# Investigating the Risk Factors on Crash Severity for Selected Risky Roads in Al-Diwaniyah City by Utilizing a Binary Probit Model

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**Abstract.** Traffic crashes are one of the main reasons for the deaths of many people and the loss of property. Road safety is a crucial aspect of transportation that aims to prevent crashes and injuries on the road, and several contributing factors affect it. In this study, the binary probit model using the N-Logit software was applied to crash-related data to examine the contribution of several variables to severe crash outcomes in Al-Diwaniyah City. Crash severity (the dependent variable) in this study is a dichotomous variable with two categories, severe and non-severe. Because of the binary nature of this dependent variable, a binary probit model was found suitable. Out of 37 independent variables obtained from Al-Diwaniyah Hospital traffic crash reports between 2014 and 2021 and from fieldwork to evaluate the pavement surface condition using the pavement condition index (PCI), six were statistically significantly associated with severe crashes. These factors include driver age, spring and summer seasons, pavement surface conditions, pedestrian collisions, and multi-vehicle crashes. Some proposals were also recommended to reduce traffic crashes, such as using median barriers to regulate pedestrian crossing, managing a proper number of lanes in the roads to avoid congestion due to a large number of vehicles, assessing the condition of the pavement surface annually at least, to identify pavement defects and conduct appropriate maintenance. Therefore, governments and transportation agencies must prioritize regular pavement condition evaluation as part of their maintenance programs for roads and highways. In conclusion, road safety is a complex issue that requires a multi-faceted approach involving various stakeholders such as government agencies, law enforcement agencies, vehicle manufacturers, drivers, pedestrians, and other road users.

**Keywords:** Crash severity; pavement condition index; Pavement defects; binary probit model; Risk factors.

## 1. INTRODUCTION

Despite the growth of the road network and the spread of modern technology used in road design, the number and seriousness of crashes are increasing worldwide for many reasons, including those related to human, environmental, or other factors. Although the causes of crashes are usually complex and contain several factors, they have been divided into four categories: the actions of the driver, the mechanical state of the vehicle, the geometric characteristics of the road, and the vehicle's climatic surroundings [1]. Roadway causes account for 3% of all road crashes, whereas a mix of road and non-road variables causes 34%. Human conduct causes 57% of collisions, but when combined with other variables, it generates 93% of road crashes [2], see Figure 1.

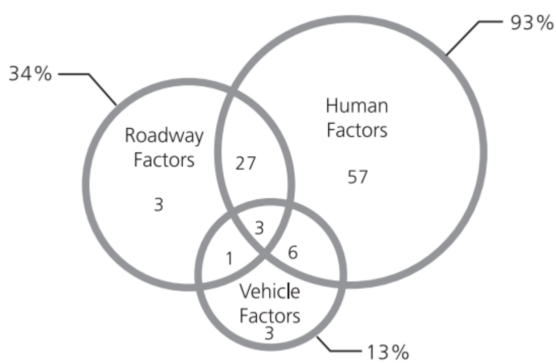


Figure 1: Proportion of contributing factors to vehicle crashes [2].

Traffic crashes are becoming more common in Iraq, as in many other countries, due to a growth in the number of cars, a poor transportation infrastructure, poor road design and maintenance, and a lack of gadgets and programs that serve and organize traffic. Therefore, the situation has deteriorated [3]. According to the Iraqi Ministry of Health (MoH) Annual Statistical Reports for 2017 and 2019, road traffic deaths are the eighth largest cause of death in Iraq, with 3.47% in 2017 and the seventh (4.9%) in 2019. A study was conducted in

Iraq to analyze traffic crash rates in the Iraqi governorates for data between 2005 and 2011[4], where there was a clear increase in crashes from 9010 in 2005 to 22,983 in 2011. The results found that the governorates of Baghdad, Babel, Basra, and Al-Diwaniyah recorded the highest rate of vehicle overturning on wet roads. This is due to vehicle slipping, not taking the necessary precautions during rainy weather, and poor road maintenance [5]. The condition of the pavement is one of the primary factors that cause crashes and increases their severity due to the city's defective construction or poor maintenance. The influence of road surface defects on traffic crashes is a global worry. When pavement reaches the end of its useful life, the pavement surface suffers from distress, making it unable to offer a smooth surface for users. Pavement defects include raveling, potholes, upheavals, rutting, depressions, shoving, and cracking. This is due to various reasons, such as water penetration, stress from heavy truck loads, seasonal temperature variations, and sun exposure. As result of climate change, such as severe rains and snow, damaged pavements Potholes have both internal and external causes, including the deterioration and reactivity or endurance of the pavement material itself to climate change, such as excessive rainfall and snowfall, and a lack of quality control and construction management. Potholes can cause flat tires and wheel damage, reduced vehicle impact and damage, collisions, and severe crashes [6-9].

