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Ordinal regression analysis of traffic collision accidents in Jordan 2021: factors and severity assessment

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Abstract: One of the significant challenges that the world is confronting is road traffic accidents. The aim of this study is to determine the key factors contributing to traffic collision accidents and to utilize an ordinal regression model to identify the factors that contribute to accident severity. This will be achieved by fitting a suitable equation based on a dataset obtained from the Traffic Institute's database for the year 2021. The findings from the ordinal logistic regression analyses indicate that weather conditions, road surface, speed limit and illumination levels are significant factors that contribute to the severity of crashes with p-values of 0.003, 0.085, 0.025 and .002 respectively. Hour of the day, day of the week, week and governorate are insignificant in collision accidents in Jordan in 2021. In this comprehensive study on traffic collision accidents in Jordan during 2021, our analysis has revealed some significant findings. Our data indicates that the peak period for traffic collision accidents was between 18:00 to 18:59, and Thursday was found to have the highest number of incidents. In terms of the month, July recorded the highest number of accidents. It was also noted that Amman had the largest share of accidents. These findings highlight the need for increased awareness and stricter enforcement of traffic regulations during peak periods and in high-risk areas.

1 Introduction

The prevalence of traffic accidents and their resulting fatalities, injuries, and associated social and economic impacts represent a major challenge for nations worldwide. Collision accidents are defined as incidents involving the interaction of two or more vehicles and their drivers, caused by factors such as violation of traffic regulations, failure to yield, driver distraction, and driver fatigue. In 2021, approximately 1 million car accidents took place in Jordan, leading to 589 fatalities resulting solely from collision accidents [1].

As a result of the surrounding circumstances, Jordan has experienced a significant increase in population and vehicles, leading to a discrepancy in traffic accident rates despite preventive and remedial measures taken by public security departments.

A quick look at the results of road accidents in Jordan in 2021 shows that 160,600 accidents occurred, of which 11,241 were serious, resulting in 589 fatalities and 737 severe injuries, 6,325 moderate injuries, and 10,423 minor injuries, with a monetary cost estimated at 320 million Jordanian Dinars [1].

The study aims to identify the key factors that contribute to traffic collision accidents across various governorates in Jordan and their relationship with the level of injury severity.

To achieve the study's aim, a comprehensive analysis of traffic collision accidents in Jordan was conducted. The study analyzed data from the Jordanian Traffic Institute's database on collision accidents that occurred in 2021. The sample consisted of all recorded collision accidents across various governorates in Jordan during the study period, and the data included information on the date, time, location, and severity of the accidents, as well as the factors that contributed to them. To analyze the data, descriptive statistics were used to identify the frequency and distribution of collision accidents by time of day, weather conditions, and other factors. Additionally, logistic regression analysis was used to identify the factors that were significantly associated with the severity of injuries sustained in the accidents.

Overall, this study provides a comprehensive analysis of traffic collision accidents in Jordan and identifies key factors that contribute to their occurrence and severity. The findings of this study can inform the development of targeted interventions and policies aimed at reducing the incidence and severity of traffic collision accidents in Jordan.

2 Literature review

Extensive research has been carried out to determine the foremost factors that lead to different accident types, such as collision accidents. Han [2] conducted a study utilizing a black box camera mounted within vehicles to assess the level of damage and circumstances surrounding traffic collisions. He discovered a cost-effective method for predicting and preventing collision accidents, a finding that represents an improvement over traditional approaches. Didin et al. [3] studied previous studies focused on rear-end collisions as a try to concentrate on the

