random parameter (Figure 6b) (55.2% below zero), indicating a 44.8% chance that local people had a higher probability of death. This variable exhibited unobserved heterogeneity in variances, specifically LOCAL_ADDRESS: WET. The parameter value was negative, suggesting that wet road surfaces can reduce the crash variance for local YAMs.

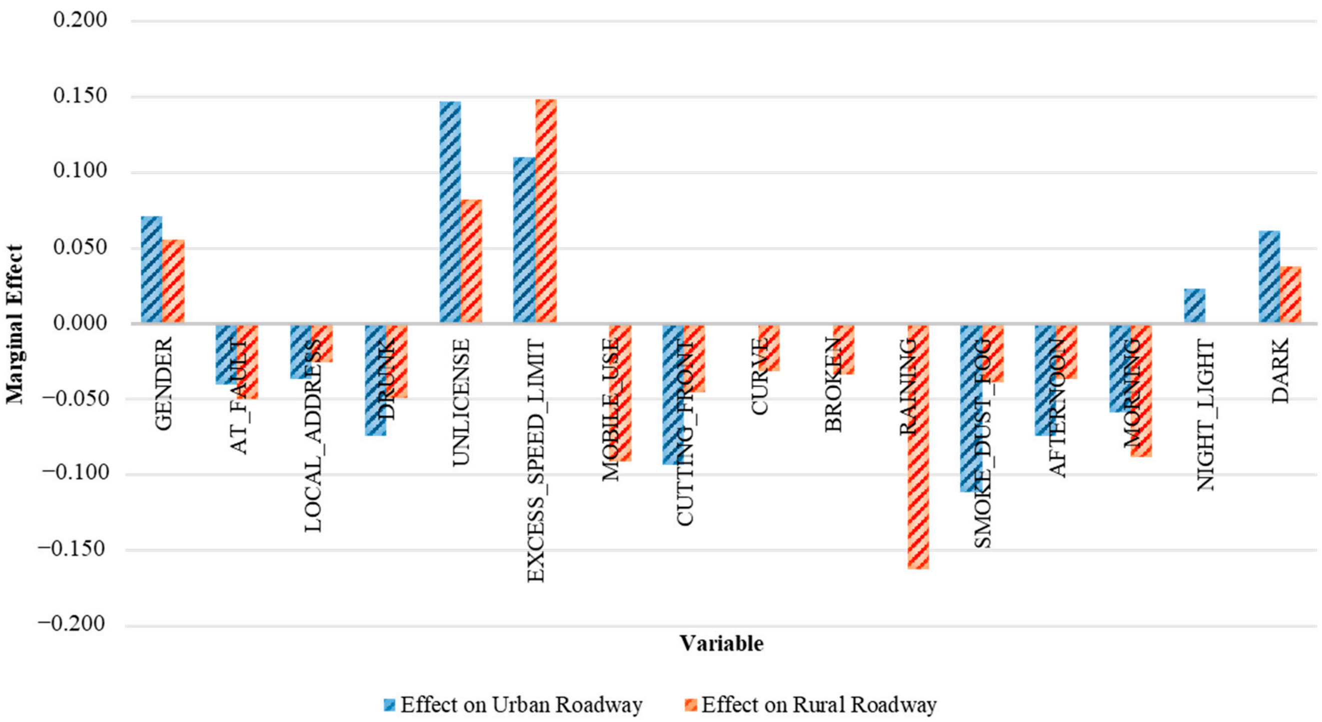


Figure 5. Marginal Effects.