A study was conducted on the Japanese island of Shikoku's rural highway networks. This study examines the empirical links between pavement conditions and crash risk. The Pavement Factors include IRI, cracking ratio, and rutting depth. The Poisson regression model is used in the analysis. Other data was used in the study, including AADT, surface condition, weather data, pavement condition data, and crash histories. According to the model estimation results, rutting depth can considerably raise crash risk, especially in wet conditions, but the IRI has the opposite effect. This seemingly contradictory finding can be explained by the driver becoming cautious and slowing down when driving portions with higher IRI scores. In major categories, the cracking ratio had a considerable effect on increasing crash risk [10]. The literature has indicated several factors significantly influencing the crash-injury severity level sustained by road users. Driver age and gender, crash type, weather, lighting conditions, pavement condition, collision of more than two pedestrians, City streets, the driver was drunk, driver's actions, Vehicular speed, Road environment, Intersections without signs, High residential density are some of the most crucial variables, which have been extensively explored as to their effect on severity [11-14]. Abdel-Aty [15] investigated the effect of resurfacing pavement on multilane arterials on Florida roads. They used the empirical Bayes technique and discovered that pavement resurfacing works reduced the total number, seriousness, and rear-end collisions. In traffic safety investigation based on crash and road maintenance data from Western Sweden, Othman [16] found that wheel rut depth had a negative impact on traffic safety.

There has become an urgent need to study the impact of the state of pavement and other risk factors on crash severity because there is no clear study in Iraq, especially in Al-Diwaniyah City, specializing in evaluating the pavement condition and its impact on traffic safety. So, the study aims to find the relationship between pavement surface condition and other factors and traffic safety by applying advanced econometric techniques models.

## 2. STUDY AREA AND METHODOLOGY

Iraq is one of the largest Arab population nations, with 438,000 sq km of total access area and an overall population of approximately 40,150,200 million in 2020; nearly 70 % live in urban areas. The study focused on Al-Diwaniyah City because it lacks much scientific research and studies, especially in the field of traffic safety, in addition to the deterioration of the economic situation and what is caused by a lack of services, especially road services. Hence, the city suffers from an acute shortage of paving and road maintenance services. Al-Diwaniyah City is an Iraqi city in the Middle Euphrates region, with an area of 8153 sq km and a Population of 1,076,658. In this study, the crash data available in Al-Diwaniyah General Teaching Hospital were relied upon due to the lack of information and data available in the General Traffic Department regarding traffic crashes on the internal roads in the city. Around 5996 crashes were obtained for the internal roads registered in Al-Diwaniyah Hospital from 2014 to 2021. Where the percentage of crashes for each road was taken separately, and then the roads with the highest percentage of crashes were chosen out of the total number of vehicle crashes in the studied regions, which is (1804) traffic crashes include Al-Askari Street with 707 traffic crashes, Al-Urouba street with 379 traffic crashes, Al-Wahda street with 271 traffic crashes, Al-Jamhouri street with 235 traffic crashes, Al-Jazaer street with 212 traffic crashes. In this study, some data were collected, including crash data, speed limit, evaluation of the pavement surface condition by using the pavement condition index (PCI), and other road characteristics.

### 2.1 Fieldwork

Pavement Condition Evaluation (PCE) is a critical process that helps to determine the condition of a road or pavement. It involves assessing various factors, such as surface distress, roughness, and skid resistance, to determine the overall condition of the pavement. PCE helps identify any road surface hazards that could pose a risk to motorists, such as potholes, cracks, and uneven surfaces. By identifying these hazards early on, appropriate measures can be taken to repair or maintain the road surface before crashes occur. The dimensions and area of the selected roads surface defects to identified pavement condition index for (Al-Askari Street, Al Wahda Street, Al-Jamhouri Street, Al-Urouba Street, and Al-Jazaer Street), were calculated according to the standard specification (ASTM D6433 − 18, 2018) [17]. The pavement Condition Index (PCI), which indicates the state of the surface road, is one of the various methods for assessing the road's condition. PCI is a visual survey that produces a numerical range from 0 to 100, with 0 being the worst road condition with the most surface road defects and 100 representing the best road condition with the least pavement defects. The PCI evaluates the quantity, severity, and type of pavement surface distress [18].

