

Article

Enhancing Road Safety Strategies through Applying Combined Treatments for Different Crash Severity

Mohammad Nour Al-Marafi ¹, Taqwa I. Alhadidi ^{2,*}, Mohammad Alhawamdeh ¹ and Ahmed Jaber ^{3,*}

¹ Civil Engineering Department, Tafila Technical University, Tafila 66110, Jordan; mohammad.almarafi@ttu.edu.jo (M.N.A.-M.); mohammad.h@ttu.edu.jo (M.A.)

² Civil Engineering Department, Al-Ahliyya Amman University, Amman 19328, Jordan

³ Department of Transport Technology and Economics, Faculty of Transportation Engineering and Vehicle Engineering, Budapest University of Technology and Economics, Műegyetem rkp. 3, H-1111 Budapest, Hungary

* Correspondence: t.alhadidi@ammanu.edu.jo (T.I.A.); ahjaber6@edu.bme.hu (A.J.)

Abstract: This research examines the utility of combined crash modification factors (CMFs) in minimizing crash severity at urban roundabouts. Conventional CMFs typically assess the influence of singular interventions on road safety. However, traffic dynamics and the interactions among multiple safety measures necessitate a more comprehensive strategy. This study introduces a novel methodology for developing integrated CMFs that accounts for the interactive effects of multiple safety measures, providing a comprehensive understanding of their collective impact on road safety. The investigation utilized data from 16 urban roundabouts in Amman, Jordan, from 2015 to 2021. Regression models have been employed to develop individual and combined CMFs for various geometric and traffic characteristics, such as entry and exit widths, speed limits, and weaving patterns. Key findings indicate that interventions, such as reducing speed limits, modifying entry and exit widths, and adjusting weaving lengths, significantly improve safety. The analysis identifies hazardous roundabouts and proposes effective single and combined treatments to mitigate crash risks. This study highlights the importance of considering multiple treatments simultaneously to improve the predictive accuracy of safety assessments and supports the development of more effective road safety strategies tailored to specific crash types and severities. The approach demonstrates a significant potential to enhance road safety analysis and decision-making, ultimately contributing to safer road environments.

Keywords: road safety; crash modification factors; combined treatments; geometric design



Citation: Al-Marafi, M.N.; Alhadidi, T.I.; Alhawamdeh, M.; Jaber, A. Enhancing Road Safety Strategies through Applying Combined Treatments for Different Crash Severity. *Urban Sci.* **2024**, *8*, 109. <https://doi.org/10.3390/urbansci8030109>

Academic Editor: Luis Hernández-Callejo

Received: 12 July 2024

Revised: 4 August 2024

Accepted: 7 August 2024

Published: 12 August 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Road traffic crashes are a global concern, requiring a deeper understanding of the contributing factors and the development of effective road safety strategies. Approximately 1.3 million people are killed and 20–50 million are seriously injured on the road annually [1]. World Health Organization (WHO) data show that about 90% of these casualties occur in middle and low-income countries. Approximately half of those fatalities are “vulnerable” road users—pedestrians, cyclists, motorcyclists, children, and the elderly [2]. Currently, road traffic injuries are the leading cause of death in people aged 5–29 years; they are projected to be the seventh leading cause of death by 2030 [1]. Road safety is therefore one of the most pressing global public health issues today. The international community has responded with the adoption of road safety targets for reducing the number of those killed and seriously injured on the road (KSI), as well as a variety of efforts to stabilize and reverse this “negative” trend. Thus, in March 2010, the General Assembly of the United Nations (UN) proclaimed the period 2011–2020 the *Decade of Action for Road Safety* [3].

Roundabout implementation has been identified as a successful strategy to increase traffic safety [4]. A decrease in total crashes and a significant reduction in crash severity have

been found to be associated with roundabouts design [5]. It has also been highlighted in the research of Novák et al. [6] that, while roundabouts are generally the type of intersection with the highest absolute safety, concerning comparative safety the entity might vary with different designs. Over the years, intensive research has been conducted to understand and evaluate the safety and performance of roundabouts. This has included the development of safety performance functions (SPFs) and crash modification factors (CMFs) for roundabouts, at entry, exit and circulating lanes [7,8].

In order to enhance road safety and contribute to the reduction of traffic crashes, significant efforts have been made towards understanding and implementing effective safety measures. CMFs arguably represent one of the most powerful tools for this objective, providing a quantitative estimate of the expected change in crash occurrences, as a result of safety interventions [9–12]. Traditionally, CMFs have been developed and employed to quantify the impact of (single) individual measures on road safety [7,9,11–18]. Nevertheless, road safety is a dynamic and complex concept, since the driving environment, traffic conditions, and influencing factors are all interlinked and cannot be imminently separated. Consequently, a different perspective is required; one that considers the interactions and combined effects of various measures. The use of regression models alone to establish CMFs may be challenging, as research has shown [19]; consequently, it is important to use multiple CMFs from different studies and methodologies to create more robust, reliable safety assessments [11]. Integrating CMFs from different sources permits multiple factors influencing crash outcomes to be considered, thereby contributing to a more comprehensive understanding of safety impacts [20].

The importance of considering different crash types when developing CMFs has been a recurring theme in the research of Shahdah et al. [21]. The analysis of distinctive crash scenarios, including truck-related, motorcycle, run-off-the-road, and non-intersection-related crashes, allows researchers to develop interventions that are tailored to address the unique challenges associated with each crash type [22]. Likewise, it is critical to differentiate between single-vehicle and multiple-vehicle crashes, as the contributing factors and subsequent mitigation strategies may be distinctly different [23].

In addition, the establishment of CMFs for specific road features and treatments (e.g., horizontal curves, intersections, signalized corridors) demonstrates that an “all or nothing” approach to safety assessment is not desirable [24–26]. Different treatments may have different degrees of safety effects in crash reduction; the adage “multiple CMFs” is intended to capture the concept that different treatments have varying safety implications [27]. Multiple Crash Modification Factors (CMFs) are essential in transportation safety research to ensure that the safety effectiveness of various safety treatments and interventions is appropriately evaluated. One of the key roles that CMFs serve is to make the benefits of safety comparable across different types of safety treatment and different roadway conditions [28].

As a response, this paper introduces the notion of combined CMFs, which are capable of capturing the interacting effects and the effects of the interaction among multiple safety interventions, thus offering a comprehensive view of road safety management. The significance of the application of this concept lies in the potential to provide a refined road safety analysis and decision-making processes. The principles for understanding how different safety measures interact and affect overall safety will enable policymakers and engineers to effectively prioritize and apply the more cost-effective or beneficial interventions. It is anticipated that the adoption of this concept will provide a methodological framework in which combined CMFs will be calculated, in such a way as to significantly enhance the accuracy of safety assessments and support the development of a safer road environment. The contribution of this paper is to evaluate the effectiveness of the combined CMFs on different crash severity. The paper continues previous work as it expands on the developed CMFs at different crash severity levels, to quantify the effectiveness of implementing the combined CMFs at these different levels.

The structure of this paper is as follows: in the next section a literature review on CMFs is presented, showing the evolution of their use and the reason for combined CMFs. The third section describes the methodology for developing and testing the combined CMFs. It includes data collection, statistical analysis, and model validation. The fourth and fifth sections present the results of the analysis, discuss their implications for road safety practice and policy, and offers directions for future work in this field.

2. Literature Review

Crash modification factors for roundabout development are key to advancing road safety. An effort has been made to explore this topic outside the present framework to provide more background on the safety performance of roundabouts, as well as the various components of the roundabout.