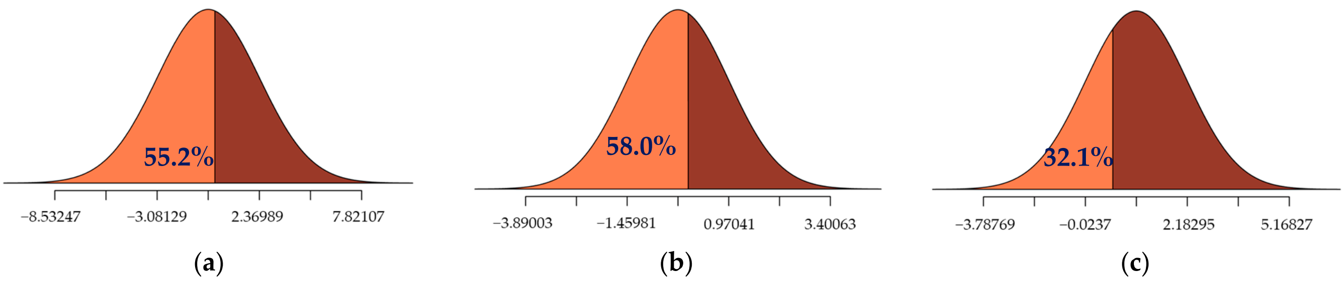


Figure 6. Distribution of random parameters in the urban roadway model. (**a**) FOREIGN; (**b**) LOCAL_ADDRESS; and (**c**) EXCESS_SPEED_LIMIT.

Wearing a helmet was not significant in the model, which is intriguing given the findings of previous research. In most cases, wearing a helmet reduces the chances of death for motorcyclists [36]. The insignificance of helmet-wearing could be interpreted as not significantly reducing the likelihood of death in YAM crashes. One possible reason is that many YAMs use half helmets, which have a higher chance of resulting in death compared to full helmets. Ijaz et al. [5] found that the use of a standard helmet was significantly more effective in reducing the likelihood of death. YAMs who crashed while drunk had a lower chance of death, which is not entirely consistent with Lin et al. [15], who found that drunk driving is a significant risk factor for severe motorcycle crash injuries in university neighborhoods. However, similar to Se et al. [6], the reason may be that, even though the YAMs rode fast while drunk, their physical strength resulted in injuries but not death. In urban areas, the parameters were more negative than on rural roads, indicating a lower chance of death, which could be due to the greater density of rescue points, allowing for quicker access to victims. Unlicensed YAMs had a higher probability of death (ME Urban = 0.1475 (t-stat = 11.8), ME Rural = 0.0823 (t-stat = 7.56)), with crashes in urban areas almost twice as likely to be fatal as those in rural areas. Similar to Chang and Yeh [37], this may be attributed to the greater variety of cars on urban roads compared to rural roads, leading to crashes with larger vehicles and a lack of skills to avoid crashes, ultimately resulting in more severe crashes.

Several key factors contribute to crashes. One significant cause is crashes resulting from exceeding the speed limit in both urban and rural areas, which leads to a higher likelihood of fatal outcomes. The crash model reveals a higher ME value for rural roads (ME Urban = 0.1100 (t-stat = 9.77), ME Rural = 0.1486 (t-stat = 20.52)), indicating that if a crash involving a YAM occurs due to speeding, it is more likely to be fatal in rural settings. This may be attributed to fewer vehicles on rural roads, encouraging drivers to drive faster, and weaker or virtually nonexistent speed law enforcement, which increases young adult males' confidence in their speed use [38]. Regarding the crash model for urban roads, EXCESS_SPEED_LIMIT is identified as a random parameter, implying that speeding accounts for approximately 32.1% of non-fatal crashes, as shown in Figure 6c. Unobserved heterogeneity in the mean reveals a negative parameter for RAINING, which suggests that crashes occurring during rainy weather lower the mean of EXCESS_SPEED_LIMIT. In other words, while a YAM crash may be caused by exceeding the speed limit, the likelihood of fatality decreases if the crash happens when it is raining. Similarly, the unobserved heterogeneity in variance shows that crashes on wet road surfaces reduce the variance of the scale of random parameter EXCESS_SPEED_LIMIT. Other factors, such as traffic signal violations and illegal overtaking, are not significant in the model. Mobile phone use while driving is only significant in rural road models. The sudden cut in front is significant in both models (ME Urban = −0.0933 (t-stat = 8.67), ME Rural = −0.0456 (t-stat = 5.49)), resulting in a lower chance of fatality.