The most prominent defects that were observed in the study areas were Alligator cracks, Corrugation, Depressions, Polished Aggregate, Longitudinal and Transverse cracking, Patching, Potholes, Rutting, and Raveling. Data were obtained from the roads on which the study was conducted and measured manually using a measuring tape, including the width of the road, the presence of a median or not in the road, and the number of lanes. Fieldwork results were as follows: Askari Street with 6.7 meters of Road width, no presence of a median, a number of lanes are two, and a PCI value was 52.1 and pavement surface condition Classified as poor, Al Wahda Street with 12 meters of Road width, no presence of a median, a number of lanes are three, and a PCI value was 57.6 and classified as fair, Al-Jamhouri Street with 10 meters of Road width, presence of a median, a number of lanes are three, and a PCI value was 67.2 and classified as fair, Al-Urouba Street with 10 meters of Road width, presence of a median, a number of lanes are three, and a PCI value was 70.7 and classified as fair, and Al-Jazaer Street with 10.6 meters of Road width, presence of a median, a number of lanes are three, and a PCI value was 73.7 and classified as satisfactory. Classified according to the standard specification [17].

### 2.2 Theoretical Methodology

This study's main interest is predicting driver injury severity, the dependent variable, as a function of predictor variables. Due to the lack of available information, the study focused on the severity of the crashes, where fatal crashes were collected with severe injury under the name of severe, and they were considered as dependent variables, and the rest of the study variables were independent variables. In this study, binary probit models were used to model the probability of two possible outcomes of collision severity using the NLogit program. It is one of the world's most powerful programming languages for statistical computing, machine learning, and graphics, and it is a language and development environment specialized in data analysis and representation. The response variable severity of driver injury, severe (grouping of severe and fatal collisions), or no severe, is a binary outcome. Thus, double regression models have been suitable procedures since their inception to predict a parallel secondary variable as an action of the indicator factors and create a mathematical model for the most important factors that have a Specific effect on the crash severity. As a result, the response variable y can have the following binary values:

$$\begin{cases} y=1 & \text{Yes (fatal or severe)} \\ y=0 & \text{No (no severe)} \end{cases}$$

The binary probit model takes on the form of a binary index response model [19]:

$$P(y=1|X) = G(X\beta) = p(X) \tag{1}$$

In the case of the probit model, in which $G(\cdot)$ is a cumulative distribution function (CDF), a more general form of the effect of an explanatory variable $\boldsymbol{X}$ on a binary outcome can be expressed as follows [19]:

$$y* = \alpha + \beta X + \varepsilon \quad \text{With: } y = 1[y* > 0] \tag{2}$$

Where $y = 1[y* > 0]$ represents a crash in which an injury occurred ($y = 0$ otherwise). Considering this formula, the probit model specifies the conditional probability and is a special case of Eq. (1) [19-21]. Using the presented probit model, the probability of being severe injury crash (i.e., $y$ takes on the value 1) is computed. Referring to Eq. (1), $\boldsymbol{\beta}$ is a vector of estimable parameters, and $\boldsymbol{X}$ represents a vector of explanatory variables (e.g., gender, age, pavement surface condition, weather condition, crash location, speed, collision with, crash type), and $\varepsilon$ is a disturbance term with a standard normal distribution. After applying the random technique, it is found that there are no random parameters in variables to account for heterogeneous effects and any potential connections among the unknown factors. Finally, the marginal effects are calculated to obtain the effect of one unit variance of the indicative variable X on injury severity as given by Equation [22]:

$$\frac{\partial y}{\partial xi} = \beta_i \emptyset(\beta_\circ + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n \tag{3}$$

Following the collection of the necessary data for the study (crash data, assessment of the condition of the pavement surface, speed limits, driver characteristics, spatial and temporal characteristics, and other road characteristics), the variables were sorted and indexed in the Excel software, and each variable has its own code, as shown in Table 1.