main risk factors that affect crash accidents. They found that there were many factors that led to rear-end collisions, such as: the behaviour of driving, retarding and acceleration, headway time and collision time. Han [4] presented a new approach to make a full analysis of a collision between vehicles. The approach was introduced because of the difficulty of gathering accurate information. As a result, the method used a vector as a main factor to define many relevant factors, such as the direction and speed of a vehicle, and then present qualitative calculations. A. Rakhonde et al. [5] presented a new smart vehicle system to detect collision accidents and monitor pollution. They found that the response time for medical cars was reduced while the sensors were installed on the tires and they were able to alarm for the collision crash in different directions. Yang et al. [6] designed a new algorithm to detect vehicle collisions during driving based on using Android installed on smartphones. The procedure was to send all the information to the preset mobile number when the collision is detected and the camera starts work by taking an instant photo and sending it to the number. Darwish [7] investigated the factors that influence a driver's decision to either stop at intersections or continue driving without stopping. Results showed 48% of drivers stopped completely, with female drivers and bus drivers stopping more often. Driver age and compliance with stop signs were directly proportional. Cheng et al. [8] used statistical analysis to construct discrete choice models to investigate the impact of multiple factors on crash severity on a freeway in China. Based on 1154 accidents, the study found 11 significant factors affecting crash severity, including driver gender and age, vehicle type, road conditions, and lighting. The results can be used to develop targeted proposals for improving traffic management. Prajongkhaa et al. [9] investigated the causes of injuries and deaths resulting from motorcycle rear-end collisions and analyzed factors contributing to their severity level in Thailand. The study found that perception failure was the primary contributing factor and that collisions with parked vehicles resulted in higher probabilities of death. The findings can be used to develop policies and countermeasures to prevent and reduce the severity of MC rear-end crashes. Yang et al. [10] utilized data from the Chinese National Automobile Accident In-Depth Investigation System to develop a prediction model for traffic accident severity. Using random forest, they identified seven important accident features, including four new features not previously ranked. The optimized model resulted in higher accuracy for predicting traffic accident severity. Infante et al. [11] analyzed daily road traffic accident (RTA) data from 2016 to 2019 in a district of Portugal to identify the determinants of the type of RTA (collision, crash, or pedestrian running-over). The study found that geographical, meteorological, time of day, driver and vehicle characteristics, and road characteristics were significant determinants. The authors compared several machine learning algorithms, and found that combining these with ROSE for class balancing improved their performance, with random forest performing the best. Li et al. [12] aimed to predict the severity of traffic accidents on mountain freeways using machine learning algorithms. Four models were constructed using SVM, DTC, Ada_SVM and Ada_DTC, and RF was used for feature selection. Rainfall intensity, collision type, number of vehicles involved and road section type were found to be important variables. The combination of Ada_SVM and RF achieved the best prediction performance, with 78.9% and 88.4% prediction precision and accuracy, respectively.

3 Methodology

Data on road traffic accidents that occurred between January and December 2021 were gathered from the traffic institute, which, among its various responsibilities, keeps records of all accidents and crash-related information, including the degree of injuries sustained and property damage. These statistics are published annually in both soft and hard copies.

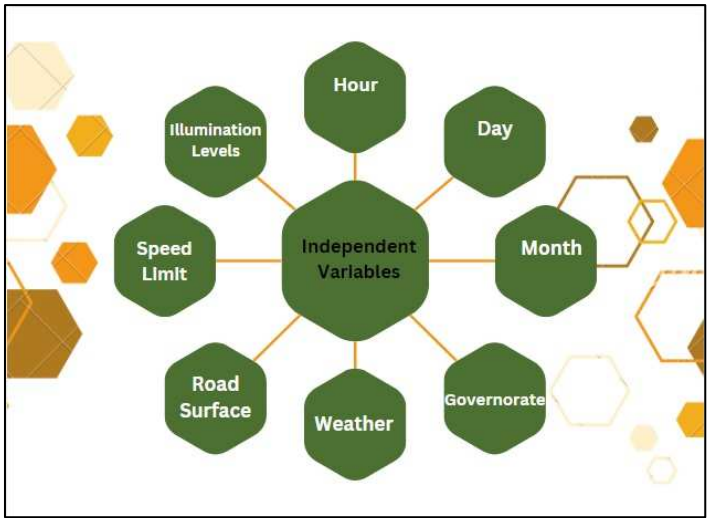

Figure 1 Independent variables

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This comprehensive study encompasses all governorates in Jordan, divided into twelve distinct segments. Several critical variables will be meticulously analyzed, including the hour of the day, day of the week, monthly trends, governorate location, weather conditions, road surface state, speed limit, and illumination levels (Figure 1).

Hourly recordings of the time of day were meticulously gathered, as well as daily recordings of the day of the week, covering a comprehensive range from Saturday to Friday. All twelve governorates and twelve months were meticulously included in the study.

The weather conditions were thoroughly evaluated and divided into six categories, including clear sky, high winds, frosty, foggy, dusty, and rainy. The road surface conditions were meticulously analyzed and sorted into seven unique categories, including arid, frosty, glacier, sandy, oily, clayey, and muddy. The speed limit was further divided into nine distinct groups, while the illumination level was categorized into six separate types.

Following data collection, statistical analysis was performed on the exported data using SPSS. The severity level of accidents is the dependent variable in this study and has been classified into four distinct categories: 1-Fatal, 2-Severe, 3-Moderate, and 4-Minor (Figure 2).