The road factor was only significant in the rural crash model. Crashes occurring on curved roads or roads with damaged surfaces were found to have a lower likelihood of resulting in fatalities. A plausible explanation for this is that YAMs tend to adjust their driving behavior, slowing down when approaching curves or damaged road surfaces. However, the curve variable was identified as a random parameter in Figure 7a (58.2% below zero), suggesting that around 40.8% of crashes on curved roads lead to high fatality rates. This type of crash may be the result of a group of individuals driving at such high speeds that they cannot reduce their speed in time. The variable exhibits unobserved heterogeneity in variance, CURVE: VIOLATION, which indicates that traffic sign violations increase the variance of the random parameter of CURVE.

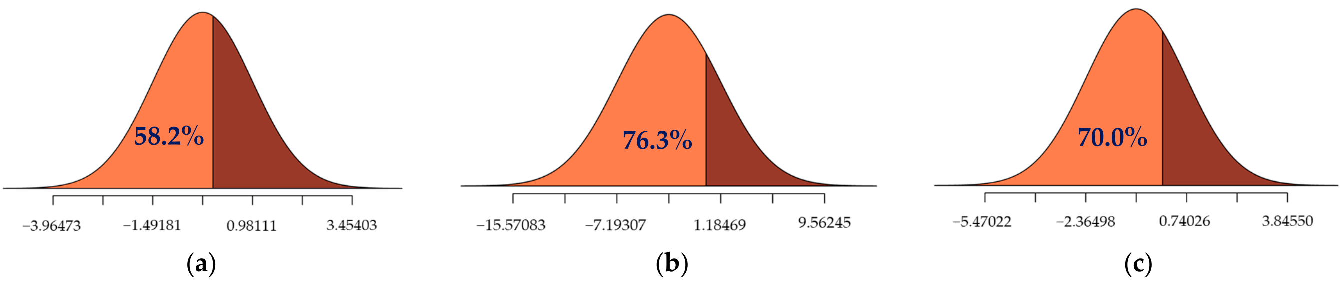


Figure 7. Distribution of random parameters in the rural roadway model. (**a**) CURVE; (**b**) RAINING; and (**c**) MORNING.

Crashes during rainy weather are only significant on rural roads and were identified as a random parameter, with a mean ME of −0.1626, suggesting that such crashes result in fewer fatalities. The distribution is 76.3% below zero (Figure 7b). This finding is reasonable since motorcycles often cannot continue driving in rainy conditions. Se et al. [39] also noted another behavior increased cautiousness and slower driving in rain. Although the risk of a crash may be higher in wet conditions, the severity tends to be lower compared to driving in dry conditions. Unobserved heterogeneity in the means of this variable includes: (1) RAINING: HELMET, a positive parameter that indicates an increased mean value, and (2) RAINING: NIGHT_LIGHT, a negative parameter that signifies a decreased mean value.

SMOKE_DUST_FOG were significant in both models, with the potential to reduce fatality rates, while wet crashes were not significant in either model.

The crash time variable, which was found to be significant during both morning and afternoon in both models for crashes occurring in the same direction, is associated with a lower likelihood of fatalities. This suggests that driving in sufficient light reduces the severity of crashes. A possible reason is that YAMs can see more clearly and reduce their speed before a crash occurs. However, the MORNING variable for rural crashes was identified as a random parameter with a distribution of 70.0% below zero, as shown in Figure 7c. In these cases, 30% of crashes have a high probability of fatality. As for the unobserved heterogeneity in the mean, MORNING: ILLEGAL_OVERTAKING showed a positive direction, indicating an increase in the mean, while MORNING: NIGHT_LIGHT implies that the likelihood of death decreases during daylight incidents.

Nighttime crashes and well-lit roads, which are significant only for the YAM crash model in urban areas, are likely to result in increased fatalities. It is evident that speed usage is higher at night. The DARK variable, which refers to operating motorcycles in unlit areas, is significant in both models (ME Urban = 0.0617 (t-stat = 3.87), ME Rural = 0.0376 (t-stat = 5.00)) and is highly likely to lead to fatal crashes. Comparing the ME values reveals that roads in urban areas have higher fatality risks, as these roads often have other types of vehicles that tend to travel at higher speeds at night. Additionally, reduced visibility can intensify crash severity [40].