Table 1: The Descriptive statistics for aggregate data.

| Variable | | Code |
|---|---|---|
| **Severe Injury** | 1 if Severe Injury is involved, 0 otherwise | |
| **Gender** | Female | 1 if Female involved, 0 otherwise |
| | male | 1 if Male involved, 0 otherwise |
| **Driver Age** | Age18 | 1 if Age18 is involved, 0 otherwise |
| | Age19-21 | 1 if Age19-21 involved, 0 otherwise |
| | Age 22-35 | 1 if Age 22-35 involved, 0 otherwise |
| | Age 36-50 | 1 if Age 36-50 involved, 0 otherwise |
| | Age51-65 | 1 if Age 51-65 are involved, 0 otherwise |
| | Age 65 | 1 if age>65 involved, 0 otherwise |
| **Time** | Morning | 1 if the crash occurs (6:00-11:59am), 0 otherwise |
| | Afternoon | 1 if the crash occurs (12:00-5:59pm), 0 otherwise |
| | Evening | 1 if the crash occurs (6:00-11:59pm), 0 otherwise |
| | Night | 1 if the crash occurs (12:00-5:59am), 0 otherwise |
| **collision with** | Pedestrian | 1 if pedestrian involved, 0 otherwise |
| | car | 1 if car is involved, 0 otherwise |
| | motorcycle | 1 if motorcycle involved, 0 otherwise |
| | Bicycle | 1 if Bicycle involved, 0 otherwise |
| **Crash Type** | Multi-vehicle crash | 1 if multi-vehicle crash is involved, 0 otherwise |
| | single-vehicle crash | 1 if a single-vehicle crash is involved, 0 otherwise |
| **Weather** | Spring | 1 if (3,4,5) months involved, 0 otherwise |
| | Summer | 1 if (6,7,8) months involved, 0 otherwise |
| | Autumn | 1 if (9,10,11) months involved, 0 otherwise |
| | Winter | 1 if (12,1,2) months involved, 0 otherwise |
| **Pavement condition** | Poor | 1 if Poor, 0 otherwise |
| | Fair | 1 if fair, 0 otherwise |
| | Satisfactory | 1 if satisfactory, 0 otherwise |
| **Number of lanes** | Two lanes | 1 if two lanes, 0 otherwise |
| | Three lanes | 1 if Three lanes, 0 otherwise |
| **Speed Limit** | 1 if not within the speed limit, 0 within the speed limit | |
| **Median** | 1 if median exists, 0 if no median | |
| **Street Width** | continues | |

## 3. RESULTS

### 3.1 Descriptive Statistics

Table 2 represents the statistical description of the factors that are a significant influence on driver injury severity, which included human factors (driver age), the cause of the crash (pedestrians), the type of crash (multi-vehicle collision), weather (spring, summer), the condition of the pavement surface (fair). The results indicate that the Multi-vehicle collision was found to be the highest value among the other factors, with a mean of 85%, and fair pavement surface condition was the second highest value, with a mean of 49%.

Table 2: Statistical description of the significant variables.

| Variable | Mean | Standard Deviation |
|---|---|---|
| Age1821(1 if driver Age18-21 involved, 0 otherwise | 0.181 | 0.385 |
| Pedestrian (1 if pedestrian involved, 0 otherwise) | 0.277 | 0.448 |
| Multi-vehicle crash (1 if multi-vehicle collision involved, 0 otherwise) | 0.854 | 0.353 |
| Spring (1 if spring is involved, 0 otherwise) | 0.229 | 0.421 |
| Summer (1 if summer is involved, 0 otherwise) | 0.2561 | 0.437 |
| Fair (1 if fair involved, 0 otherwise) | 0.491 | 0.500 |

### 3.2 Binary Probit Model Results

The analysis utilized all 1804 observations from our dataset (it could use fewer observations if any of our variables had missing values). A total of 37 variables were introduced into the NLogit 6 program to find a statistical model that relates the relationship of the variables to the severity of the traffic crashes and shows which one affects the severe injury outcome. A Chi-squared likelihood ratio of 45.145 indicates that the model as a whole is statistically significant. That is, it fits significantly better than a model with no predictors, as the results of the study showed that there are six variables were found to be statistically significant in the binary probit, which plays a fundamental role in the severity of the traffic crash within the study sample of the studied roads in the city of Al-Diwaniyah. These factors affect the severity of the injury of the driver. Table 3 shows the coefficients, standard errors, t-stat, and marginal effect, of significant factors with a 95% confidence interval of the coefficients. Out of 37 factors, only age 18-21, pedestrians, multi-vehicle collision, spring and summer seasons, and the fair pavement surface condition were statistically significant in the binary probit model based on the parameters calculated in the model.