2.1. Safety Performance of Roundabouts

More focus was made on appearance practices to develop safety performance functions and CMFs for urban roundabouts, entry, exit, and circulating lanes, focusing on the entering annual average daily traffic (AADT) and the number of circulating lanes as a factor in the assessment of safety [7]. Chen also examined the impact of signalized intersections converted into roundabouts and found a diminishing safety benefit of roundabouts for total crash reduction as the traffic volume increases, developing the CMF to indicate the need to consider traffic volume impact on the safety benefit of roundabouts [29]. Moreover, Gbologah et al. found that converting stop-controlled and conventional intersections to three- and four-leg roundabouts reduced crash frequency, particularly injury/fatal crashes. These results highlight the importance of comparing roundabouts and traditional intersection design for their beneficial safety effects [30]. Furthermore, findings have indicated the relevance of developing conflict modification factors based on proactive safety diagnostic approaches, which is relevant in improving the safety at roundabouts by targeting the various types of crashes and the overall safety reduction [6,31].

2.2. Estimation of CMFs

The accuracy of CMFs depends on the link function of the variables. The studies concluded that, when developing CMFs using regression models, the link function is critical. It also concluded that, when variables have large nonlinear safety effects, traditional generalized linear models (GLMs) should be avoided when modeling crashes or developing CMFs [10,18,32,33]. In other words, in the traditional GLM with a linear link function, the model assumes a direct relationship between the response and predictor variables. On the other hand, using the log link function ensures that the model's outputs remain within the acceptable data range and distribution, which improves the interpretability and accuracy of the model's predictions. For Poisson and negative binomial distributions, the typical link function is the log link to ensure that the model's predictions remain continuous and positive. In a study by Park et al. [10], they compared five functions: linear, quadratic, inverse, exponential, and power functions, based on the R-squared value. The results showed that the exponential nonlinear model is the best-fitting function for the crash data. Generally, the exponential link in Poisson and negative binomial regression models can correctly describe how crash data is random, positive, and discrete [8,18].

2.3. Combined CMFs

Researchers focus on evaluating and improving methods to combine CMFs for multiple treatments on roadways, aiming to overcome overestimation and produce more reliable results. Park and Abdel-Aty [32] proposed a new method for combining CMFs, demonstrating better predictive performance compared to existing methods and developing an adjustment function using weighted regression models to account for different severity levels, road types, and negative safety effectiveness. In another study, Al-Marafi et al. [33] conducted analytical familiarity to assess combined CMFs for multiple treatments at high-

risk crossings in Queensland's Toowoomba regional city, using data from 106 intersections. The study employed sixteen variables, explored four forecasting combined CMF techniques, and applied the empirical Bayesian process to identify the critical intersections. The study recommended applying a combination of treatments to enhance safety in high-risk intersections, as the results demonstrated that applying multiple treatments yields higher safety benefits than single treatments.

In order to combine multiple CMFs to obtain accurate results, one should consider numerous studies that developed CMFs for a particular scenario. Hallmark et al. [34] used a full Bayes modeling methodology to develop CMFs for rural curves with dynamic speed feedback signs for total crashes and single-vehicle crashes. On the other hand, CMFs were developed for rural 2-lane highways considering two primary variables, horizontal curve radii and side friction demand, for various combinations of different geometric design criteria [35]. Other studies focused on the safety effects of signal conversion to develop CMFs for fatal and injury crashes and property damage-only crashes [36]. For example, Lee et al. developed CMFs for left-turn signal conversions for safety evaluation [37]. Researchers worked on one-way arterial CMFs for safety performance that could be used for prediction models [38]. Many similar studies above highlight the necessity of such factors in assessing safety measures and their crash reduction impacts. There is also a focus on the effects of widening shoulders on rural multi-lane roads and the use CMFs and CM-Functions for different approaches to assess safety [39]. Researchers discussed one more example of the use of weather-related crashes on freeways, emphasizing the factors that may vary significantly across various conditions and severities [40].

Among all of these studies, the effect of the combined crash modification factor on different crashes' severity was not studied before. This study bridges this gap by incorporating different methods to estimate the effect of implementing different modeling techniques.

3. Research Methodology

In this section, the research methodology is presented. It starts with the data collection description, followed by generating the CMF using the cross-sectional method. Subsequently, the different roundabouts were ranked using their average ranked rate.

As we mentioned earlier, we collected several variables to quantify the safety performance of the roundabouts. The developed research methodology is shown in Figure 1 below.

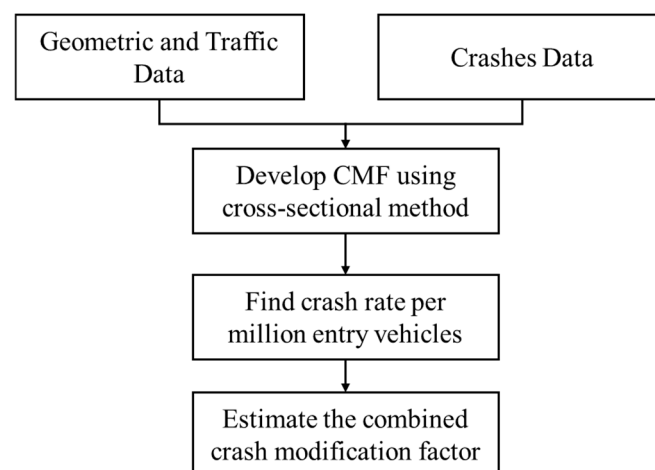


Figure 1. Research Methodology.

Figure 1 shows the developed research methodology. The research starts with collecting geometric and traffic data. We used our previous study results to show that a developed crash modification factor was developed using the crash frequency estimated models.

3.1. Data Collection

The data needed for this research mainly comprises 16 urban roundabouts. The collected variables contain crash, geometric, and traffic data. These roundabouts are located in Amman, the capital of Jordan. Out of the 16 roundabouts, 12 have four legs and 4 have five legs. The crash data were collected from 2015 until 2021 from the Jordanian Traffic Institute. The crash data covers the number of crashes, crash severity, type and number of vehicles involved, and the date and time of occurrence. Traffic volume count, speed, and geometric characteristics were collected from the Greater Amman Municipality (GAM). Figure 2 shows the geometric characteristics of the roundabouts.

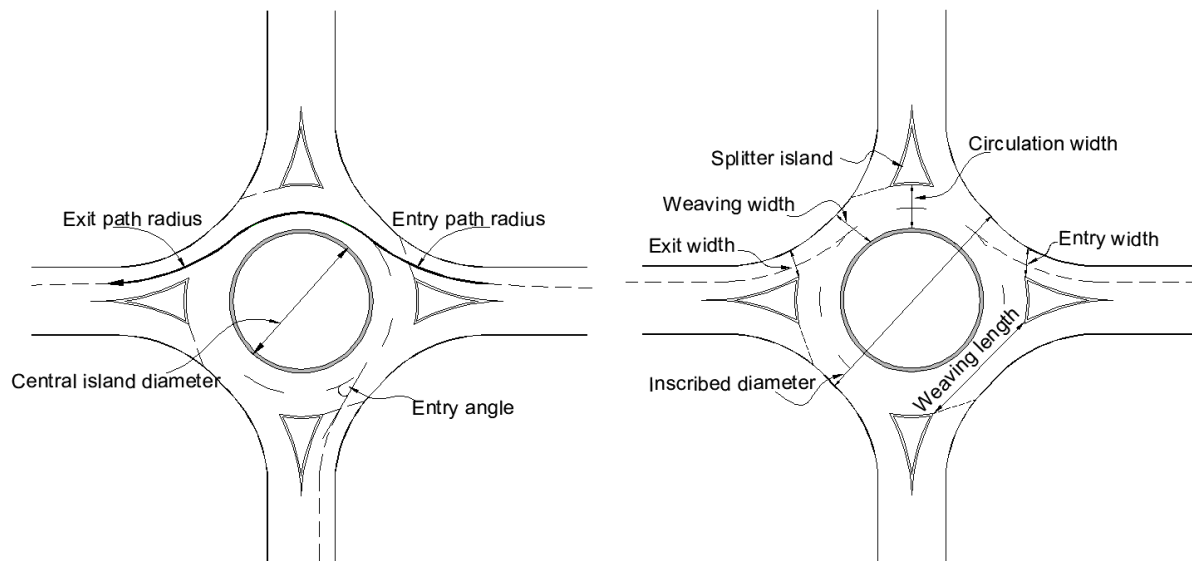


Figure 2. Roundabout geometric characteristics.