6. Conclusions and Implementations

This study aimed to examine the factors influencing injury severity among Young Adult Motorcyclists (YAMs) by comparing crashes on local roads in urban and rural areas. The model development utilized data from motorcycle crashes throughout Thailand from 2018 to 2020. Geographic Information System (GIS) tools were employed to identify whether a crash took place on an urban or rural local roadway. The method employed was a Random Parameter Logit Model with Unobserved Heterogeneity in Means and Variances (RPLMV). The McFadden ρ^2 value fell within acceptable limits. This research contributes to the understanding of YAM-related crashes and offers policy recommendations that serve as guidelines for reducing injury severity among YAMs involved in local road crashes.

In summary, the analysis yielded several key findings. Firstly, both the urban and rural models exhibited parameter values that shared the same direction, indicating some level of consistency in their respective relationships with the variables under consideration. Nevertheless, notable distinctions emerged in terms of the Marginal Effects (ME), with certain variables demonstrating significance exclusively in one of the models. In the context of the urban local roadway model, variables associated with high marginal effects included instances where the rider did not possess a driver's license, occurrences of male drivers exceeding speed limits, accidents transpiring at night without adequate lighting, and accidents occurring at night with adequate lighting. These factors collectively contributed to an elevated likelihood of fatal outcomes for YAMs. Conversely, variables such as proximity to intersections, accidents transpiring in foggy or smoky conditions, and those transpiring during the afternoon and morning hours appeared to hold the potential to mitigate the severity of YAM fatalities in this urban context. Conversely, the rural local roadway model identified a distinct set of variables that exerted a pronounced influence on collision outcomes. This set of variables included male drivers, instances where the driver did not possess a valid driver's license, and accidents attributed to drivers exceeding legal speed limits. Conversely, accidents occurring during rain, around curves, those involving local riders, and those transpiring during the daytime and nighttime hours were associated with a reduced likelihood of YAM fatalities in the rural setting. In conclusion, the analysis underscores the nuanced dynamics at play within urban and suburban contexts, revealing variations in the significance and impact of specific variables on the severity of accidents involving young adult males. These findings provide valuable insights for crafting targeted safety measures and interventions in these distinct roadway environments.

Policy recommendations to reduce injury severity in YAM crashes were derived from notable marginal effect values. Exceeding the speed limit is the primary cause of YAM crashes, leading to a high likelihood of fatalities, particularly on rural roads. For rural roads, it is recommended to increase law enforcement measures. However, due to the extensive spatial areas, this may be challenging. As a result, it is advisable to initially focus on areas with high motorcycle crash density. Subsequently, CCTV cameras can be installed to monitor speed in these areas. Additionally, traffic engineering principles can be applied, such as installing speed warning signs and utilizing pavement on urban roads [41]. Despite the presence of stringent speed control measures, checkpoints at night should also be established in areas with high concentrations of motorcycle crashes.