The probit regression coefficients give the t-stat or probit index change for a one-unit change in the predictor. For a one-unit increase in age 18-21, the t-stat value is 2.27 and increases by 0.024. For each one-unit increase in pedestrians, the t-stat value is 2.43 and increases by 0.024. For each one-unit increase in a multi-vehicle collision, the t-stat value is 3.17 and increases by 0.040. For each one-unit growth in spring, the t-stat value is 2.18 and increases by 0.024. For each one-unit increase in Summer, the t-stat value is -1.94 and decreases by -0.019; for each one-unit rise in fair pavement surface condition, the t-stat value is 2.73 and increases by 0.023. A parameter with a positive sign implies that the severity level of harm for this variable has increased. In contrast, a parameter with a negative value suggests that the severity level of damage has reduced. The Log-Likelihood value is -243.98458, McFadden's Pseudo $R^2$ is 0.38, the AIC value is 502.0, and AIC/N value is 0.278.

Table 3: Significant variables of the binary probit model.

| Variable | Coefficient | Standard Error | t-stat | Marginal Effect |
|---|---|---|---|---|
| Constant | 1.201 | 0.146 | 8.21 | - |
| Age18-21 | 0.431 | 0.189 | 2.27 | 0.024 |
| Pedestrian | 0.415 | 0.171 | 2.43 | 0.024 |
| Multi-vehicle collision | 0.451 | 0.142 | 3.17 | 0.040 |
| Spring | 0.437 | 0.20036 | 2.18 | 0.024 |
| Summer | -0.251 | 0.129 | -1.94 | -0.019 |
| Fair | 0.341 | 0.125 | 2.73 | 0.023 |
| Log-likelihood function | | -243.985 | | |
| Restricted log-likelihood | | -266.557 | | |
| Chi-squared | | 45.145 | | |
| McFadden Pseudo R-squared | | 0.38 | | |
| Inf. Cr AIC | | 502.0 | | |
| Estimation based on N | | 1804 | | |
| AIC/N | | 0.278 | | |

## 4. DISCUSSION

### 4.1 Human Factors

Driver age is a human factor contributing to the severity of traffic crashes. Drivers' ages are considered potential risk factors. This study divides driver age into five groups: ≦18; 19-21; 22-35; 36-50; and 51-65. The findings of this study revealed that being between the ages of 18 and 21 significantly affects the severity of a traffic collision, with a marginal effect of 0.02359. Where the severity of the crash is related to the extent of the driver's awareness of traffic safety rules and the experience gained from driving a vehicle and knowing the roads and correct turns, especially at traffic intersections, and the ages within the category above may be less aware of these limitations or they may not possess a driving license. Many studies also concluded this. According to a study, young drivers between 20 and 24 were linked to a considerable increase in severity risk compared to other age groups [23]. Numerous studies have found that younger (fewer than 25) are more likely to be involved in car crashes. The justifications offered for these hikes have been thoroughly investigated [24], [25]. These are mostly associated with inexperience and risk-taking behaviors (driving while impaired by alcohol or other drugs, speeding, etc.) in younger drivers [24-27]. [28] Younger drivers (aged 17–25 years) are more likely to have right-hand cornering problems, rear-end deflections, and lose control of curves in the dark. This increases the risk of crashes in this age group. Other studies do not agree with the study's findings, as these studies found that older drivers are the age group that causes severe traffic crashes [29], [30]. [31]found that driving speed is negatively correlated with the age of the drivers. Median-aged drivers are less likely to become involved in serious injury/fatal crashes, in contrast with younger and older drivers [23].