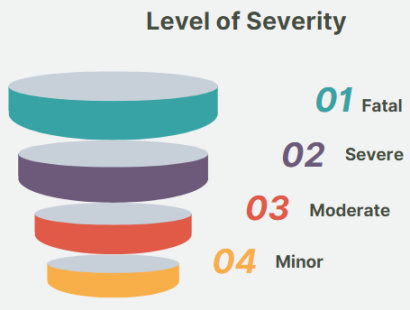

Figure 2 Types of level of severity

4 Result and discussion

4.1 Hour of the day

A thorough 24-hour analysis was conducted to determine the precise time frame in which collision accidents exhibited the highest frequency of occurrence**.** Data analysis revealed that the hour ranging from 18:00 to 18:59 had the highest incidence of collision occurrences (Figure 3). Numerous factors may account for the elevated rate of accidents during the 18:00 to 18:59 hour period. Some of the potential contributing elements include are that the 18:00 hour is often marked by peak hour traffic as individuals return home from work or school. This increase in traffic volume on roadways raises the risk of accidents. Additionally, decreased visibility during the setting sun at this time may also contribute to an elevated risk of collisions. Furthermore, driver fatigue is another factor to consider. Individuals who have been driving for prolonged periods during the day may experience fatigue and decreased levels of alertness in the evening, contributing to a heightened risk of accidents.

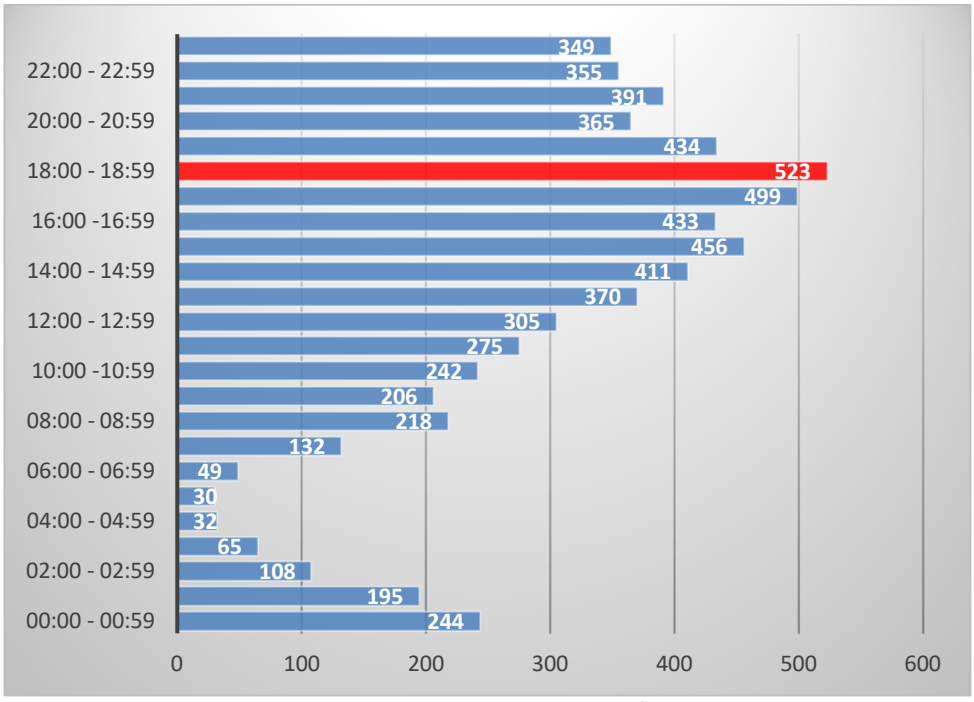

Figure 3 Collision accidents vs. hour of the day

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4.2 Day of the week

An in-depth analysis was conducted by incorporating all days in the examination, with the purpose of uncovering the critical day. The results of the study indicated that Thursday had the highest frequency of collision accidents, with 1137 incidents recorded (Figure 4). A major contributing factor to the elevated frequency of collision accidents on Thursday may be attributed to the increased rush hour traffic during the evening hours. With Thursday being considered the terminal day of the workweek, a substantial number of commuters strive to leave work and return home in preparation for the weekend. This results in congested roadways and heightened traffic volume, which can increase the likelihood of collisions. Furthermore, the extended travel times associated with increased traffic on Thursday may lead to increased driver frustration and potentially reckless driving behaviour, further exacerbating the situation and contributing to the higher frequency of collision accidents.