In Figure 2, various terms are introduced. Roundabout size is defined using the inscribed diameter. It measures the distance between the outer edges of the circulatory roadway. The entry width is the width of the entry approach, and the exit width is the width of the exit approach where it meets the inscribed circle. The entry and exit angles are the angles of deflection of vehicles entering and exiting the roundabout. Approach and departure width refer to the half of the roadway width that is approaching or departing the roundabout. The intersection approach is a road length of 20 m downstream of the roundabout yield sign. Table 1 shows the summary statistics of the collected data. The roundabouts considered in the present study have large variations in geometric and traffic characteristics. Hence, the relationship between crashes and variables of interest could be modeled with a good degree of accuracy.

Table 1. Statistical summary of the dataset.

Variable	Mean	St. Dev.	Minimum	Maximum	Variable Type
Total annual crashes	202.90	151.56	20.00	612.0	Count
Annual fatal and injury crashes	4.15	2.78	0.00	11.00	Count
Annual PDO crashes	198.75	149.59	19.00	603.00	Count
Number of approaches	4.40	0.68	4.00	6.00	Count
Entry width (m)	7.18	3.15	3.00	12.30	Count
Exit width (m)	8.66	3.99	4.80	16.00	Continuous
Inscribed diameter (m)	74.05	28.70	31.00	158.00	Continuous
Central diameter (m)	58.30	29.56	19.00	154.00	Continuous
Circulating width (m)	8.90	2.47	6.00	15.00	Continuous
Entry path radius (m)	69.50	26.37	28.00	140.00	Continuous

Table 1. Cont.

Variable	Mean	St. Dev.	Minimum	Maximum	Variable Type
Exit path radius (m)	75.00	27.43	35.00	145.00	Continuous
Entry angle (Degree)	28.90	5.53	18.00	38.00	Continuous
Splitter radius (m)	77.75	29.13	35.00	162.00	Continuous
Weaving width (m)	10.62	2.89	7.50	19.00	Continuous
Weaving length (m)	42.50	11.55	30.00	76.00	Continuous
Speed Limit (Km/h)	60.00	3.24	50.00	70.00	Continuous
Total entering volume in AADT	62,695.56	27,400.42	22,712.00	114,304.00	Continuous

PDO: Property Damage Only. AADT: Annual Average Daily Traffic.

3.2. Crash Prediction Model Development

Crash prediction models (CPMs) were developed mainly by using GLM with a log link function. In model building, the model type is chosen based on the response variable type. As we built a CPM to predict the number of crashes (count type), we used the common models, i.e., negative binomial (NB) and Poisson regression. As mentioned previously, these two types are more appropriate for analyzing crash data [9,18,33,41–43]. The general formula for the NB or Poisson model is presented in Equation (1).

$$y = \exp(b_0 + B_i X_i) + e \quad (1)$$

where y is the expected number of crashes, b_0 is the intercept that explains the minimum value of the expected number of crashes, B_i is the coefficient of the i th variable, X_i is the explanatory variable, and e is the error term, which explains the difference between the actual values and expected values. In a previous work, different CMFs for different roadway crash severity were developed.

3.3. Estimate Crash Rate

In order to assess the roundabouts' safety performance, we estimate the average crash rate and rearrange the roundabouts based on their crash risk. In this step, we estimate the crash risk index. Equation (2) was used to calculate the crash rate.

$$CR_i = \frac{N_i \times 10^6}{365 \times T \times Q_i} \quad (2)$$

where N_i represents the number of crashes observed during the study period, T is the duration of the study period in years, and Q_i is traffic volume in AADT.

3.4. Evaluate the Effectiveness of the Combined CMF

In this step, we calculate the effectiveness of implementing the different combined treatments using the developed CMF in step one. In essence, three different methods were implemented. The first step assumed the independence between treatments, the second one used the turner models where we used the multiplicative weighted factor, and the third approach was meta-analysis.

3.4.1. Assume Independence of Treatments

In this method, the different CMFs were assumed to be independent. This method was adopted by the Highway Safety Manual. In essence, when multiple CMFs are implemented, each treatment is independent. As such, the effect of the combined CMF can be calculated using Equation (3).

$$CMF_{combined, i} = CMF_{i1} \times CMF_{i2} \times \dots \times CMF_{ij} \quad (3)$$

where CMF_{ij} is the crash modification factor associated with treatment j ($j = 1, 2, 3, \dots, n$) at i th roundabout.

3.4.2. Multiply Weighted Factor (Turner Method)

In the Turner method, a specific weighted factor is applied, especially when we implement two or more treatments. The combined CMF is estimated using Turner's techniques, as shown in Equation (4).

$$CMF_{combined,i} = 1 - \left[\frac{2}{3} (1 - (CMF_{i1} \times CMF_{i2} \times \dots \times CMF_{ij})) \right] \quad (4)$$

3.4.3. Meta-Analysis Approach

In this approach the combined CMFs for the same countermeasure are estimated from several studies. In this method, the combined CMF is calculated using Equation (5). Another border when using the combined CMF are the results when we combined multiple CMFs for the same treatment, as shown in Equation (6).

$$CMF_{combined,i} = \frac{\sum_{j=1}^n CMF_{unbiased,r} / S_j^2}{\sum_{j=1}^n 1 / S_j^2} \quad (5)$$

$$S = \sqrt{\frac{1}{\sum_{j=1}^n 1 / S_u^2}} \quad (6)$$

where $CMF_{combined}$ is the combined unbiased CMF at i th roundabout, $CMF_{unbiased}$ is the unbiased CMF value for treatment j , n is the number of treatments to be combined, S is the standard error for the combined CMF, and S_u is the standard error of the unbiased CMF.

Previous studies [9,10,33] have compared and investigated these three methods based on the difference between the actual and predicted values of combined CMFs. The studies found that because the ratio of actual to predicted CMF values is closer to 1.0, these methods are appropriate for reasonably accurately evaluating the safety effects of combined treatments. In addition, the results showed that crash reductions achieved through combined road treatments are greater than those obtained with single treatments. To improve accuracy in this study, we adopted the average values for these three methods as an adjustment approach to estimate the effect of the proposed combined treatments.

4. Research Results

4.1. Model Development

In a previous study, the different CMFs were estimated using negative binomial estimation in Equation (1). This assumption was based on calculating and analyzing two values: Pearson's chi-square (χ^2) divided by the degrees of freedom and the deviance divided by degrees of freedom [33]. The negative binomial model assumption was considered valid because the sum of these two values falls within the range of 0.80 to 1.20. Generally, different models have different explanatory variables, and these variables were statistically significant at 90% confidence level. For all the developed models, the nonlinear model equation is presented in Table 2. The developed model for the total crashes indicated that the total number of crashes increases with an increase in the number of approaches, inscribed diameter, weaving width, and speed limit; on the other hand, as the exit width increases, the total number of crashes decreases. Entering width and entering AADT were significant in estimating the PDO and the fatal and injury crashes. The PDO model increases with the increasing number of approaches, entry width, speed limit and entering AADT, while PDO decreases with the increases in exit width, and central diameter. Fatal and injury prediction values increase with the increase in entry width, entry path radius, entry angle, and entering AADT, while fatal and injury prediction value decreases with the increase in circular width. The interaction effects among other explanatory variables were

also investigated, but there were no significant interactions for the different developed models. A summary of the total expected prediction crashes is presented in Table 2.