### 4.2 Weather Conditions

Among the weather conditions considered in this study, the effect of seasonal variation on crash severity was found to be significant. According to the weather in Iraq, the seasons are divided into winter: December, January, and February; Spring: March, April, and May; Summer: June, July, and August; autumn: September, October, and November. Weather condition is one of the factors affecting the severity of traffic crashes. According to the statistical analysis, the results showed that the spring season increases the risk of severe collisions with an impact factor of 0.02377. At the same time, the summer season contributes to a decrease in the risk of traffic crashes with an impact factor of -0.01888. Spring season impacts the severity of crashes because it witnesses rain, which affects the resistance to slipping. In summer, traffic crashes may decrease slightly. The weather conditions may be in the best possible condition. Therefore, the paving surface is dry, which reduces the possibility of the vehicle slipping and thus reduces the severity of the crashes that occurs for some reason. Summer time does not have a significant detrimental effect on vehicular crashes in the short term; Summer time significantly reduces vehicular crashes in the long term, with an 8–11% decrease in pedestrian crashes and a 6–10% decrease in vehicular collisions in the weeks following the switch from Spring to Summer [32] There are many studies mentioned that Winter season increases the probability of an injury compared to other seasons, i.e., Fall, Spring, and Summer. There are two impacts of poor weather conditions in winter, and drivers frequently slow down to avoid the vehicle slipping due to the poor pavement condition, which lowers the risk of a tragic collision compared to spring. Snow or ice, on the other hand, lengthens the braking distance and increases skidding, which causes more injury collisions compared to Summer [33].

### 4.3 Pavement Surface Condition

The condition of the pavement surface affects the severity of the traffic crash due to damage to the pavement surface or for any other reason. The study concluded that the fair pavement surface condition affects the severity of the traffic collision with a marginal effect coefficient of 0.023 and a 95% confidence interval. The accumulation of cracks in a road increases the risk of injury to the driver because it reduces the efficiency of the pavement surface and thus reduces the design life of the road. The authors [34] investigated the link between pavement roughness and distresses such as potholes, rut depth, raveling, cracking, and patch deterioration. The study found the primary contributors to pavement roughness are potholes, totally cracked areas, and raveling. Anastasopoulos [35] found through statistical analysis that the pavement's roughness increases the frequency of traffic crashes. Rut depth and patching, on the other hand, have a relatively minor influence on the roughness of the pavement. The rate of collapse increases when the international roughness index (IRI) or rut depth exceeds certain criteria [36]. In this study, potholes constituted 36%, 18% rutting, 71% longitudinal and transverse cracks, 33% alligator cracks,11% groove, and 21% depression of the total sections in the study area, which causes an increase in the roughness of the pavement surface.

Figure 2 can illustrate the relationship between crash rate and rutting. The total rutting areas for each road were calculated to find their relationship to the crash rate of the roads using the SPSS program. Through the figure, the effect of rutting is shown, as we notice an increase in the number and seriousness of traffic crashes by increasing the rutting in the surface of the pavement because it can cause hydroplaning, which leads to the vehicle being pulled into the rutted the condition of the pavement surface affects the severity of the traffic crash that occurs due to damage to the condition of the pavement surface or for any other reason. The study concluded that the fair pavement surface condition affects the severity of the traffic collision with a marginal effect coefficient of 0.023 and a 95% confidence interval. The accumulation of cracks in a road increases the risk of injury to the driver because it reduces the efficiency of the pavement surface and thus reduces the design life of the road. Chandra et al. [34] investigated the link between pavement roughness and distresses, such as potholes, rut depth, raveling, cracking, and patch deterioration. The study found the primary contributors to pavement roughness are potholes, totally cracked areas, and raveling. Anastasopoulos [35] found through statistical analysis that the pavement's roughness increases the frequency of traffic crashes. Rut depth and patching, on the other hand, have a relatively minor influence on the roughness of the pavement.

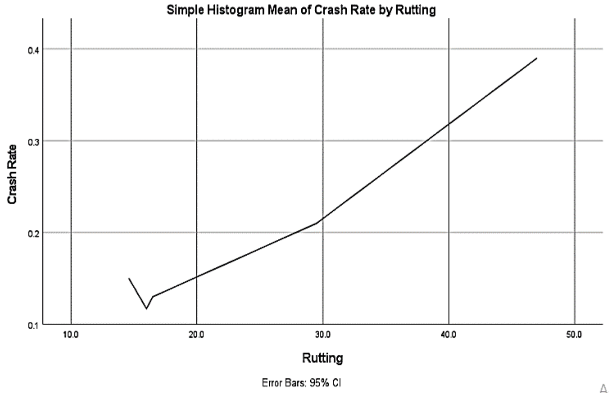


Figure 2: Relationship between crash rate and rutting.