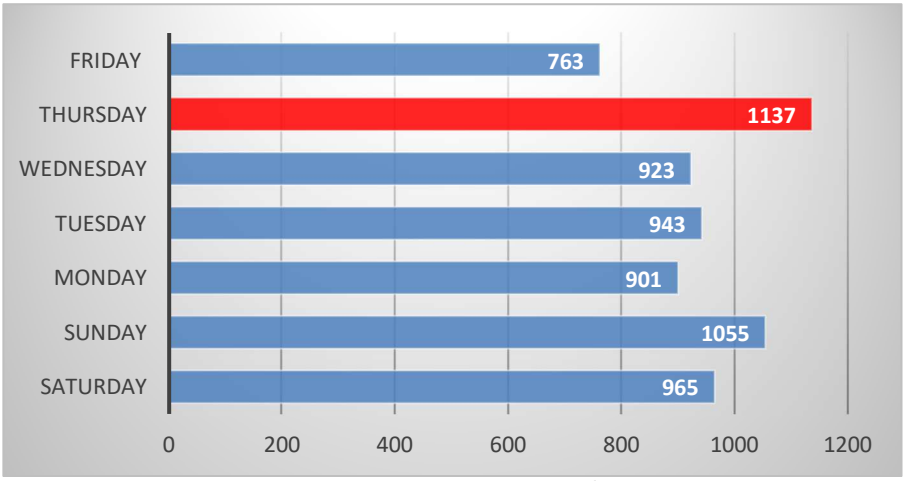

Figure 4 Collision accidents vs. day of the week

4.3 Monthly trends

The results of the study, which were derived from a thorough examination of collision accidents over a one-year period, indicated that July was the month with the highest frequency of collision accidents reported (Figure 5). The higher frequency of collision accidents in July can be attributed to several factors. One potential explanation is the increased influx of returning expatriates, particularly from neighboring countries such as Saudi Arabia and Kuwait, using their vehicles, which results in an increase in traffic volume and congested roadways.

Another possible explanation for the increased frequency of collision accidents in July is the presence of various holidays and festive events in Jordan. The summer season often sees an increase in road trips, family vacations, and other travel activities, which can lead to higher traffic volume and a higher likelihood of collisions.

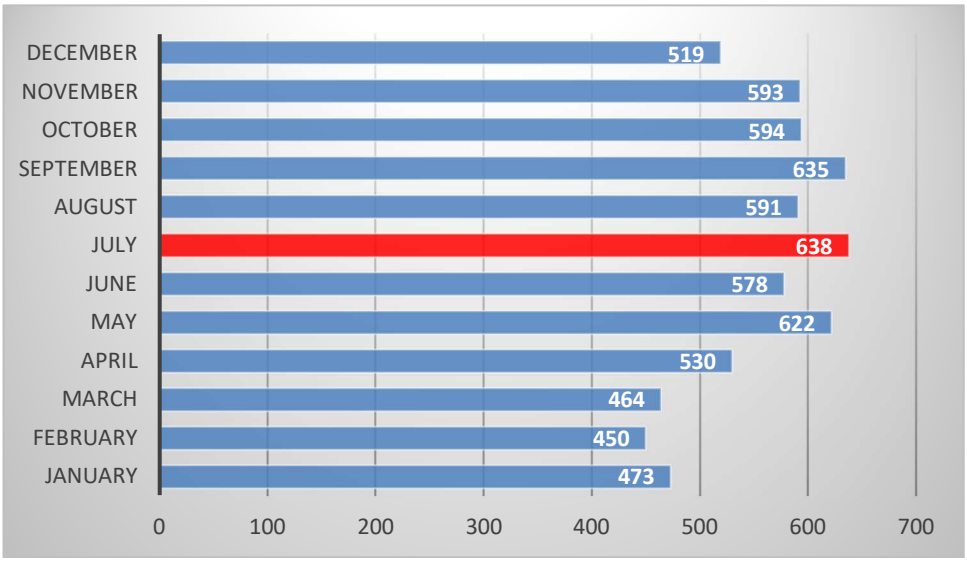

Figure 5 Collision accidents vs. month of the year

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4.4 Governorate location

The higher number of collision accidents recorded in the capital city of Amman (2842 accidents, Figure 6) may be due to a variety of factors. One possible explanation is the higher population density in Amman estimated to be over 4 million in 2021 * which leads to increased traffic volume and a greater likelihood of collisions. Additionally, the presence of a complex road network in Amman, with a large number of intersections, overpasses, and underpasses, could increase the likelihood of collision incidents and contribute to the higher number of recorded accidents in the city. Furthermore, the city's status as the political and economic center of Jordan could also result in higher levels of vehicular traffic.