Table 2. CMF functions developed using data from previous study.

Design Feature	Crash Modification Functions			Standard Error (S.E.)		
	Total Crashes	PDO ¹	Severe Crashes ²	Total Crashes	PDO	Severe Crashes
Speed limit (SL)	$e^{0.047 \times [X_{11} - 60]}$	$e^{0.045 \times [X_{11} - 60]}$	-	0.005	0.009	-
Entry width (EnW)	-	$e^{0.100 \times [X_2 - 7]}$	$e^{0.048 \times [X_2 - 7]}$	-	0.015	0.069
Exit width (ExW)	$e^{-0.052 \times [X_3 - 8]}$	$e^{-0.041 \times [X_3 - 8]}$	-	0.009	0.008	-
Weaving width (WW)	$e^{0.078 \times [X_9 - 10]}$	-	-	0.010	-	-
Weaving length (WL)	-	-	$e^{0.014 \times [X_{10} - 30]}$	-	-	0.010
Entry angle (EnA)	-	-	$e^{0.038 \times [X_8 - 29]}$	-	-	0.017
Entry path radius (EnR)	-	-	$e^{0.010 \times [X_7 - 30]}$	-	-	0.009

¹ PDO, property damage only crashes. ² Severe crashes, including fatal and injury crashes.

4.2. Identifying Hazardous Intersections

The hazardous roundabouts were identified based on the crash rate (i.e., Crashes per Million Vehicles entering roundabouts), as shown in Table 3.

Table 3. Average crash rate per million vehicles at identified roundabouts.

Roundabout ID	Roundabout Coordinates		Crash per Million Vehicles			Average
	Latitude	Longitudinal	Total Crashes	PDO	Severe Crashes	
Rou.1	31°58'24.26" N	35°50'20.31" E	31.872	15.719	0.216	15.936
Rou.2	31°59'35.93" N	35°55'48.35" E	29.193	14.181	0.416	14.596
Rou.3	31°57'14.22" N	35°54'38.37" E	25.280	12.356	0.283	12.640
Rou.4	32°3'1.00" N	35°53'4.62" E	22.937	11.097	0.371	11.469
Rou.5	31°56'55.90" N	35°53'33.12" E	22.336	10.925	0.243	11.168

Table 3 shows the average crash rate for the five most critical roundabouts. Results indicated that roundabout 1 has the highest number of total crashes, the highest in terms of total traffic crashes, the highest in PDO crashes and the lowest in severe crashes. Conversely, roundabout 2 has the highest percentage of severe crash rates and the second-highest average crash rate. Roundabout 5 has the lowest average crash rate. Several CMFs can improve the computed CMF. The estimated CMF for implementing one single treatment is shown in Table 4.

Table 4. Estimated CMFs from a single appropriate treatment at identified roundabouts.

Crash Type	Type of Treatment	Labeling	CMF (S.E.)	Applicable
Total	Reduce speed limit by 10 kph	R_SL	0.625 (0.003)	Rou.1, Rou.2, Rou.3, Rou.4, Rou.5
	Reduce weaving width by 3.6 m	R_WW	0.755 (0.008)	Rou.2, Rou.3, Rou.4
	increase exit width by 3.6 m	I_ExW	0.830 (0.007)	Rou.1, Rou.2, Rou.4, Rou.5
PDO	increase exit width by 3.6 m	I_ExW	0.860 (0.007)	Rou.1, Rou.2, Rou.4, Rou.5
	reduce entry width by 2.0 m	R_EnW	0.819 (0.012)	Rou.3
	reduce speed limit by 10 kph	R_SL	0.638 (0.006)	Rou.1, Rou.2, Rou.3, Rou.4, Rou.5
Severe crashes	reduce entry angle by 5°	R_EnA	0.827 (0.014)	Rou.2, Rou.3, Rou.4
	reduce entry path radius by 2.0 m	R_EnR	0.980 (0.009)	Rou.1, Rou.2, Rou.4, Rou.5
	reduce weaving length by 2.0 m	R_WL	0.972 (0.009)	Rou.1, Rou.4

Table 4 shows the effect of implementing a single treatment on the CMF and its standard error for different crash type severity, as well as on the total crashes. Notably, interventions such as reducing the speed limit by 10 kph demonstrate a substantial decrease in total crashes across all roundabouts, with a CMF of 0.625. Moreover, measures focusing on increasing exit width by 3.6 m exhibit noteworthy CMFs, indicating significant reductions in both total and PDO crashes at multiple roundabouts. Combining the different treatment types with their impacts is shown in Table 4.

Table 5 shows the effect of implementing a combined treatment of the combined crash modification factors for the different crash severity types. Notably, interventions combining reductions in speed limits with modifications to exit widths consistently demonstrate promising results in reducing both total and PDO crashes across several roundabouts. Similarly, treatments targeting entry angle combined with adjustments to entry radius and weaving length exhibit notable effectiveness in reducing severe crashes, particularly at specific roundabouts. The effects of implementing several combined treatments on the combined CMF are discussed below.

Table 5. Estimated CMFs from combined appropriate treatments at identified roundabouts.

Crash Type	Combination of Treatments	Combined CMF			Avg. CMF	Applicable
		Method 1	Method 2	Method 3 (S.E.)		
Total crashes	R_WW + I_ExW	0.627	0.751	0.797 (0.005)	0.725	Rou.2, Rou.4
	R_SL + I_ExW	0.519	0.679	0.657 (0.003)	0.618	Rou.1, Rou.2, Rou.4, Rou.5
	R_SL + R_WW	0.472	0.648	0.641 (0.003)	0.587	Rou.2, Rou.3, Rou.4
	R_SL + R_WW + I_ExW	0.392	0.594	0.667 (0.003)	0.551	Rou.2, Rou.4
	I_ExW + R_EnW	0.704	0.803	0.850 (0.006)	0.786	Rou.3
PDO	R_SL + I_ExW	0.549	0.669	0.732 (0.005)	0.660	Rou.1, Rou.2, Rou.4, Rou.5
	R_SL + R_EnW	0.523	0.682	0.674 (0.005)	0.626	Rou.3
	R_SL + I_ExW + R_EnW	0.449	0.633	0.743 (0.004)	0.608	Rou.3
Severe crashes	R_WL + R_EnR	0.953	0.968	0.976 (0.006)	0.966	Rou.1, Rou.4
	R_EnA + R_EnR	0.810	0.874	0.935 (0.008)	0.873	Rou.2, Rou.4
	R_EnA + R_WL	0.804	0.869	0.930 (0.008)	0.868	Rou.4
	R_EnA + R_EnR + R_WL	0.788	0.859	0.950 (0.006)	0.866	Rou.4

5. Analysis of the Impact of Variables on Road Safety

5.1. Change Speed Limit

The connection between the CMF and speed limits is depicted in Figure 3. The graph displays the data plotted for total crashes (solid blue line) and Property Damage Only (PDO) crashes (dashed red line). As the speed limit increases from 35 km/hr to 70 km/hr, the CMF significantly increases, indicating a higher likelihood of crashes at faster speeds. Notably, the trends for total crashes and PDO crashes are closely aligned, suggesting a consistent impact of speed on both types of incidents. The graph clearly shows a positive correlation between the speed limit and crash risk, emphasizing the importance of carefully evaluating speed limit settings in traffic safety management to reduce crashes.

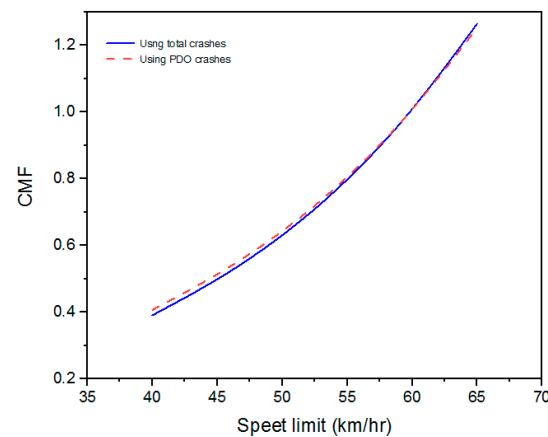


Figure 3. CMFs for speed limit treatments.