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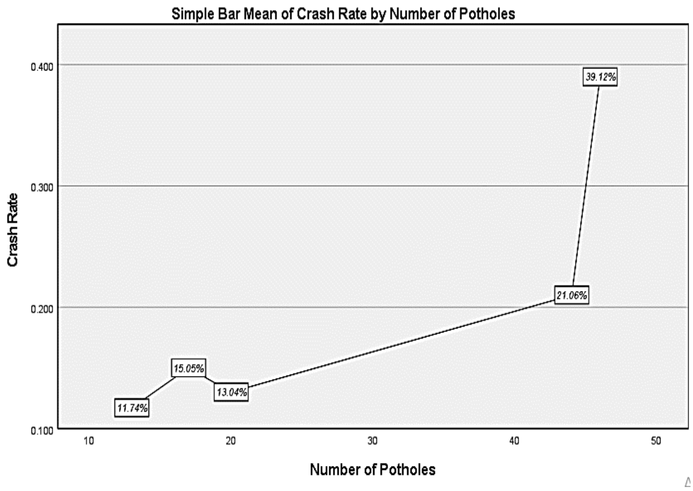


Figure 3: Relationship between crash rate and potholes.

### 4.4 Pedestrian collisions

Collisions between pedestrians and vehicles are an unfortunate part of modern life, with often tragic and costly outcomes. In this study, collisions with a car, a motorcycle, a bicycle, and pedestrians were analyzed to determine the most significant factor that impacted the severity of the crash. A collision with a pedestrian directly constitutes a more significant risk with a marginal effect of 0.02380, and the percentage of crashes with pedestrians was 28%. Where pedestrians involved in collisions are at a disadvantage relative to drivers or vehicle occupants, US pedestrian fatalities [37] are between 11 and 12% of all traffic-related fatalities. Most safety programs aim to reduce the frequency of pedestrian and vehicle collisions, but few have specifically focused on reducing the risk of severe injury or death [38]. More than two-thirds of pedestrian deaths occurred in cities, with only 13% of cities responsible for more than two-thirds of all pedestrian deaths between 1997 and 2006 [37]. The vehicle's collision speed most significantly influences the severity of the pedestrian's damage. The danger of injury is more serious for the lower extremities and cranium. When the vehicle's speed is below 30 km/h, a substantial reduction in all injuries can be obtained for all kinds of vehicles [39].

### 4.5 Collision Type

Many reasons lead to crashes and serious injuries, including high speed, lack of attention, alcohol, car derailment, etc., leading to a collision, rollover, run-over, or something else. It has been noted from the data obtained that the type of collision for the crash recorded in the hospital was a collision, and the type of collision was determined as a single-vehicle crash or multi-vehicle crash. The analysis found that the collision of the vehicle with another vehicle or several vehicles is a statistically significant factor that increases the severity of the traffic crash, with a marginal effect of 0.04016. Schneider [40] found that in single-vehicle crashes, the probability of fatal injury increases by approximately 2% for every 1% rise in speed. Among multiple vehicle collisions, fatalities were 2.9 and 2.2% more likely for similar speed increases at the intersection and non-intersection locations. When trucks or motorcycles are engaged in a multi-vehicle crash, the driver's injuries and deaths can be more serious. It has been found that poor illumination and poor weather conditions greatly increase the intensity of multi-vehicle collision injuries.

## 5. CONCLUSIONS

- Evaluating the pavement surface condition, identifying road surface defects for proper maintenance, and resurfacing roads to maintain ride quality and skid resistance within the approved specifications in road design.
- Awareness of traffic safety rules through the preparation of special plans and programs that urge cooperation between people and traffic to adhere to traffic instructions and speed limits, avoid high speeds, use alcoholic substances, stress the possession of a driver's license and a seat belt, and hold violators and defaulters accountable.
- Conducting more research on the risk factors that increase the severity of traffic collisions to reduce their impact as it can:

- Allocating special crossings for pedestrians to reduce pedestrian crashes, and special bridges can be established for that.
- Designing roads according to the standards of modern technology and suitable for high traffic loads, managing a proper number of lanes in the roads to avoid congestion due to a large number of vehicles, street width, in addition to other characteristics of the road such as curvature of the road, the presence of median, and others.
- Carrying out emergency maintenance, preparing special equipment for that, and manpower equipped for any emergency, especially during the rainy seasons, in anticipation of any emergency.
- The competent authorities, especially the General Traffic Directorate, must record all crash information in a special form traffic crash, whether for internal or external roads and facilitate the obstacles for researchers interested in traffic safety.

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