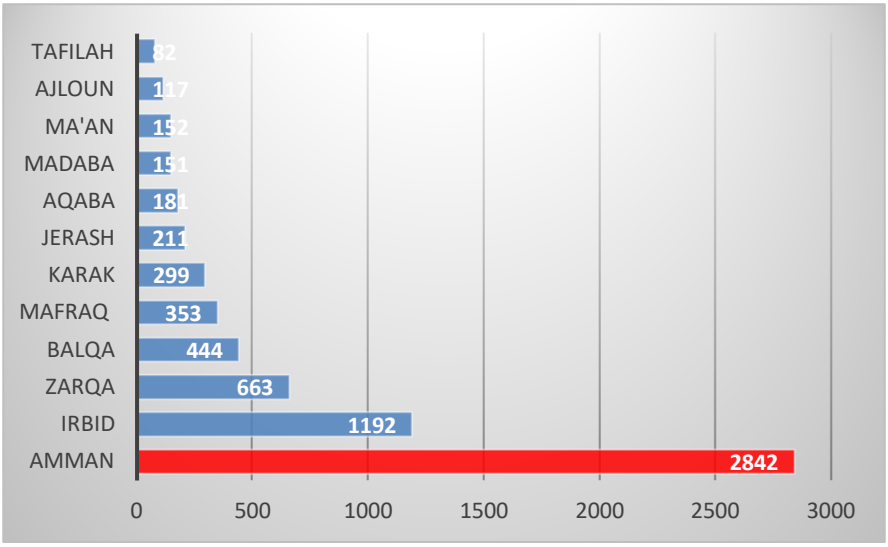

Figure 6 Collision accidents vs. governorate

4.5 Weather conditions

The data analysis revealed a clear trend, with the highest frequency of collision accidents being recorded in clear sky weather conditions, representing a staggering 96.5% of the total accidents observed in the study(Figure 7). The contributing factors behind this trend can be attributed to several key mechanisms. Firstly, increased visibility under clear sky conditions is known to facilitate high-speed and aggressive driving. Secondly, drivers may experience a false sense of security in clear weather, leading to decreased attention levels and elevated risk-taking behavior. Finally, glare from the sun in clear weather conditions can significantly impair drivers' visibility and increase the risk of collision accidents.

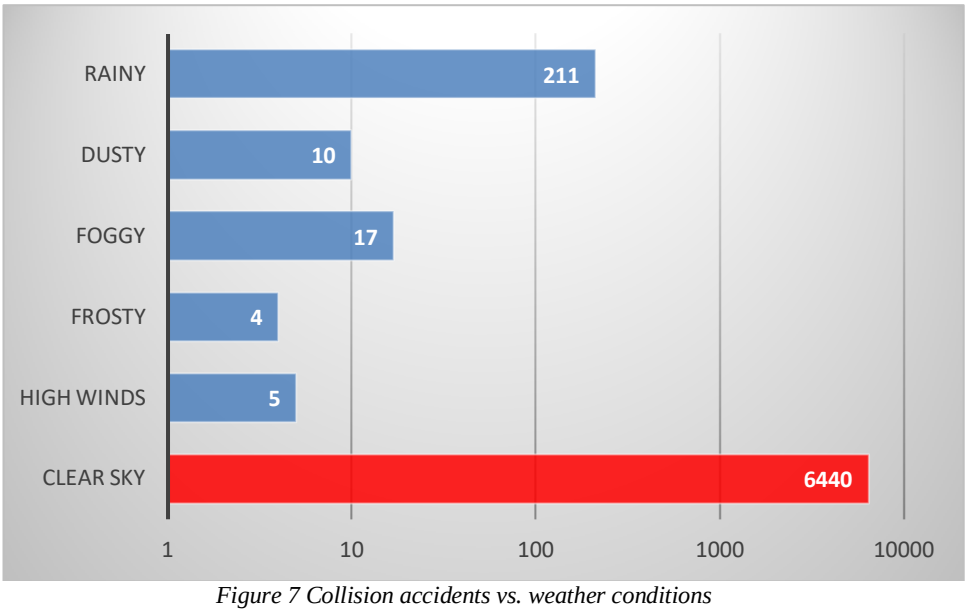

Figure 7 Collision accidents vs. weather conditions

4.6 Road surface state

It was noted that when the road surface is arid the number of collision accident is recored as a high level with a percentage of 96% (Figure 8). This phenomenon could be attributed to the notion that drivers tend to feel a false sense of comfort and security when driving on arid road surfaces. The absence of visible road hazards, such as oil or other slippery substances, can result in drivers adopting higher speeds and more aggressive driving behaviors.