5.2. Modify Both Exit Width and Weaving Width

The connection between the Crash Modification Factor (CMF) and alterations in road geometry, specifically the expansion of exit width and the diminution of weaving width, has been investigated. The results are shown in Figure 4. Results indicate that the enhancement of exit width (I_ExW) and the diminution of weaving width (R_WW) lead to a diminution in the CMF, implying advancements in safety and a reduction in the probability of crashes. It is noteworthy that the diminution of weaving width has a more conspicuous impact on enhancing safety, as evidenced by a more precipitous decline in the CMF, as compared to the augmentation of exit width. This suggests that tighter weaving areas might reduce crash occurrences more efficaciously by potentially simplifying driving maneuvers and diminishing vehicle conflicts.

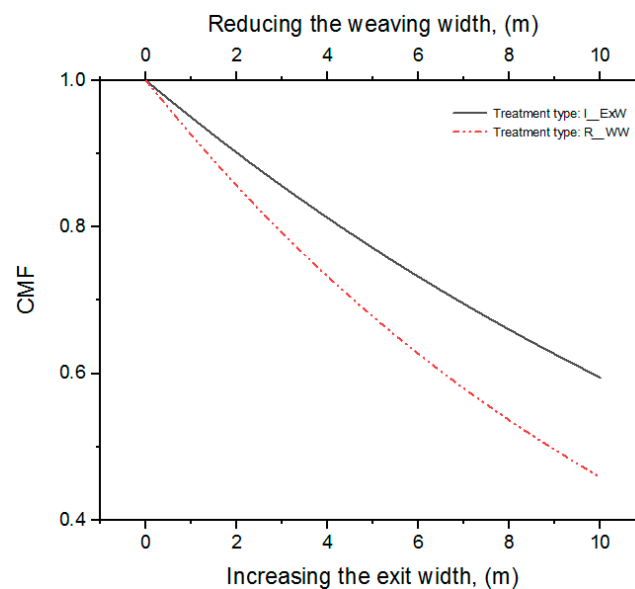


Figure 4. CMFs for exit width and weaving width treatments (using total crashes).

5.3. Modify Both Entry and Exit Width

Changing both entry and exit width affects the CMF, as shown in Figure 5. Results indicated that both reducing the entry width and increasing the exit width decreases the CMF. Notably, wider exit width helps in safer lane changing and deceleration; conversely, a narrower entry width reduces vehicle speed and requires more attention by a driver in merging.

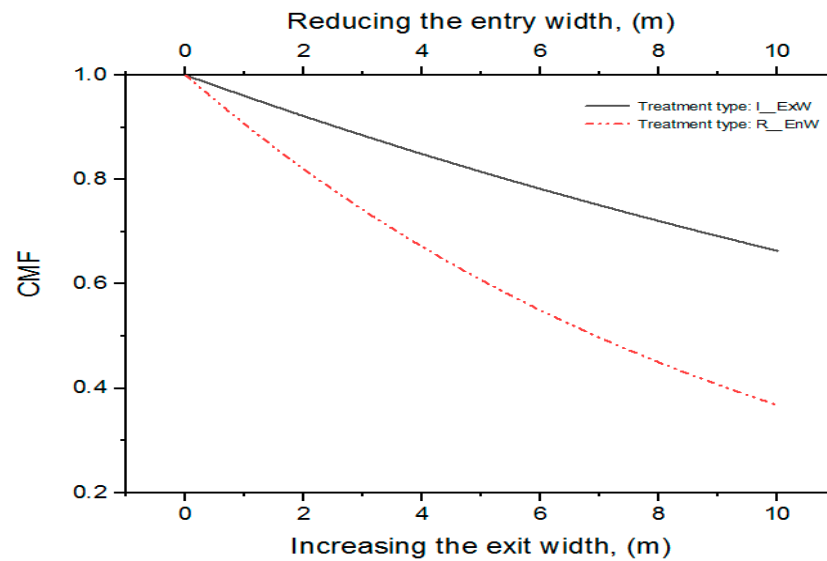


Figure 5. CMFs for exit width and entry width treatments (using PDO crashes).

5.4. Modify Entry Path Radius and Weaving Length

Modifying both entry radius and weaving length affects crash modification factor results, as shown in Figure 6. In essence, reducing the length of the weaving area and the radius of the entry path reduces CMF. Specifically, a shorter weaving length leads to a more significant reduction in CMF, indicating a larger impact on safety compared to reducing the entry path radius. This suggests that shorter weaving sections might limit high-speed weaving maneuvers and potential conflict points, thus enhancing safety. Meanwhile, reducing the entry path radius also lowers CMF, possibly by forcing slower entry speeds and reducing aggressive merging behaviors. These findings highlight important considerations for road design aimed at reducing crash likelihood and enhancing overall traffic safety. It should be mentioned that a roundabout's geometric design influences the application of these treatments, and we also estimated the safety effect only on severe crashes, so the results are not applicable to other crash types.

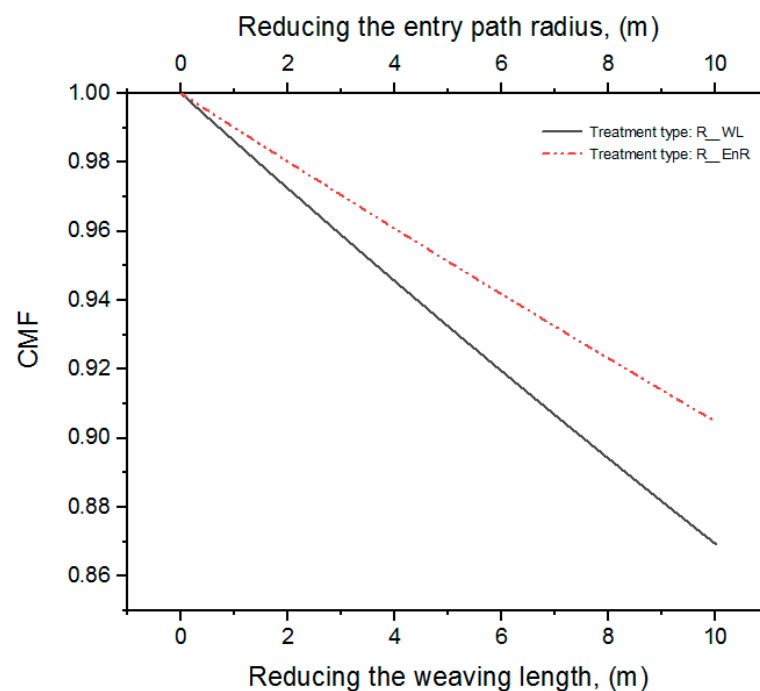


Figure 6. CMFs for weaving length and entry path radius treatments (using severe crashes).

5.5. Multiply Treatment Effect on CMF

Figure 7 shows the impact of various combined road safety treatments on the Crash Modification Factor (CMF) for PDO. Results indicate the effectiveness of strategies that modify entry and exit widths alongside other interventions. Notably, the treatment that combines reducing the entry width with reducing the speed limit (represented by the green dash-dot line) shows the most significant reduction in CMF, indicating a superior safety benefit. Other combinations, such as increasing exit width while reducing speed limits (blue dotted line) and others involving variations of entry and exit width adjustments, also effectively lower the CMF, albeit to varying degrees. This analysis underscores that multi-faceted approaches to road design and regulation, which address several aspects of road geometry and traffic control simultaneously, can substantially enhance traffic safety.