Another issue identified in this study is the involvement of unlicensed YAMs in crashes, who were found to have a higher fatality risk. Parameter values revealed that urban local roads had higher fatality rates. It is suggested to increase traffic discipline checks by randomly setting up driver's license checkpoints, preferably in areas with a high YAM population, such as near universities. For rural roads, although less dangerous than urban roads, it is still important to educate people about the benefits of holding a driver's license. In addition to law enforcement, this can improve YAMs' riding skills and knowledge of traffic rules. Driver's license authorities could collaborate with schools in rural areas to offer training courses and license tests for students. Males were found to have a higher likelihood of fatalities than females, with similar marginal effect values for both urban and rural roads. One recommendation for both areas is to publicize crash statistics highlighting the increased risk for males among YAMs, raising awareness about crashes among men. Riding motorcycles at night on unlit roads was found to have a higher fatality rate, with urban roads posing a higher risk. Unlit areas with heavy motorcycle traffic should be identified, and road maintenance agencies should consider installing lighting. Additionally, regular inspections of pavement reflectivity are recommended. Road safety-related agencies, such as driver's licensing authorities, law enforcement agencies, road maintenance and lighting organizations, and road safety campaign groups, can use these suggestions to reduce YAM injuries. The transferability of our proposed models to other countries is a vital aspect of our research. Our study focuses on traffic patterns in Thailand, characterized by a prevalence of motorcycles, diverse vehicle types, varying speed limits, and varying levels of regulatory enforcement. However, it is important to note that these characteristics are not unique to Thailand and are shared by many countries with similar traffic dynamics. For example, nations such as Vietnam, Indonesia, and Malaysia exhibit traffic patterns that bear striking resemblance to Thailand's. In these countries, motorcycles play a dominant role in their transportation systems, and the road networks are often shared by a mix of vehicles, including automobiles, light trucks, and heavy-duty trucks. Speed limits in these countries typically range from 80 to 100 km per hour, and enforcement practices exhibit variations, with stricter measures in urban areas and more leniency in peripheral regions. While our recommendations have been tailored to the specific context of Thailand, they provide a strong foundational framework that can be adapted and customized for these comparable nations. Nevertheless, a preliminary similarity assessment is advised before implementing our proposed measures, as each country may possess unique nuances in their traffic infrastructure, regulations, and cultural considerations.

Additional recommendations for initiating a countermeasure, given budgetary constraints pertaining to the establishment of checkpoints or the installation of nighttime lighting, necessitate careful consideration. A hotspot characterization study or the identification of hazardous locations can provide a comprehensive assessment of the frequency of YAM collisions. This causal inference approach allows for a systematic examination of accident-prone areas and their accident concentration. By identifying and prioritizing these high-risk locations, limited resources can be allocated effectively to maximize safety improvements. This strategy ensures that corrective measures are deployed where they can have the most significant impact, contributing to a more targeted and efficient road safety initiative.

Helmet usage and its influence on accident severity are substantial focal points in this study. The detailed examination reveals that helmet use did not demonstrate statistically significant effects in both urban and rural settings. However, this outcome prompts the need for a more comprehensive inquiry. Notably, the apparent insignificance may be linked to factors such as the prevalence of substandard or half-face helmets, which provide only minimal reductions in the likelihood of fatalities and appear to have limited impact on overall injury severity. To address these concerns, it is essential to prioritize a thorough research agenda. Upcoming research initiatives should encompass extensive impact testing of the diverse helmet types available in Thailand, with the aim of ascertaining their efficacy in mitigating head injuries and diminishing injury severity. Furthermore, the exploration of the medical aspects surrounding this issue, including a thorough investigation into the force of impact and its repercussions on injury severity, particularly among drivers under the age of 30, is imperative. Pursuing these research directions will offer a deeper understanding of the intricate relationship between helmet quality and accident outcomes, ultimately contributing to the enhancement of safety measures and more effective strategies for injury prevention.

Author Contributions: Conceptualization, T.C.; methodology, T.C.; software, T.C. and V.R.; validation, C.S. and C.B.; formal analysis, T.C.; investigation, F.A. and S.J.; data curation, C.B.; writing—original draft preparation, T.C. and F.A.; writing—review, and editing, T.C. and C.S.; visualization, S.J.; supervision, V.R.; project administration, S.J.; funding acquisition, S.J. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by Suranaree University of Technology (SUT) [Grant number: full-time 61/05/2564].

Institutional Review Board Statement: This research was approved by the Ethics Committee for Research Involving Human Subjects, Rajamangala University of Technology Isan (HEC-01-65-078).

Informed Consent Statement: Not applicable.

Data Availability Statement: Data available on request due to restrictions, e.g., privacy or ethical.

Acknowledgments: The authors would like to thank Department of Disaster Prevention and Mitigation, Ministry of Interior for supporting the road traffic crash data.

Conflicts of Interest: The authors declare no conflict of interest.

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