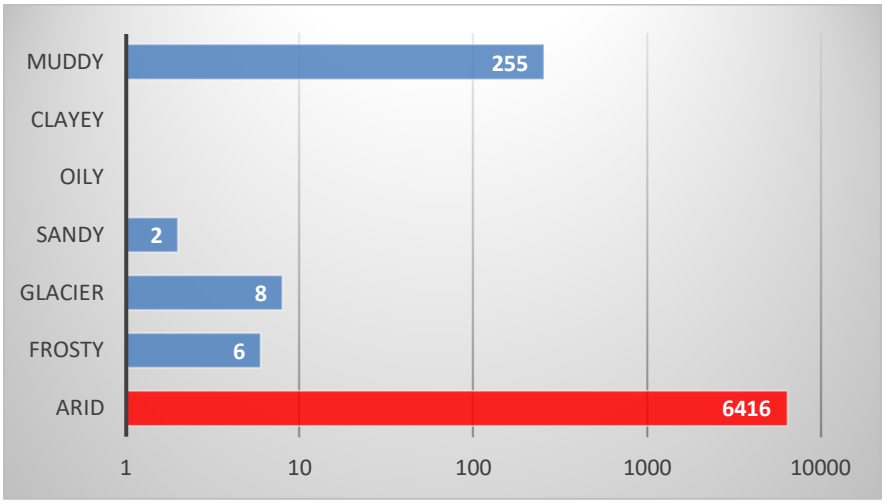

Figure 8 Collision accidents vs. road surface state

4.7 Speed limit

The observation that roads with a speed limit of 60 km/hr recorded the highest incidence of collision accidents among the 9 categories of speed limits, with a rate of 35% (Figure 9), is particularly noteworthy. The reason why the highest incidence of collision accidents was recorded for roads with a speed limit of 60 km/hr, and not higher or lower speeds, could be due to several factors. Firstly, roads with a speed limit of 60 km/hr are often found in urban areas where there is a high volume of traffic and complex road networks, which can increase the risk of collisions. Secondly, the speed limit of 60 km/hr may not accurately reflect the typical driving speeds on these roads, leading to an increased risk of collision as drivers may be traveling at speeds that are either too fast or too slow for the conditions.

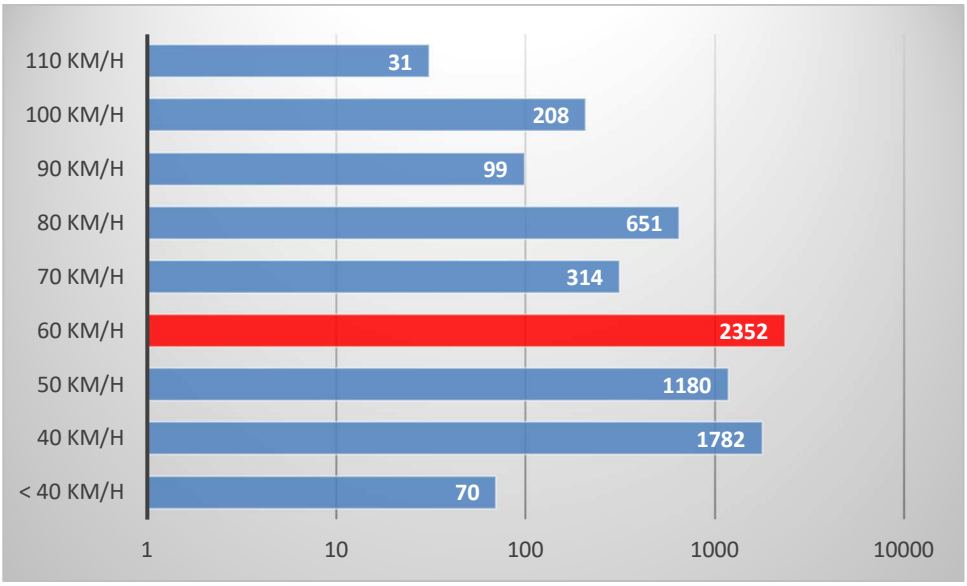

Figure 9 Collision accidents vs. speed limit

4.8 Illumination levels

It was established that, among the various illumination levels, daytime was recorded as the most prevalent, accounting for 58.7% of all recorded events (Figure 10). The elevated risk of collision accidents can be attributed to several factors. One major contributor is the increased

volume of traffic during daylight hours as compared to other levels of illumination. This results in a greater number of vehicles on the road and a higher probability of vehicle interactions, thus creating more opportunities for collisions to occur.