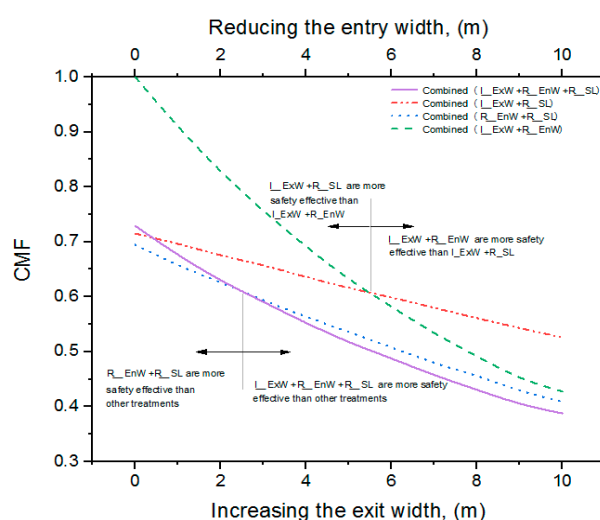


Figure 7. Combined CMFs for exit width, entry width, and speed limit treatments (using PDO crashes). (In this figure, the speed limit treatment is adopted as a speed reduction of 10 kph).

Figure 8 shows the effects of various combinations of road design modifications on the CMF, focusing on reducing the weaving length and entry path radius along with adjusting the entry angle. The results demonstrate that all combinations lead to a decrease in CMF, signifying improved safety with each treatment. Notably, the combination that includes reducing weaving length, entry radius, and adjusting the entry angle (depicted by the purple line) shows the most significant reduction in CMF, highlighting its superior effectiveness in enhancing road safety. This suggests that a comprehensive approach to modifying multiple aspects of road geometry can substantially decrease the likelihood of crashes, providing critical insights for optimizing traffic safety through road design.

However, the traffic volume influences the application of these treatments because a reduction in weaving length negatively affects roundabout capacity. Additionally, a shorter weaving length makes it less comfortable for drivers to weave in a crowded environment. In the same manner, reducing the entry angle at the roundabout is associated with reducing the entry width. Therefore, road engineers must implement any changes in these parameters with care and a high degree of accuracy.

Figure 9 demonstrates the effectiveness of various combinations of roadway design modifications on the CMF with a focus on reducing weaving width. It highlights that the most substantial safety improvements are observed with combinations that include reducing weaving width, increasing exit width, and lowering speed limits (represented by the green line). These results underscore the importance of a holistic approach to road safety interventions. Specifically, the graph shows that strategies combining geometrical adjustments of the road with speed control measures are more effective in reducing crash occurrences than strategies focusing on a single type of modification. This analysis is crucial

for traffic engineers and planners aiming to enhance road safety through comprehensive, multi-faceted roadway design improvements.

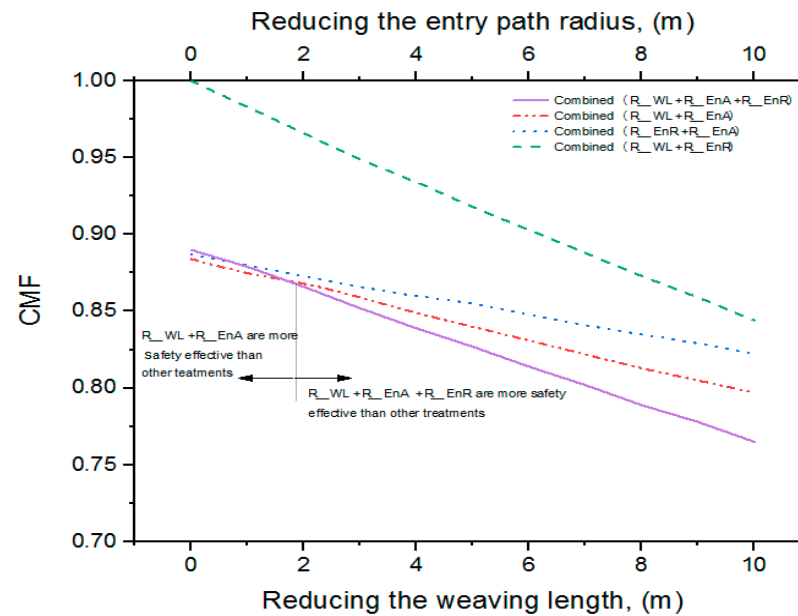


Figure 8. Combined CMFs for weaving length, entry path radius, and entry angle treatments (using severe crashes). (In this figure, the entry angle treatment is adopted as an entry angle reduction of 5°).

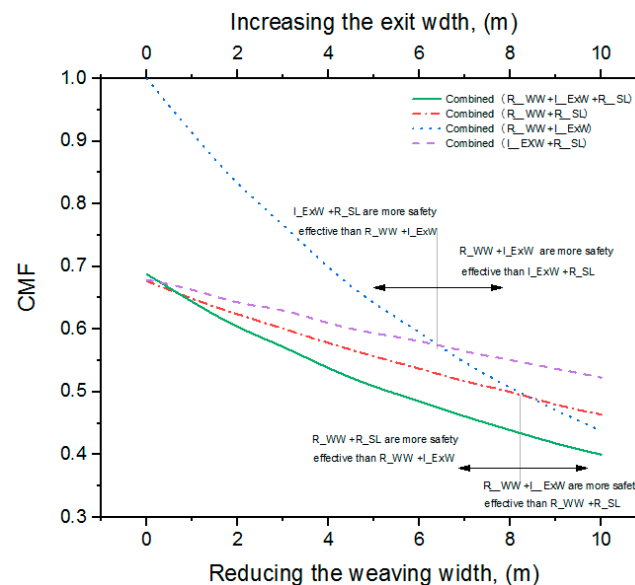


Figure 9. Combined CMFs for weaving width, exit width, and speed limit treatments (using total crashes). (In this figure, the speed limit treatment is adopted as a speed reduction of 10 kph).

6. Discussion

In this section, we discuss the results and findings by grouping as follows:

6.1. Roundabout Safety Performance

Roundabout Rou.1 demonstrates the highest total crash rate per million vehicles and the highest rate of property-damage-only (PDO) crashes, indicating a potential area of concern. However, it also displays promising results with some treatment combinations, such as $R_{WL} + R_{EnR}$, which yield a combined crash modification factor (CMF) of 0.976, suggesting a significant reduction in severe crashes. Roundabouts Rou.2, Rou.3, and Rou.4

exhibit varying degrees of crash risk, with specific treatments showing effectiveness in reducing total, PDO, and severe crashes. For example, combinations like R_WW + I_ExW and R_EnA + R_EnR exhibit high combined CMFs, indicating substantial reductions in crash risks. Roundabout Rou.5 generally shows lower crash rates across all categories, with specific treatment combinations demonstrating effectiveness in further reducing crash risks, particularly in total and PDO crashes.

6.2. Treatment Effectiveness

Combinations involving reductions in speed limits (R_SL) combined with modifications to exit widths (I_ExW) consistently display promising results across multiple roundabouts, suggesting their effectiveness in reducing both total and PDO crashes.

Treatments targeting entry angle (R_EnA) combined with adjustments to entry radius (R_EnR) and weaving length (R_WL) exhibit notable effectiveness in reducing severe crashes, particularly at Rou.4. These combinations exhibit high combined CMFs, indicating significant reductions in crash risks.

6.3. Implications for Road Safety

1. The comprehensive analysis provided by this table enables transportation authorities to identify effective strategies for reducing crash risks and improving road safety at roundabouts.
2. By leveraging insights from treatment effectiveness, authorities can prioritize and implement targeted interventions tailored to specific roundabout characteristics and crash types.

6.4. Interventions

Continuous monitoring and evaluation of roundabout safety performance, coupled with evidence-based interventions, are crucial for fostering safer road environments and reducing the incidence of crashes.

1. **Entry and Exit Width Modifications:** Increasing the exit width and reducing the entry width both effectively lower the CMF, indicating improvements in road safety. This suggests that wider exits allow for safer vehicle maneuvers while exiting, and narrower entries help control the speed and flow of entering traffic, leading to fewer crashes.
2. **Weaving Length and Entry Path Radius:** Reducing both the weaving length and the entry path radius consistently leads to lower CMFs. This points to the benefit of limiting high-speed weaving and forcing slower speeds upon entry, which reduces the potential for crashes.
3. **Combined Treatments Involving Speed Limits:** Combinations that include reducing speed limits along with other geometric changes (like reducing weaving length or modifying entry and exit widths) show a more significant decrease in CMFs. This underlines the compounded benefits of integrating speed management with physical roadway adjustments.
4. **Comparative Effectiveness of Combined Treatments:** Among various combined treatments, those involving a reduction in weaving length alongside other modifications (such as adjusting entry angles and widths) generally yield the most safety benefits. The results indicate that tackling multiple factors—geometric design and speed control—simultaneously provides the most effective means of reducing crash probabilities.

7. Conclusions

The comprehensive analysis of roundabout safety performance and treatment effectiveness underscores the importance of proactive measures in mitigating crash risks and improving road safety. Across the studied roundabouts, varying degrees of crash risk were observed, highlighting the need for targeted interventions tailored to specific roundabout characteristics and crash types.

The findings reveal several key insights:

1. **Identified Risk Areas:** Roundabouts such as Rou.1 exhibit higher crash rates, emphasizing the importance of prioritizing safety improvements in these areas. However, even roundabouts with lower crash rates require attention to maintain and further enhance safety standards.
2. **Effective Treatments:** Certain treatments, such as reducing speed limits combined with modifications to exit widths, consistently demonstrate promising results in reducing crash risks across multiple roundabouts. Additionally, interventions targeting entry angle combined with adjustments to entry radius and weaving length show notable effectiveness in reducing severe crashes.
3. **Synergistic Effects:** The analysis of combined crash modification factors (CMFs) highlights the synergistic effects of combining multiple treatments. Strategic combinations of treatments can result in significant reductions in crash risks, emphasizing the importance of considering holistic approaches to roundabout safety improvement.
4. **Continuous Monitoring and Evaluation:** Continuous monitoring and evaluation of roundabout safety performance are essential for identifying emerging trends, evaluating the effectiveness of implemented interventions, and informing future decision-making processes.

In conclusion, enhancing roundabout safety requires a multifaceted approach that integrates data-driven insights, evidence-based interventions, and ongoing evaluation efforts. By prioritizing targeted interventions based on the identified risk areas and leveraging effective treatments, transportation authorities can create safer road environments and reduce the incidence of crashes at roundabouts, ultimately ensuring the well-being of all road users. Finally, the study recommends conducting additional research to apply and validate the proposed treatment in other regions, as well as various road characteristics and different types of severe crashes.

Author Contributions: Conceptualization, M.N.A.-M., T.I.A., M.A. and A.J.; methodology, M.N.A.-M., T.I.A. and M.A.; software, M.N.A.-M., T.I.A. and M.A.; formal analysis, M.N.A.-M., T.I.A. and M.A.; investigation, M.N.A.-M., T.I.A. and M.A.; resources, M.N.A.-M., T.I.A., M.A. and A.J.; writing—original draft preparation M.N.A.-M., T.I.A., M.A. and A.J.; writing—review and editing, M.N.A.-M., T.I.A., M.A. and A.J.; visualization, M.N.A.-M., T.I.A., M.A. and A.J.; supervision, M.N.A.-M., T.I.A. and M.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data could be provided by requesting the corresponding authors.

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

References

1. WHO. *Road Traffic Injuries*; WHO: Geneva, Switzerland, 2022.
2. Jaber, A.; Al-Sahili, K. Severity of Pedestrian Crashes in Developing Countries: Analysis and Comparisons Using Decision Tree Techniques. *SAE Int. J. Transp. Saf.* **2023**, *11*, 307–320. [\[CrossRef\]](#)
3. Kasymova, N. *United Nations Population Fund Statistical and Financial Review, 2022 ANNEXES*; United Nations Population Fund: New York, NY, USA, 2022.
4. Distefano, N.; Leonardi, S.; Pulvirenti, G.; Romano, R.; Boer, E.; Wooldridge, E. Mining of the Association Rules between Driver Electrodermal Activity and Speed Variation in Different Road Intersections. *IATSS Res.* **2022**, *46*, 200–213. [\[CrossRef\]](#)
5. Peiris, S.; Corben, B.; Nieuwesteeg, M.; Gabler, H.C.; Morris, A.; Bowman, D.; Lenné, M.G.; Fitzharris, M. Evaluation of Alternative Intersection Treatments at Rural Crossroads Using Simulation Software. *Traffic Inj. Prev.* **2018**, *19*, S1–S7. [\[CrossRef\]](#) [\[PubMed\]](#)
6. Novák, J.; Ambros, J.; Frič, J. How Roundabout Entry Design Parameters Influence Safety. *Transp. Res. Rec. J. Transp. Res. Board* **2018**, *2672*, 73–84. [\[CrossRef\]](#)
7. Vinayaraj, V.S.; Perumal, V. Developing Safety Performance Functions and Crash Modification Factors for Urban Roundabouts in Heterogeneous Non-Lane-Based Traffic Conditions. *Transp. Res. Rec. J. Transp. Res. Board* **2023**, *2677*, 644–661. [\[CrossRef\]](#)
8. Vinayaraj, V.S.; Perumal, V. Safety evaluation of urban roundabouts in India: A safety performance function-based approach. *Traffic Saf. Res.* **2022**, *3*, 15. [\[CrossRef\]](#)