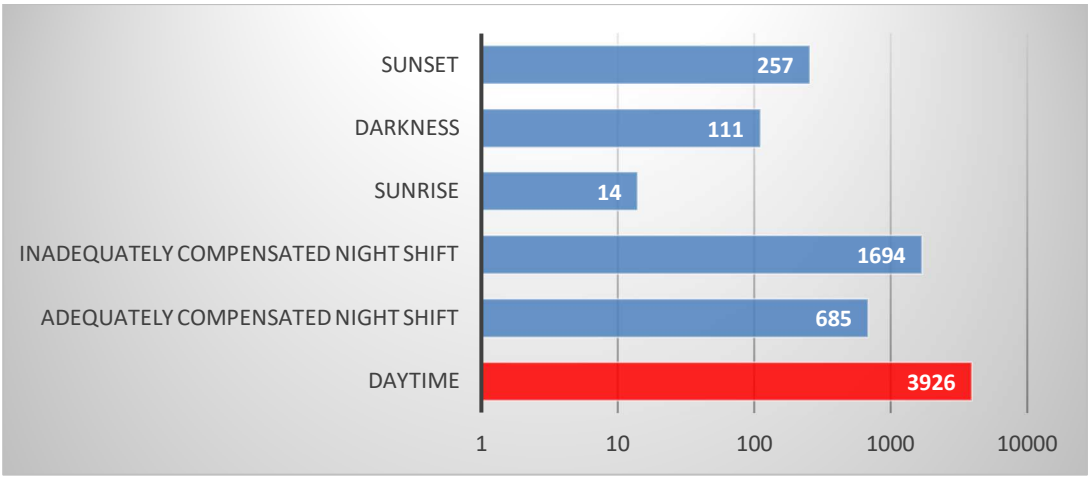

Figure 10 Collision accidents vs. illumination levels

4.9 Statistical analysis

For the purpose of this research, the statistical analysis was conducted using SPSS ver. 22. The initial data was extracted from the traffic institute and documented in an Excel sheet. However, before importing the data into the software, it was necessary to carefully review and prepare it to ensure compatibility with SPSS. In this study, a descriptive data analysis technique called cross-tabulation was employed to uncover, illustrate, and concisely summarize the data points in a manner that satisfies all of the data conditions. Specifically, a cross-tabulation table was utilized to describe the relationship between four dependent variables and eight independent variables. The resulting output from the SPSS analysis can be observed in Table 1, provided as an example below.

Table 1 Descriptive Cross-Tabulation Analysis of Collision Severity and Independent Variables

			Weather Conditions						
			Clear sky	High winds	Frosty	Foggy	Dusty	Rainy	Total
Collision Severity	Minor	Number	3763	2	2	9	5	123	3904
		Percent	58.4%	40%	50%	52.9%	50%	58.2%	
	Moderate	Number	2405	1	1	6	3	78	2494
		Percent	37.3%	20%	25%	35.2%	30%	36.9%	
	Severe	Number	149	0	0	0	0	4	153
		Percent	2.3%	0%	0&	0%	0%	1.9%	
	Fatal	Number	123	2	1	2	2	6	136
		Percent	2%	40%	25%	11.9%	20%	3%	
	Total		6440	5	4	17	10	211	6687

To ascertain the relevance of variables to be incorporated in the model, the Chi-square test (X^2) of independence was employed. Following this, the ordinal logistic regression model was utilized to examine the road crash factors that are closely linked with the severity level of the crash. Any variables that exhibited a statistically significant association with road crash severity level, at a significance level of 5%, were subjected to further analysis through the Ordinal Logistic Regression model.

To provide an example, let's consider the study's utilization of two nominal data variables. The first variable, 'level of crash severity,' includes four distinct categories, namely fatal ,minor injury, moderate injury, and severe injury. The second variable pertains to road surface state and is comprised of seven categories, including arid, frosty, glacier, and other. A significant application of the chi-square test is to determine if two variables are statistically independent, and this is known as the chi-square test of independence. This test analyzes the association or independence between two nominal or dichotomous variables. Before selecting the appropriate chi-square test for association, it is crucial to inspect and assess the data to be analyzed.

The findings of the chi-square test applied to the dataset are presented in Table 2. Only the variables that displayed a statistically significant association with road crash severity level, at a 5% significance level, were further scrutinized through the application of the Ordinal Logistic Regression model. The outcomes demonstrate that four variables indicate a strong correlation with road crash severity level, and their significance values were found to be less than ($p<0.05$).

Table 2 Chi-square results for the variables include in the model

Dependent Variable	Independent Variable	Value	d.f.	P-value
Level of Severity	Hour of the day	11.262	23	0.351
	Day of the week	2.183	6	0.125
	Month of the year	25.856	11	0.256
	Governorate	1.983	11	0.112
	Weather Condition	0.65	5	0.003
	Road Surface state	6.586	6	0.085
	Speed Limit	51.256	8	0.025
	Illumination Levels	2.256	5	0.002

To investigate whether the severity of collision accidents is significantly linked to eight distinct factors, the null and alternative hypotheses were established as follows:

The null hypothesis (H_0) posits that there is no significant relationship between the severity of collision accidents and the eight different factors examined in this study. On the other hand, the alternative hypothesis (H_1) states that a significant association exists between the severity of collisions and the different factors considered.