9. Al-Marafi, M.N.; Somasundaraswaran, K. A review of the state-of-the-art methods in estimating crash modification factor (CMF). *Transp. Res. Interdiscip. Perspect.* **2023**, *20*, 100839. [\[CrossRef\]](#)
10. Park, J.; Abdel-Aty, M.; Lee, C. Exploration and comparison of crash modification factors for multiple treatments on rural multilane roadways. *Accid. Anal. Prev.* **2014**, *70*, 167–177. [\[CrossRef\]](#) [\[PubMed\]](#)
11. Wu, L.; Lord, D. Examining the influence of link function misspecification in conventional regression models for developing crash modification factors. *Accid. Anal. Prev.* **2017**, *102*, 123–135. [\[CrossRef\]](#)
12. Wu, L.; Lord, D.; Geedipally, S.R. Developing Crash Modification Factors for Horizontal Curves on Rural Two-Lane Undivided Highways Using a Cross-Sectional Study. *Transp. Res. Rec. J. Transp. Res. Board* **2017**, *2636*, 53–61. [\[CrossRef\]](#)
13. Bahar, G. Methodology for the development and inclusion of crash modification factors in the first edition of the highway safety manual. *Transp. Res. Circ.* **2010**, E-C-142.
14. Wang, J.-H.; Abdel-Aty, M.; Wang, L. Examination of the reliability of the crash modification factors using empirical Bayes method with resampling technique. *Accid. Anal. Prev.* **2017**, *104*, 96–105. [\[CrossRef\]](#) [\[PubMed\]](#)
15. Lee, C.; Abdel-Aty, M.; Park, J.; Wang, J.-H. Development of crash modification factors for changing lane width on roadway segments using generalized nonlinear models. *Accid. Anal. Prev.* **2015**, *76*, 83–91. [\[CrossRef\]](#) [\[PubMed\]](#)
16. Wu, L.; Lord, D.; Zou, Y. Validation of crash modification factors derived from cross-sectional studies with regression models. *Transp. Res. Rec.* **2015**, *2514*, 88–96. [\[CrossRef\]](#)
17. Russo, B.J.; Savolainen, P.T.; Gates, T.J. Development of Crash Modification Factors for Installation of High-Tension Cable Median Barriers. *Transp. Res. Rec. J. Transp. Res. Board* **2016**, *2588*, 116–125. [\[CrossRef\]](#)
18. Al-Marafi, M.N.; Somasundaraswaran, K.; Ayers, R. Developing crash modification factors for roundabouts using a cross-sectional method. *J. Traffic Transp. Eng. English Ed.* **2020**, *7*, 362–374. [\[CrossRef\]](#)
19. Zegeer, C.; Lyon, C.; Srinivasan, R.; Persaud, B.; Lan, B.; Smith, S.; Carter, D.; Thirsk, N.J.; Zegeer, J.; Ferguson, E.; et al. Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments. *Transp. Res. Rec. J. Transp. Res. Board* **2017**, *2636*, 1–8. [\[CrossRef\]](#)
20. Kodi, J.H.; Kitali, A.E.; Ali, S.; Alluri, P.; Sando, T. Estimating Safety Impacts of Adaptive Signal Control Technology Using a Full Bayesian Approach. *Transp. Res. Rec. J. Transp. Res. Board* **2021**, *2675*, 1168–1179. [\[CrossRef\]](#)
21. Shahdah, U.; Saccomanno, F.; Persaud, B. Integrated Traffic Conflict Model for Estimating Crash Modification Factors. *Accid. Anal. Prev.* **2014**, *71*, 228–235. [\[CrossRef\]](#)
22. Khan, G.; Bill, A.R.; Chitturi, M.V.; Noyce, D.A. Safety Evaluation of Horizontal Curves on Rural Undivided Roads. *Transp. Res. Rec. J. Transp. Res. Board* **2013**, *2386*, 147–157. [\[CrossRef\]](#)
23. Persaud, B.; Lyon, C.; Bagdade, J.; Ceifetz, A.H. Evaluation of Safety Performance of Passing Relief Lanes. *Transp. Res. Rec. J. Transp. Res. Board* **2013**, *2348*, 58–63. [\[CrossRef\]](#)
24. Rezapour, M.; Wulff, S.S.; Ksaibati, K. Predicting Truck At-Fault Crashes Using Crash and Traffic Offence Data. *Open Transp. J.* **2018**, *12*, 128–138. [\[CrossRef\]](#)
25. Kay, J.; Gates, T.J.; Savolainen, P.T.; Mahmud, S. Safety Performance of Unsignalized Median U-Turn Intersections. *Transp. Res. Rec. J. Transp. Res. Board* **2022**, *2676*, 451–466. [\[CrossRef\]](#)
26. Le, T.Q.; Gross, F.; Harmon, T. Safety Effects of Low-Cost Systemic Safety Improvements at Signalized and Stop-Controlled Intersections. *Transp. Res. Rec. J. Transp. Res. Board* **2017**, *2636*, 80–87. [\[CrossRef\]](#)
27. Asaduzzaman, M.; Thapa, R.; Codjoe, J.A. Safety and Operational Effectiveness of Protected Only Versus Protected/Permitted Left-Turn Signal Phase. *Transp. Res. Rec. J. Transp. Res. Board* **2022**, *2676*, 347–356. [\[CrossRef\]](#)
28. Lindley, I. Investigating Approaches to Advancing Knowledge on the Effects of Road Safety Treatments: An Application to Ontario Rural Two-Lane Highways. Ph.D. Thesis, Toronto Metropolitan University, Toronto, ON, Canada, 2017.
29. Chen, Y. Integrating Information from Prior Research into a Before-After Road Safety Evaluation through Bayesian Approach and Data Sampling. Ph.D. Thesis, Toronto Metropolitan University, Toronto, ON, Canada, 2013. [\[CrossRef\]](#)
30. Gbologhah, F.E.; Guin, A.; Rodgers, M.O. Safety Evaluation of Roundabouts in Georgia. *Transp. Res. Rec. J. Transp. Res. Board* **2019**, *2673*, 641–651. [\[CrossRef\]](#)
31. Sadeq, H.; Sayed, T. Automated Roundabout Safety Analysis: Diagnosis and Remedy of Safety Problems. *J. Transp. Eng.* **2016**, *142*, 04016062. [\[CrossRef\]](#)
32. Park, J.; Abdel-Aty, M.A. Alternative approach for combining multiple crash modification factors using adjustment function and analytic hierarchy process. *Transp. Res. Rec. J. Transp. Res. Board* **2017**, *2636*, 15–22. [\[CrossRef\]](#)
33. Al-Marafi, M.N.; Somasundaraswaran, K.; Bullen, F. Development of crash modification factors for intersections in Toowoomba city. *Int. J. Urban Sci.* **2021**, *25*, 104–123. [\[CrossRef\]](#)
34. Hallmark, S.L.; Qiu, Y.; Hawkins, N.; Smadi, O. Crash Modification Factors for Dynamic Speed Feedback Signs on Rural Curves. *J. Transp. Technol.* **2015**, *5*, 9–23. [\[CrossRef\]](#)
35. Himes, S.; Porter, R.J.; Hamilton, I.; Donnell, E. Safety Evaluation of Geometric Design Criteria: Horizontal Curve Radius and Side Friction Demand on Rural, Two-Lane Highways. *Transp. Res. Rec. J. Transp. Res. Board* **2019**, *2673*, 516–525. [\[CrossRef\]](#)
36. Khattak, Z.H.; Fontaine, M.D. Evaluating the Safety Effects of Span Wire to Mast Arm Signal Conversion. *Transp. Res. Rec. J. Transp. Res. Board* **2018**, *2672*, 21–31. [\[CrossRef\]](#)

37. Lee, T.; Cunningham, C.; Simpson, C.L. Safety Evaluation for Conversion From Protected-Only Left-Turn Phasing to Time-of-Day Protected-Permissive Left-Turn Phasing Using Flashing Yellow Arrows. *Transp. Res. Rec. J. Transp. Res. Board* **2023**, 2677, 609–619. [[CrossRef](#)]
38. Geedipally, S.R.; Lord, D.; Pratt, M.P.; Fitzpatrick, K.; Park, E.S. Safety Performance of One-Way Arterials. *Transp. Res. Rec. J. Transp. Res. Board* **2020**, 2674, 548–559. [[CrossRef](#)]
39. Park, J.; Abdel-Aty, M. Safety Effects of Widening Shoulders on Rural Multilane Roads: Developing Crash Modification Functions with Multivariate Adaptive Regression Splines. *Transp. Res. Rec. J. Transp. Res. Board* **2016**, 2583, 34–41. [[CrossRef](#)]
40. Wang, K.; Zhao, S.; Jackson, E. Multivariate Poisson Lognormal Modeling of Weather-Related Crashes on Freeways. *Transp. Res. Rec. J. Transp. Res. Board* **2018**, 2672, 184–198. [[CrossRef](#)]
41. Anjana, S.; Anjaneyulu, M.V. Development of Safety Performance Measures for Urban Roundabouts in India. *J. Transp. Eng.* **2015**, 141, 04014066. [[CrossRef](#)]
42. Qawasmeh, B.; Kwigizile, V.; Oh, J.-S. Performance and safety effectiveness evaluation of mini-roundabouts in Michigan. *J. Eng. Appl. Sci.* **2023**, 70, 36. [[CrossRef](#)]
43. Sacchi, E.; Bassani, M.; Persaud, B. Comparison of safety performance models for urban roundabouts in Italy and other countries. *Transp. Res. Rec. J. Transp. Res. Board* **2011**, 2265, 253–259. [[CrossRef](#)]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.