To investigate any potential links between level of accident severity and different factors, a chi-square test was performed. The study assessed eight different variables pertaining to these factors. The results indicate that out of the eight variables, four showed a significant association with level of severity as illustrated below in Table 3.

Table 3 Chi-square results for the significant variables include in the model

Dependent Variable	Independent Variable	Value	d.f.	P-value
Level of Severity	Weather Condition	0.65	5	0.003
	Road Surface state	6.586	6	0.085
	Speed Limit	51.256	8	0.025
	Illumination Levels	2.256	5	0.002

The dataset was analyzed using the Ordinal Logistic technique, and the results of the impact of associated variables on road accident severity level are presented in Table 4. Out of the eight variables examined, the study found that only four were statistically significant. The estimated β coefficients of the ordinal logistic regression analysis are reported in the results.

Table 4 Results of Ordinal Logistic Regression Analysis for Variables Impacting Collision Severity Levels

Independent Variable	Beta(β)	Std. Error	Z value	Pr(>|z|)
Hour of the day	0.06	0.03	2.03	0.041491
Day of the week	0.24	0.03	6.32	4.69E-14
Month of the year	0.52	0.03	18.25	Less than 2e-16
Governorate	-0.08	0.02	-4.05	1.92E-06
Weather Condition	-0.18	0.02	-3.65	$5.92*10^{-4}$
Road Surface state	-0.22	0.04	-4.99	2.30E-08
Speed Limit	0.00	0.00	-8.36	8.49E-15
Illumination Levels	0.06	0.03	2.56	0.040326

The results of the odd ratio and their corresponding 25% and 95% confidence intervals for each coefficient are presented in Table 5. As shown in Tables 5 and 6, the coefficient β for the weather condition was -0.18 and -0.22 for road surfce state, with odds ratios of 1.691 and 1.800, respectively. This indicates that the likelihood of a crash resulting in fatal/serious/minor injury is 1.691 times higher for weather condition and 1.800 times higher for road surfce state. Additionally, the odds of a accidents being fatal/serious/minor is highest for hour of the day, with a 1.656 times higher likelihood compared to day of the week.

Table 5 Odd ratio values and confidence interval

Independent Variable	Odds Ratio (OR)	2.5%	97.50%
Hour of the day	1.656	1.596	1.668
Day of the week	1.291	1.215	1.372
Month of the year	0.836	0.755	0.924
Governorate	0.919	.0.881	0.953
Weather Condition	1.691	0.645	0.736
Road Surface state	1.800	0.785	0.812
Speed Limit	0.997	0.997	0.998
Illumination Levels	0.999	0.856	0.965

5 Conclusion

In conclusion, this study provides valuable insights into the patterns and potential factors associated with collision accidents in Jordan. By identifying specific time periods, weather conditions, and other factors that contribute to the risk of collision accidents, the study can inform the development of targeted interventions to reduce the incidence of such accidents.

One of the key contributions of this work is its emphasis on the need for a multifaceted approach to addressing collision accidents in Jordan. Rather than focusing solely on one factor, such as speed limits or road infrastructure, the study highlights the importance of considering a range of factors, including traffic volume and weather conditions. This approach can help to ensure that interventions are effective in addressing the specific causes of collision accidents in Jordan.

Another important contribution of this work is its recommendations for further research. The study identifies areas where additional research is needed, particularly in the case of collisions that involve multiple factors. This information can guide future research efforts and help to build a more comprehensive understanding of the causes and consequences of collision accidents in Jordan.

Overall, the study provides a valuable contribution to the field of road safety in Jordan, and its findings can inform the development of policies and interventions aimed at reducing the incidence of collision accidents. However, there is always room for improvement, and future studies could build on this work by incorporating additional data sources, such as accident reports or driver behavior surveys, to further explore the factors contributing to collision accidents in Jordan.

6 Recommendations

Further research could investigate the relationships and interactions between the various factors that contribute to traffic collision accidents in Jordan, such as traffic volume, road surface conditions, weather conditions, and driver behavior, to inform the development of more effective government programs and policies aimed at reducing their incidence. Additionally, future research could explore the potential for using predictive modeling techniques based on historical data to forecast the likelihood and severity of traffic collision accidents in high-risk areas, which could help government agencies to implement proactive measures to reduce their risk. By improving our understanding of the complex factors that contribute to traffic accidents and using predictive modeling, future research could help reduce the incidence and severity of traffic collision accidents in Jordan.

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Review process
Single-blind peer review process.